

Ronan School District #30

SCIENCE CURRICULUM

K-12

2004

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ACKNOWLEDGEMENTS

A standards-based system of curricular and instructional programs that accelerates and sustains the early and continued achievement in the science by all students in the Ronan school system, kindergarten through grade twelve, is described in this curriculum. In adapting this curriculum to meet the needs of Ronan Schools, we used many sources: the Montana standards, the California standards, Lawrence Hall of Science—FOSS, and National Science Teachers Association standards. We are indebted for the extensive research that these organizations have done. I would like to thank the following teachers that worked diligently on this document:

Dave Koehler	KWH
Scott Graham	KWH
Celie Aylesworth	Pablo
Shon Potter	Pablo
Bill Posivio	RMS
Tom Linse	RMS
Chris Briske	RHS
Phil Engeldrum	RHS

The principals provided leadership to identify the appropriate personnel for the curriculum writing team; they will be responsible along with the teachers for ensuring the curriculum's implementation.

Lana K. Hunter, EdD

Science Education Educators have the opportunity to foster and inspire in students an interest in science; the goal is to have students gain the knowledge and skills necessary to be competitive in the global, information-based economy of the twenty-first century. This document connects the learning of science with the fundamental skills of reading, writing, and mathematics. The science standards contain a concise description of what to teach at specific grade levels; this document extends those guidelines by providing the scientific background and the classroom context. This document is intended to (1) organize the body of knowledge that students need to learn during their elementary and secondary school years; and (2) illuminate the methods of science that will be used to extend that knowledge during the students' lifetimes. Although the world will certainly change in ways that can hardly be predicted in the new century, students will be prepared to meet new challenges if they have received a sound, basic education.

The Challenges Elementary school students often learn much from observing and recording the growth of plants from seeds in the classroom. But are the same students well served if seed planting is a focus of the science curriculum in the next year and the following one as well? The same question may well be asked of any instructional activity. To overcome the challenges in science education, several strategies are recommended:

Prepare Long-Term Plans Long-term planning of a science curriculum over a span of grades helps students learn new things and develop new skills each year. A standards-based curriculum helps students who move from district to district; they will be more likely to receive a systematic and complete education. The curriculum is designed to ensure that all students have a rich experience in science at every grade level and that curriculum decisions are not made haphazardly. Instructional programs need the curriculum to be incorporated at each grade level and should be comprehensive and coherent over a span of grade levels. The hope is that in the near future teachers will have a much greater degree of certainty about the knowledge and skills the students already possess as they file into the classroom at the beginning of a school year. Less time will be spent on review, and teachers will also have a clear idea of the content their students are expected to master at each grade level and in each branch of science.

Meet the Curricular Demands of Other Core Content Areas The *English Communication Arts Curriculum* and *Mathematics Curriculum* explicitly require uninterrupted instructional time in those subjects. In the early elementary grades, students need to receive at least 150 minutes of reading/language arts instruction daily and 60 minutes of mathematics instruction. At the elementary school level, the pressure to raise the academic performance of students in reading/ language arts and mathematics tempts some administrators to eliminate science instruction. This action is not necessary and reflects, in fact, a failure to serve the students. The *Science Curriculum* helps to organize and focus elementary science instruction, bringing it to a level of efficiency so that it need not be eliminated. All teachers, particularly those who teach multiple subjects, need to use their instructional time judiciously. One of the key objectives set forth in the

Mathematics Curriculum applies equally well to the study of science: “During the great majority of allocated time, students are active participants in the instruction.” In this case *active* means that students are engaged in thinking about science. If the pace of an activity is too fast or too slow, students will not be “on task” for much of the allotted time. When large blocks of time for science instruction are not feasible, teachers must make use of smaller blocks. For example, an elementary teacher and the class may have a brief but spirited discussion on why plant seeds have different shapes or why the moon looks different each week. **For kindergarten through grade three, standards-based science content is now integrated into nonfiction material in the basic reading/language arts reading: In order to protect English language arts instructional time, those K–3 content standards in history–social science and science that lend themselves to instruction during the language arts time period are addressed within the language arts materials, particularly in the selection of expository texts that are read to students, or that students read.** There is no begrudging of the extended time needed for students to master reading, writing, and mathematics, for those are fundamental skills necessary for science. The *English Communication Arts Curriculum* states this principle clearly: “Literacy is the key to becoming an independent learner in all the other disciplines.” The *Mathematics Curriculum* bears a similar message: “The mathematics curriculum focus on essential content for all students and prepare students for the study of advanced mathematics, science and technical careers, and postsecondary study in all content areas.” Despite the aforementioned curricular demands, the science standards should be taught comprehensively during the elementary grades. This challenge can be met with careful planning and implementation.

Set Clear Instructional Objectives In teaching the science curriculum, our schools must have a clear idea of our instructional objectives. Science education is meant to teach, in part, the specific knowledge and skills that will allow students to become literate adults. Science education, however, is more than the learning of interesting facts; it is the building of intellectual strength in a more general sense: The scholarly and scientific disciplines won their primacy in traditional programs of education because they represent the most effective methods which have been devised through millennia of sustained effort, for liberating and organizing the powers of the human mind. Science education in kindergarten through grade twelve trains the mind and builds intellectual strength and must not be limited to the lasting facts and skills that can be remembered into adulthood. Science must be taught at a level of rigor and depth that goes well beyond what a typical adult knows. It must be taught “for the sake of science” and not with any particular vocational goal in mind. The study of science disciplines the minds of students; and the benefits of this intellectual training are realized long after schooling, when the details of the science may be forgotten.

Model Scientific Attitudes Science must be taught in a way that is scholarly yet engaging. That is, an appropriate balance must be maintained between the fun and serious sides of science. A physics teacher might have students build paper airplanes to illustrate the relationship between lift and drag in airflow; but if the activity is not deeply rooted in the content of physics, then the fun of launching paper airplanes displaces the intended

lesson. The fun of science may be a way to help students remember important ideas, but it cannot substitute for effective instruction and sustained student effort. There are certain attitudes about science and scientists that a teacher must foster in students. Scientists are deeply knowledgeable about their fields of study but typically are willing to admit that there is a great deal they do not know. In particular, they welcome new ideas that are supported by evidence. In doing their research good scientists do not attempt to prove that their own hypotheses are correct but that they are incorrect. Though somewhat counterintuitive, this path is the surest one to finding the truth. Classroom teachers must always provide rational explanations for phenomena. They need to be honest about what they do not know and be enthusiastic about learning new things along with their students. They must convey to students the idea that there is much to learn and that phenomena not currently understood may be understood in the future. Knowledge in science is cumulative, passed from generation to generation, and refined at every step.

Provide Balanced Instruction Some of the knowledge of science is best learned by having students read about the subject or hear about it from the teacher; other knowledge is best learned in laboratory or field studies. Direct instruction and investigative activities need to be mutually supportive and synergistic. Instructional materials need to provide teachers with a variety of options for implementation that are based on the science standards. For example, students might learn about Ohm’s law, one of the guiding principles of physics, which states that electrical current decreases proportionately as resistance increases in an electrical circuit operating under a condition of constant voltage. In practice, the principle accounts for why a flashlight with corroded electrical contacts does not give a bright beam, even with fresh batteries.

Ensure the Safety of Instructional Activities Safety is always the foremost consideration in the design of demonstrations, hands-on activities, laboratories, and science projects on site or away from school. Teachers need to be familiar with the science safety. Safety needs to be taught. Knowing and following safe practices in science are a part of understanding the nature of science and scientific procedures.

Teachers need to use instructional activities or readings that are grounded in science and that provide clear and non-superficial lessons. The content must be scientifically accurate, and the breadth and depth of the science standards need to be addressed. Initial teaching sequences must communicate with students in the most straightforward way possible, and expanded teaching used to amplify the students’ understanding. The concrete examples, investigative activities, and vocabulary used in instruction need to be unambiguous and chosen to demonstrate the wide range of variation on which scientific concepts can be generalized.

Guiding Principles The following principles form the basis of an effective science education program. They address the complexity of the science content and the methods by which science content is best taught. They clearly define the attributes of a quality science curriculum at the elementary, middle, and high school levels. **Effective**

science programs are based on standards and use standards-based instructional materials. Comprehensive, standards-based programs are those in which curriculum, instruction, and assessment are aligned with the grade-level-specific curriculum (kindergarten through grade eight) and the content strands (grades nine through twelve). Students have opportunities to learn foundational skills and knowledge in the elementary and middle grades and to understand concepts, principles, and theories at the high school level.

1. Every laboratory science course is based on the curriculum and ensures that students master both the content-specific standards and Investigation and Experimentation standards.
2. All students take, at a minimum, two years of laboratory science providing fundamental knowledge in at least two of the following content strands: biology/life sciences, chemistry, and physics.

Effective science programs develop students' command of the academic language of science used in the content standards.

The lessons explicitly teach scientific terms as they are presented in the curriculum. New words (e.g., *photosynthesis*) are introduced to reflect students' expanding knowledge, and the definitions of common words (e.g., *table*) are expanded to incorporate specific meanings in science. Developing students' command of the academic language of science must be a part of instruction at all grade levels. Scientific vocabulary is important in building conceptual understanding. Teachers need to provide explanations of new terms and idioms by using words and examples that are clear and precise.

Effective science programs reflect a balanced, comprehensive approach that includes the teaching of investigation and experimentation skills along with direct instruction and reading.

A balanced, comprehensive approach to science includes the teaching of investigation and experimentation skills along with direct instruction and reading. Investigation and experimentation standards are progressive and need to be taught in a manner integral to the physical, life, and earth sciences as students learn quantitative skills and qualitative observational skills. For example, the metric system is first introduced in elementary, but students use and refine their skill in metric measurement through high school. The methods and skills of scientific inquiry are learned in the context of the key concepts, principles, and theories set forth in the standards. Effective use of limited instructional time is always a major consideration in the design of lessons and courses. Laboratory space and equipment, library access, and resources are essential to support students' academic growth in science.

Effective science programs use multiple instructional strategies and provide students with multiple opportunities to master the content standards. Multiple instructional strategies, such as direct instruction, teacher modeling and demonstration, and investigation and experimentation, are useful in teaching science and need to be included in instructional materials. Those strategies help teachers capture student

interest, provide bridges across content areas, and contribute to an understanding of the nature of science and the methods of scientific inquiry.

Benchmarks for investigation and experimentation are included at each grade level and differ from the other standards in that they do not represent a specific content area. Investigation and experimentation cuts across all content areas, and those standards are intended to be taught in the context of the grade-level content. Hands-on activities may compose 25 percent of the science instructional time in kindergarten through grade eight. Instruction is designed and sequenced to provide students with opportunities to reinforce foundational skills and knowledge and to revisit concepts, principles, and theories previously taught. In this way student progress is appropriately monitored.

Effective science programs include continual assessment of students' knowledge and understanding, with appropriate adjustments being made during the academic year.

Effective assessment (on a continuing basis through the academic year) is a key ingredient of standards-based instruction. Teachers assess students' prerequisite knowledge, monitor student progress, and evaluate the degree of mastery of the content called for in the curriculum. Lessons include embedded unit assessments that provide formative and summative assessments of student progress.

Effective science programs continually engage all students in learning and prepare and motivate students for further instruction in science. Students who are unable to keep up with the expectations for learning science often lack basic skills in reading comprehension and mathematics. Therefore, students who need extra assistance to achieve grade-level expectations are identified early and receive support. Schools need to use transitional materials that accelerate the students' reading and mathematics achievement to grade level. Advanced learners must not be held back but be encouraged to study science content in greater depth.

Effective science programs have adequate instructional resources as well as library-media and administrative support.

The Science Curriculum for Kindergarten Through Grade Five

The following Montana Science Standards will be integrated into the curriculum at each grade level:

Standard 1—Students design, conduct, evaluate and communicate scientific investigations.

Standard 2—Students demonstrate knowledge of properties, forms, changes and interactions of physical and chemical systems.

Standard 3—Students demonstrate knowledge of characteristics, structures and function of living things, the process and diversity of life, and how living organisms interact with each other and their environment.

Standard 4—Students demonstrate knowledge of the composition, structures, processes and interactions of Earth’s systems and other objects in space.

Standard 5—Students understand how scientific knowledge and technological developments impact society.

Standard 6—Students understand historical developments in science and technology.

Kindergarten

The elementary school science program provides the foundational skills and knowledge students will need in middle school and high school. They learn essential investigation and experimentation skills that will continue to be developed through high school.

Elementary school students respond positively to well-structured activities and expository reading materials that connect the world around them to the science content. Students raise questions, follow their curiosity, and learn to be analytical. They are encouraged to practice open and honest expression of ideas and observations; they learn to listen to and consider the ideas and observations of other students. Both teachers and students need to enjoy the adventure of science.

This enjoyable adventure includes the school library-media center as a natural partner in science teaching and learning. The books and other resources available in the school library enhance and expand an interest in and understanding of science. Because the school library-media center is appropriately staffed with a credentialed library-media teacher, information literacy instruction can be integrated into regular science instruction.

Here in Ronan School District #30, we have many local resources developed at SKC and in coordination with NASA Science Curriculum Project available for our use. These resources can provide additional appropriate resources for study for our students.

Each of the grade levels at the elementary school uses FOSS kits to enhance student learning. At this grade level, the kits used are as follows:

Fabric Module

In the **Fabric Module** students are introduced to a wide variety of fabrics in a systematic way, so that they become familiar with fabrics' properties, discover what happens when they are tested, and discover how they interact with other materials, including water.

STUDENTS WILL

- Develop a curiosity and interest in the physical world around them.
- Observe and describe the properties of different fabrics.
- Compare different fabrics to discover how they are alike and how they are different.
- Observe interactions of fabric with water and other substances.
- Communicate observations.
- Acquire the vocabulary associated with the properties of fabric.

Wood and Paper Module

The modern world is a wonderland of different materials for early-childhood students. Two of those materials are wood and the paper that is derived from it. Scores of different kinds of wood and paper fill students' environment. In the **Wood and Paper Module** students are introduced to a wide variety of woods and papers in a systematic way. They will observe the properties of these materials and discover what happens when they are subjected to a number of tests and interactions with other materials. Students learn that wood and paper can be recycled to create new forms of paper or wood that have new properties. Finally, they use what they know about the properties of these marvelous materials as they change wood and paper into a variety of products. Throughout the module, students have ample opportunities to compare different kinds of wood, different types of paper, and wood and paper. The concept of trees as natural resources is introduced.

STUDENTS WILL

- Develop a curiosity and interest in the physical world around them.
- Observe and describe properties of different kinds of wood and paper.
- Compare different kinds of wood and paper to discover how they are alike and how they are different.
- Observe interactions of wood and paper with water and other substances.
- Become aware of natural resources in our world.
- Communicate observations.
- Acquire the vocabulary associated with the properties of materials.

Animals Two by Two Module

The **Animals Two by Two Module** provides young students with close and personal interaction with some common land and water animals. Appropriate classroom habitats are established, and students learn to care for the animals. In four activities the animals are studied in pairs. Students observe and care for one animal over time, and then they are introduced to another animal similar to the first but with differences in structure and behavior. This process enhances opportunities for observation, communication, and comparison.

STUDENTS WILL

- Develop a curiosity and interest in the living world around them.
- Observe and describe the structures of a variety of common animals—fish, snails, earthworms, isopods, and chicks.
- Compare structures and behaviors of different pairs of animals.
- Observe interactions of animals with their surroundings.
- Communicate observations and comparisons.
- Acquire the vocabulary associated with the structure and behavior of animals.

- Handle animals carefully, and participate in the care and feeding of classroom animals.

Trees (THIS IS AN OPTIONAL UNIT)

The giant sequoia is the most massive living organism on Earth. It is a tree, magnificent in dimension and awe inspiring in its longevity and durability. To stand in the company of such giants is to experience the scale of life.

To a kindergartner the oak on the corner, the pines at the park, and the mulberry trees at school are giants. Systematic investigation of trees will bring students to a better understanding of trees' place at school and in the community, and will provide some solid experiences on the way to understanding all plants.

STUDENTS WILL

- Develop a curiosity and interest in the living things that make up their world.
- Observe and describe the properties of trees and leaves in the schoolyard.
- Compare the similarities and differences of the trees and leaves observed on mini-field trips.
- Help plant and care for a tree temporarily in the classroom, then permanently in the schoolyard.
- Observe trees throughout the school year for changes that come with the different seasons.
- Compare the shapes of leaves to geometric shapes.
- Compare the size and edges of leaves, using a reference card.
- Use pictorial experiences to heighten their awareness of the diversity and variety of trees and leaves.
- Acquire the vocabulary associated with the properties and structures of trees and leaves.

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- a. Observe common objects by using the five senses.
- b. Describe the properties of common objects.

- c. Describe the relative position of objects by using one reference (e.g., above or below).
- d. Compare and sort common objects by one physical attribute (e.g., color, shape, texture, size, weight).
- e. Communicate observations orally and through drawings.

First Grade

The elementary school science program provides the foundational skills and knowledge students will need in middle school and high school. Students are introduced to facts, concepts, principles, and theories organized under the headings of physical, life, and earth sciences. They learn essential investigation and experimentation skills that will continue to be developed through high school.

Elementary school students respond positively to well-structured activities and expository reading materials that connect the world around them to the science content. Students raise questions, follow their curiosity, and learn to be analytical. They are encouraged to practice open and honest expression of ideas and observations; they learn to listen to and consider the ideas and observations of other students. Both teachers and students need to enjoy the adventure of science.

This enjoyable adventure includes the school library-media center as a natural partner in science teaching and learning. The books and other resources available in the school library enhance and expand an interest in and understanding of science. Because the school library-media center is appropriately staffed with a credentialed library-media teacher, information literacy instruction can be integrated into regular science instruction.

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Each of the grade levels at the elementary school also uses FOSS kits to enhance student learning. At this grade level, the kits used are as follows:

Insects

The **Insects Module** provides experiences that heighten students' awareness of the diversity of animal forms. They come to know firsthand the life sequences of a number of insects. In each investigation an insect is introduced, and students observe structures and behaviors, discuss their findings, and ask questions. Students observe life cycles of insects and compare the stages of metamorphosis exhibited by each species.

STUDENTS WILL

- Develop a curiosity and interest in insects and a respect for them as living things.
- Experience some of the great diversity of forms in the animal kingdom.
- Become familiar with some of the life sequences that different types of insects exhibit (simple and complete metamorphosis).
- Observe the behaviors of insects at different stages of their life cycle.

- Provide for the needs of insects (air, water, food, and space).
- Acquire the vocabulary associated with insect life.

Solids and Liquids

The **Solids and Liquids Module** provides experiences that heighten students' awareness of the physical world. Matter with which we interact exists in three fundamental states: solid, liquid, and gas. In this module first and second graders have introductory experiences with two of these states of matter, solid and liquid.

STUDENTS WILL

- Develop a curiosity and interest in the objects that make up their world.
- Investigate materials constructively during free exploration and in a guided discovery mode.
- Recognize differences between solids and liquids.
- Explore a number of liquids.
- Observe and describe the properties of solids and liquids.
- Sort materials according to properties.
- Combine and separate solids of different particle sizes.
- Observe and describe what happens when solids are mixed with water.
- Observe and describe what happens when other liquids are mixed with water.
- Use information gathered to conduct an investigation on an unknown material.
- Acquire the vocabulary associated with the properties of solids and liquids.
- Use written and oral language to describe observations.

Pebbles, Sand, and Silt

The **Pebbles, Sand, and Silt Module** consists of four sequential investigations, each designed to introduce concepts in earth science. The investigations provide experiences that heighten students' awareness of rocks as earth materials and natural resources. They will come to know rocks by many names and in a variety of sizes. Pebbles and sand are the same material—just different sizes.

STUDENTS WILL

- Develop a curiosity and interest in the physical world around them.
- Observe, describe, and sort earth materials based on properties.
- Separate earth materials by size, using different techniques.
- Observe the similarities and differences in the materials in a river rock mixture: silt, sand, gravel, and small and large pebbles.

- Explore places where earth materials are found and ways that earth materials are used.
- Compare the ingredients in different soils.
- Organize and communicate observations through drawing and writing.
- Acquire the vocabulary associated with earth materials.

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- a. Draw pictures that portray some features of the thing being described.
- b. Record observations and data with pictures, numbers, or written statements.

Second Grade

The elementary school science program provides the foundational skills and knowledge students will need in middle school and high school. Students are introduced to facts, concepts, principles, and theories organized under the headings of physical, life, and earth sciences. They learn essential investigation and experimentation skills that will continue to be developed through high school.

Elementary school students respond positively to well-structured activities and expository reading materials that connect the world around them to the science content. Students raise questions, follow their curiosity, and learn to be analytical. They are encouraged to practice open and honest expression of ideas and observations; they learn to listen to and consider the ideas and observations of other students. Both teachers and students need to enjoy the adventure of science.

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Each of the grade levels at the elementary school uses FOSS kits to enhance student learning. At this grade level, the kits used are as follows:

Balance and Motion

We live in a dynamic world where everything is in motion, or so it seems. But not everything is moving the same way. Some things move from one place to another. Other things go around and around in a rotational motion. Still other things are stationary, stable for a time, balanced on a thin line between stop and go. These are the global phenomena that students experience in this module, **Balance and Motion**.

STUDENTS WILL

- Develop a curiosity and interest in the motion of objects.
- Investigate materials constructively during free exploration and in a guided discovery mode.
- Solve problems through trial and error.
- Develop persistence in tackling a problem.
- Explore concepts of balance, counterweight, and stability.

- Observe systems that are unstable and modify them to reach equilibrium.
- Discover different ways to produce rotational motion.
- Construct and observe toys that spin.
- Explore and describe some of the variables that influence the spinning of objects.
- Observe and compare rolling systems with different-size wheels.
- Explore and describe the motion of rolling spheres.
- Acquire the vocabulary associated with balance and motion.

New Plants

The **New Plants Module** provides experiences that heighten students' awareness of the diversity of life in the plant kingdom. Students care for plants to learn what they need to grow and develop. They observe the structures of flowering plants and discover ways to propagate new plants from mature plants (from seeds, bulbs, roots, and stem cuttings). They observe and describe changes that occur as plants grow, and organize their observations on a calendar and in a journal.

STUDENTS WILL

- Develop a curiosity and interest in plants as living things.
- Experience some of the diversity of forms in the plant kingdom.
- Provide for the needs of growing plants.
- Observe and describe the changes that occur as plants grow and develop.
- Become familiar with the structures and functions of flowering plants (root, stem, leaf, bud, flower, seed).
- Discover various ways that new plants can develop from mature plants.
- Organize and communicate observations through drawing and writing.
- Acquire the vocabulary associated with the structures of plants.

Air and Weather

The **Air and Weather Module** consists of four sequential investigations, each designed to introduce concepts in earth science. The investigations provide opportunities for young students to explore the natural world by using simple tools to observe and monitor change.

STUDENTS WILL

- Develop an interest in air and weather.
- Experience air as a material that takes up space and can be compressed into a smaller space.
- Observe the force of air pressure pushing on objects and materials.
- Observe and describe changes that occur in weather over time.

- Become familiar with instruments used by meteorologists to monitor air and weather conditions.
- Compare monthly and seasonal weather conditions using bar graphs.
- Observe the location of the Sun and the Moon in the sky over a day and the change in the appearance of the Moon over a month.
- Organize and communicate observations through drawing and writing.
- Acquire vocabulary associated with properties of air and weather conditions.

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- a. Make predictions based on observed patterns and not random guessing.
- b. Measure length, weight, temperature, and liquid volume with appropriate tools and express those measurements in standard metric system units.
- c. Write or draw descriptions of a sequence of steps, events, and observations.
- d. Construct bar graphs to record data in math activities.
- e. Follow oral instructions for a scientific investigation.

Third Grade

The elementary school science program provides the foundational skills and knowledge students will need in middle school and high school. Students are introduced to facts, concepts, principles, and theories organized under the headings of physical, life, and earth sciences. They learn essential investigation and experimentation skills that will continue to be developed through high school.

Elementary school students respond positively to well-structured activities and expository reading materials that connect the world around them to the science content. Students raise questions, follow their curiosity, and learn to be analytical. They are encouraged to practice open and honest expression of ideas and observations; they learn to listen to and consider the ideas and observations of other students. Both teachers and students need to enjoy the adventure of science.

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Each of the grade levels at the elementary school uses FOSS kits to enhance student learning. At this grade level, the kits used are as follows:

Measurement

Measurement, the process of quantifying observations, is one of the cornerstones of science. Measurement compares nature—the unknown—to a standard unit—the known. Through such comparison, the organization of the world becomes more comprehensive. The **Measurement Module** consists of four investigations, each designed to emphasize a particular type of metric measurement—length, mass, temperature, and volume.

STUDENTS WILL

- Understand the necessity for standard units of measurement.
- Develop an understanding and intuitive feel for the metric system.
- Measure length and distance in meters and centimeters with a meter tape.
- Measure mass in grams with a balance and mass pieces.
- Measure liquid volume and capacity of containers in liters and milliliters with 50-ml syringes and graduated cylinders.

- Measure temperature of liquids and air in degrees Celsius with a thermometer.
- Acquire the vocabulary associated with metric measurement.
- Exercise language and math skills in the context of metric measurement.
- Apply appropriate measuring skills in everyday situations.
- Develop and refine the manipulative skills required for making and using measuring tools.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, and organizing.

One of the following units can be optional:

Human Body

The **Human Body Module** consists of four sequential investigations that engage students in thoughtful activities about the form and function of a most remarkable machine, their own body.

STUDENTS WILL

- Observe and investigate the human skeletal and muscle systems.
- Become aware of the versatility of movement provided by an articulated skeleton.
- Gain experience with the use of photographs, diagrams, and model bones to gather information.
- Build mechanical models to demonstrate how muscles are responsible for human movement.
- Compare the bones and muscles in their own bodies to photographs and models.
- Investigate response time of hands and feet.
- Develop an awareness of human bone and muscle structure and function and an appreciation for the versatility of the human body.
- Acquire the vocabulary associated with the human skeletal and muscle systems.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, and organizing.

Magnetism and Electricity

The **Magnetism and Electricity Module** consists of five sequential investigations, each designed to introduce or reinforce concepts in physical science. The investigations provide opportunities for students to explore the natural and human-made worlds by observing and manipulating materials in focused settings using simple tools.

STUDENTS WILL

- Observe the interaction of permanent magnets with a variety of common materials.

- Discover that magnets display forces of attraction and repulsion.
- Measure the change in force between two magnets as the distance between them changes.
- Identify materials that are conductors and insulators.
- Understand and construct simple open, closed, parallel, and series circuits.
- Learn how to make an electromagnet.
- Experience the relationship between the number of turns of wire around an electromagnet core and the strength of the magnetism.
- Use their knowledge of electromagnets to make a telegraph.
- Acquire vocabulary associated with magnetism and electricity.
- Exercise language, math, and social studies skills in the context of magnetism and electricity investigations.
- Develop and refine the manipulative skills required for making investigations in magnetism and electricity.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, and organizing.

Water

Water is the most important substance on Earth. Water dominates the surface of our planet, changes the face of the land, and defines life. These powerful, pervasive ideas are introduced here. The **Water Module** consists of four investigations in which students explore properties of water, changes in water, interactions between water and other earth materials, and how humans use water.

STUDENTS WILL

- Observe and explore properties of water in liquid, solid, and gaseous states.
- Observe the expansion and contraction of water as it warms and cools.
- Investigate factors that influence evaporation and condensation of water.
- Consider components of the water cycle.
- Observe and compare how water moves through different types of earth materials, including soil and gravel.
- Consider the water quality of local water sources.
- Investigate how water can be used to do work.
- Acquire vocabulary associated with water.
- Record observations in writing and pictures.
- Exercise language, social studies, and math skills in the context of science.
- Become aware of the importance of water in their lives.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, and organizing.

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- a. Repeat observations to improve accuracy and know that the results of similar scientific investigations seldom turn out exactly the same because of differences in the things being investigated, methods being used, or uncertainty in the observation.
- b. Differentiate evidence from opinion and know that scientists do not rely on claims or conclusions unless they are backed by observations that can be confirmed.
- c. Use numerical data in describing and comparing objects, events, and measurements.
- d. Predict the outcome of a simple investigation and compare the result with the prediction.
- e. Collect data in an investigation and analyze those data to develop a logical conclusion.

Fourth Grade

The elementary school science program provides the foundational skills and knowledge students will need in middle school and high school. Students are introduced to facts, concepts, principles, and theories organized under the headings of physical, life, and earth sciences. They learn essential investigation and experimentation skills that will continue to be developed through high school.

Elementary school students respond positively to well-structured activities and expository reading materials that connect the world around them to the science content. Students raise questions, follow their curiosity, and learn to be analytical. They are encouraged to practice open and honest expression of ideas and observations; they learn to listen to and consider the ideas and observations of other students. Both teachers and students need to enjoy the adventure of science.

This enjoyable adventure includes the school library-media center as a natural partner in science teaching and learning. The books and other resources available in the school library enhance and expand an interest in and understanding of science. Because the school library-media center is appropriately staffed with a credentialed library-media teacher, information literacy instruction can be integrated into regular science instruction.

Here in Ronan School District #30, we have many local resources developed at SKC and in coordination with NASA Science Curriculum Project available for our use. These resources can provide additional appropriate resources for study for our students.

Each of the grade levels at the elementary school uses FOSS kits to enhance student learning. At this grade level, the kits used are as follows:

Physics of Sound

The **Physics of Sound Module** consists of four sequential investigations, each designed to expose a specific set of concepts. Students learn to discriminate between sounds generated by dropped objects, how sounds can be made louder or softer and higher or lower, how sounds travel through a variety of materials, and how sounds get from a source to a receiver. The investigations provide opportunities for students to explore the natural and human-made worlds by observing and manipulating materials in focused settings using simple tools.

STUDENTS WILL

- Observe and compare sounds to develop discrimination ability.
- Communicate with others using a drop code.
- Learn that sound originates from a source that is vibrating and is detected at a receiver such as the human ear.

- Understand the relationship between the pitch of a sound and the physical properties of the sound source (i.e. length of vibrating object, frequency of vibrations, and tension of vibrating string).
- Compare methods to amplify sound at the source and at the receiver.
- Observe and compare how sound travels through solids, liquids, and air.
- Use knowledge of the physics of sound to solve simple sound challenges.
- Acquire vocabulary associated with the physics of sound.
- Exercise language, social studies, and math skills in the context of the physics of sound.
- Develop and refine the manipulative skills required for investigating sound.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, and organizing.

Ideas and Inventions

The **Ideas and Inventions Module** consists of four sequential investigations that promote student creativity and inventiveness. Each investigation provides valuable science content while introducing a conventional technique for revealing the unseen.

STUDENTS WILL

- Use techniques to see details about the world that would otherwise be difficult to observe.
- Explore the techniques of chromatography, rubbing, carbon printing, and mirror imagery.
- Solve problems using the techniques of chromatography and carbon printing.
- Record and compare patterns observed in leaf veins, fingerprints, and ink pigments.
- Gain experience with texture and pattern in a variety of materials.
- Express individual and group creativity through open-ended discoveries and inventions.
- Invent applications to extend the use of specific techniques.
- Acquire the vocabulary associated with texture and patterns of materials and exercise language in the context of science.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, and organizing.

Earth Materials

The **Earth Materials Module** consists of four sequential investigations dealing with observable characteristics of solid materials from the earth—rocks and minerals. The focus is on taking materials apart to find what they are made of and putting materials

together to better understand their properties. The module introduces fundamental concepts in earth science and takes advantage of the students' intrinsic interest in the subject matter and in the physical world around them.

STUDENTS WILL

- Develop an interest in earth materials.
- Gain experiences with rocks and minerals.
- Understand the process of taking apart and putting together to find out about materials.
- Use measuring tools to gather data about rocks.
- Collect and organize data about rocks.
- Observe, describe, and record properties of minerals.
- Organize minerals on the basis of the property of hardness.
- Investigate the effect of vinegar (acid) on a specific mineral, calcite.
- Use evaporation to investigate rock composition.
- Learn that rocks are composed of minerals and that minerals cannot be physically separated into other materials.
- Compare their activities to the work of a geologist.
- Acquire vocabulary used in earth science.
- Exercise language and math skills in the context of science.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, and organizing.

Measurement

Measurement, the process of quantifying observations, is one of the cornerstones of science. Measurement compares nature—the unknown—to a standard unit—the known. Through such comparison, the organization of the world becomes more comprehensive. The **Measurement Module** consists of four investigations, each designed to emphasize a particular type of metric measurement—length, mass, temperature, and volume.

STUDENTS WILL

- Understand the necessity for standard units of measurement.
- Develop an understanding and intuitive feel for the metric system.
- Measure length and distance in meters and centimeters with a meter tape.
- Measure mass in grams with a balance and mass pieces.
- Measure liquid volume and capacity of containers in liters and milliliters with 50-ml syringes and graduated cylinders.
- Measure temperature of liquids and air in degrees Celsius with a thermometer.
- Acquire the vocabulary associated with metric measurement.
- Exercise language and math skills in the context of metric measurement.
- Apply appropriate measuring skills in everyday situations.

- Develop and refine the manipulative skills required for making and using measuring tools.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, and organizing.

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- a. Differentiate observation from inference (interpretation) and know scientists' explanations come partly from what they observe and partly from how they interpret their observations.
- b. Measure and estimate the weight, length, or volume of objects.
- c. Formulate and justify predictions based on cause-and-effect relationships.
- d. Conduct multiple trials to test a prediction and draw conclusions about the relationships between predictions and results.
- e. Construct and interpret graphs from measurements.
- f. Follow a set of written instructions for a scientific investigation.

Fifth Grade

The elementary school science program provides the foundational skills and knowledge students will need in middle school and high school. Students are introduced to facts, concepts, principles, and theories organized under the headings of physical, life, and earth sciences. They learn essential investigation and experimentation skills that will continue to be developed through high school.

Elementary school students respond positively to well-structured activities and expository reading materials that connect the world around them to the science content. Students raise questions, follow their curiosity, and learn to be analytical. They are encouraged to practice open and honest expression of ideas and observations; they learn to listen to and consider the ideas and observations of other students. Both teachers and students need to enjoy the adventure of science.

This enjoyable adventure includes the school library-media center as a natural partner in science teaching and learning. The books and other resources available in the school library enhance and expand an interest in and understanding of science. Because the school library-media center is appropriately staffed with a credentialed library-media teacher, information literacy instruction can be integrated into regular science instruction.

Here in Ronan School District #30, we have many local resources developed at SKC and in coordination with NASA Science Curriculum Project available for our use. These resources can provide additional appropriate resources for study for our students.

Each of the grade levels at the elementary school uses FOSS kits to enhance student learning. At this grade level, the kits used are as follows:

Food and Nutrition

The **Food and Nutrition Module** consists of four sequential investigations that help students understand what food is, what it is made of, and how several nutrient groups contribute to healthful nutrition.

STUDENTS WILL

- Observe and investigate properties of foods.
- Become aware of carbohydrates, proteins, fats, and vitamins as components of food.
- Gain experience with indicators.
- Use indicators to test for acid, vitamin C, sugar, and fat in foods.
- Relate the results of investigations and experiments to the amount of chemicals in foods.
- Become aware of guides for healthy nutrition.

- Become informed consumers, able to gather information about food products.
- Apply mathematics in the context of science.
- Acquire vocabulary associated with nutrition.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, organizing, and relating.

Solar Energy

The **Solar Energy Module** consists of four investigations that allow students to experience solar energy firsthand and to investigate the variables that affect solar-energy transfer.

STUDENTS WILL

- Become aware of the potential of solar energy, an inexhaustible source, as an alternative energy source to fossil fuels, a nonrenewable source.
- Observe differences in size and position of shadows as a result of the relative positions of Earth and the Sun.
- Gain experience using a compass to orient objects on Earth.
- Become proficient in using a thermometer to monitor temperature change in a variety of materials.
- Observe solar-energy transfer in a variety of situations.
- Relate the rate and amount of temperature change to variables involved in energy transfer.
- Design solar water heaters and passive solar space heaters.
- Apply mathematics in the context of science.
- Acquire vocabulary associated with solar energy and energy transfer.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, organizing, and relating.

Variables

Some of the most important scientific concepts students learn are the result of their ability to see relationships between objects and events. Relationships always involve interactions, dependencies, and cause and effect. The **Variables Module** has four investigations that help students discover relationships through controlled experimentation. Students will fling, float, fly, and flip objects as they discover relationships in each investigation.

STUDENTS WILL

- Gain experience with the concept of variable.

- Gain experience with the concept of system.
- Design and conduct controlled experiments.
- Construct materials that will be used in the investigations.
- Acquire some understanding of the behavior of pendulums.
- Gain experience with buoyancy.
- Use data to make predictions.
- Apply mathematics in the context of science.
- Record and graph data concretely, pictorially, and symbolically to discover relationships.
- Acquire the vocabulary associated with controlled experimentation.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, organizing, and relating.

Environments

All living things depend on the conditions in their environment. The study of the relationships between one organism and its environment builds knowledge of all organisms. With this knowledge comes an awareness of limits. Changes in an environment can be hard on organisms. Such knowledge is important because humans can change environments. To do so without awareness of possible consequences can lead to disasters. The **Environments Module** consists of six investigations that introduce students to these basic concepts in environmental biology.

STUDENTS WILL

- Develop an attitude of respect and understanding for life.
- Gain experience with the major environmental factors in terrestrial and aquatic systems.
- Conduct controlled experiments with plants to determine ranges of tolerance.
- Determine an organism's optimum conditions and environmental preferences.
- Organize and analyze data from experiments and investigations with plants and animals.
- Observe and describe changes in complex systems over time.
- Relate laboratory studies to natural systems.
- Apply mathematics in the context of science.
- Acquire vocabulary associated with environmental biology.
- Exercise language, math, and social studies skills in the context of biology investigations.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, organizing, and relating.

Levers and Pulleys (this is an optional unit)

Humans are the only living creatures that have been able to put materials together to construct machines to do work. Our capacity to see and invent relationships between effort and work produced through simple machines has led us into a world that is becoming more technologically oriented. Knowledge of these relationships is necessary for understanding all mechanics. The **Levers and Pulleys Module** consists of four investigations that involve students in fundamental concepts of simple machines.

STUDENTS WILL

- Gain experience with the concept of force and the application of force to do work.
- Gain experience with the relationships between the components of lever systems and pulley systems.
- Gain experience with the concept of advantage as it relates to simple machines.
- Analyze real-world tools and machines in terms of the simple machines that make them work.
- Systematically collect and record data.
- Use measurement in the context of scientific investigations.
- Use diagrams to translate three-dimensional relationships into two dimensions.
- Acquire vocabulary associated with two simple machines (levers and pulleys).
- Apply mathematics in the context of science.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing, organizing, and relating.

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- a. Classify objects (e.g., plants, leaves) in accordance with appropriate criteria.
- b. Develop a testable question.
- c. Plan and conduct a simple investigation based on a student-developed question and write instructions others can follow to carry out the procedure.
- d. Identify the dependent and controlled variables in an investigation.
- e. Identify a single independent variable in a scientific investigation and explain how this

variable can be used to collect information to answer a question about the results of the experiment.

f. Select appropriate tools (e.g., thermometers, meter sticks, balances, and graduated cylinders) and make quantitative observations.

g. Record data by using appropriate graphic representations (including charts, graphs, and labeled diagrams) and make inferences based on those data.

h. Draw conclusions from scientific evidence and indicate whether further information is needed to support a specific conclusion.

i. Write a report of an investigation that includes conducting tests, collecting data or examining evidence, and drawing conclusions.

Middle School—Grades Six Through Eight

In each grade, kindergarten through grade five, the science content standards cover the areas of physical, life, and earth sciences in approximately equal measures. In each of the middle grades, however, the content standards emphasize an individual area.

In all three of the middle grades, science instruction is intended to provide students with a solid foundation for the more formal treatment of concepts, principles, and theories called for at the high school level.

Not all students will enter middle school prepared for the rigorous science curriculum called for in the middle grades standards. Teachers should use “catch up” strategies to ensure that students are prepared for high school science. One of the key requirements is for students to have foundational reading and mathematics skills. Those curriculum documents provide specific strategies for teachers to help students who are below grade level in reading and mathematics.

Students who are prepared to undertake the study of algebra (either as a separate course or as part of an integrated mathematics course) in grade eight will be on the pathway for success in high school science. Those who are not as well prepared will struggle and may even fail in their science classes to the great frustration of their teachers and parents/guardians. For example, students who have not mastered arithmetic and algebra skills will find chemistry difficult, if not impossible. Science instruction should provide opportunities for students to use mathematics by solving problems. Teachers may use science to both reinforce mathematical abilities and deepen students’ understanding of key mathematical concepts.

Safety is always the foremost consideration in the design of demonstrations, hands-on activities, laboratories, and science projects on site or away from school. Safety should be taught. Scientists and engineers in universities and industries are required to follow strict environmental health and safety regulations. Knowing and following safe practices in science are a part of understanding the nature of science and scientific enterprise.

In middle school, students undertake the study of earth sciences. The curriculum presents many of the foundations of geology and geophysics, including plate tectonics and earth structure, topography, and energy. The material is linked to resource management, building on what students have learned in previous grades. Unless students take a high school earth science class, what they learn in grade six will be their foundation for earth science literacy.

Students in the middle school learn that this is an exciting time for the study of life sciences. Knowledge of biological systems is expanding rapidly, and the development of new technologies has led to major advances in medicine and agriculture.

Students in middle school study topics in physical sciences, such as motion, forces, and the structure of matter, by using a quantitative, mathematically based approach similar to the procedures they will use in high school. Earth, the solar system, chemical reactions, the chemistry of biological processes, the periodic table, and density and buoyancy are additional topics that will be treated with increased mathematical rigor, again in anticipation of high school courses. Students should begin to grasp four concepts that help to unify physical sciences: force and energy; the laws of conservation; atoms, molecules, and the atomic theory; and kinetic theory. Those concepts serve as important organizers that will be required as students continue to learn science. Although much of the science called for in the standards is considered “classical” physics and chemistry, it should provide a powerful basis for understanding modern science and serve students as well as adults. Mastery of the physical sciences content will greatly enhance the ability of students to succeed in high school science classes. Modern molecular biology and earth sciences, as well as chemistry and physics, require that students have a good understanding of the basics of physical sciences.

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The following Montana Science Standards will be integrated into the curriculum at each grade level:

Standard 1—Students design, conduct, evaluate and communicate scientific investigations.

Standard 2—Students demonstrate knowledge of properties, forms, changes and interactions of physical and chemical systems.

Standard 3—Students demonstrate knowledge of characteristics, structures and function of living things, the process and diversity of life, and how living organisms interact with each other and their environment.

Standard 4—Students demonstrate knowledge of the composition, structures, processes and interactions of Earth’s systems and other objects in space.

Standard 5—Students understand how scientific knowledge and technological developments impact society.

Standard 6—Students understand historical developments in science and technology.

Grade 6

Earth Science

Plate Tectonics and Earth's Structure

1. Plate tectonics accounts for important features of Earth's surface and major geologic events. As a basis for understanding this concept:

a. *Students know* evidence of plate tectonics is derived from the fit of the continents; the location of earthquakes, volcanoes, and mid-ocean ridges; and the distribution of fossils, rock types, and ancient climatic zones.

b. *Students know* Earth is composed of several layers: a cold, brittle lithosphere; a hot, convecting mantle; and a dense, metallic core.

c. *Students know* lithospheric plates the size of continents and oceans move at rates of centimeters per year in response to movements in the mantle.

d. *Students know* that earthquakes are sudden motions along breaks in the crust called faults and that volcanoes and fissures are locations where magma reaches the surface.

e. *Students know* major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.

f. *Students know* how to explain major features of Montana geology (including mountains and faults) in terms of plate tectonics.

g. *Students know* how to determine the epicenter of an earthquake and know that the effects of an earthquake on any region vary, depending on the size of the earthquake, the distance of the region from the epicenter.

Shaping Earth's Surface

2. Topography is reshaped by the weathering of rock and soil and by the transportation and deposition of sediment. As a basis for understanding this concept:

a. *Students know* water running downhill is the dominant process in shaping the landscape.

b. *Students know* rivers and streams are dynamic systems that erode, transport sediment, change course, and flood their banks in natural and recurring patterns.

c. *Students know* beaches are dynamic systems in which the sand is supplied by rivers and moved along the coast by the action of waves.

d. *Students know* earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.

Energy in the Earth System

3. Many phenomena on Earth's surface are affected by the transfer of energy through radiation and convection currents. As a basis for understanding this concept:

a. *Students know* the sun is the major source of energy for phenomena on Earth's surface; it powers winds, ocean currents, and the water cycle.

b. *Students know* solar energy reaches Earth through radiation, mostly in the form of visible light.

c. *Students know* heat from Earth's interior reaches the surface primarily through convection.

d. *Students know* convection currents distribute heat in the atmosphere and oceans.

e. *Students know* differences in pressure, heat, air movement, and humidity result in changes of weather.

Resources

4. Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their formation. As a basis for understanding this concept:

a. *Students know* the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.

b. *Students know* different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and know how to classify them as renewable or nonrenewable.

c. *Students know* the natural origin of the materials used to make common objects.

Earth in the Solar System

4. The structure and composition of the universe can be learned from studying stars and galaxies and their evolution. As a basis for understanding this concept:

a. *Students know* galaxies are clusters of billions of stars and may have different shapes.

b. *Students know* that the Sun is one of many stars in the Milky Way galaxy and that stars may differ in size, temperature, and color.

- c. *Students know* how to use astronomical units and light years as measures of distances between the Sun, stars, and Earth.
- d. *Students know* that stars are the source of light for all bright objects in outer space and that the Moon and planets shine by reflected sunlight, not by their own light.
- e. *Students know* the appearance, general composition, relative position and size, and motion of objects in the solar system, including planets, planetary satellites, comets, and asteroids.

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- a. Develop a hypothesis.
- b. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
- c. Construct appropriate graphs from data and develop qualitative statements about the relationships between variables.
- d. Communicate the steps and results from an investigation in written reports and oral presentations.
- e. Recognize whether evidence is consistent with a proposed explanation.
- f. Read a topographic map and a geologic map for evidence provided on the maps and construct and interpret a simple scale map.
- g. Interpret events by sequence and time from natural phenomena (e.g., the relative ages of rocks and intrusions).
- h. Identify changes in natural phenomena over time without manipulating the phenomena (e.g., a tree limb, a grove of trees, a stream, a hillslope).

Grade 7

Life Science

Cell Biology

All living organisms are composed of cells, from just one to many trillions, whose details usually are visible only through a microscope. As a basis for understanding this concept:

- a. *Students know* cells function similarly in all living organisms.
- b. *Students know* the characteristics that distinguish plant cells from animal cells, including chloroplasts and cell walls.
- c. *Students know* the nucleus is the repository for genetic information in plant and animal cells.
- d. *Students know* that mitochondria liberate energy for the work that cells do and that chloroplasts capture sunlight energy for photosynthesis.
- e. *Students know* cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.
- f. *Students know* that as multi-cellular organisms develop, their cells differentiate.

Genetics

A typical cell of any organism contains genetic instructions that specify its traits. Those traits may be modified by environmental influences. As a basis for understanding this concept:

- a. *Students know* the differences between the life cycles and reproduction methods of sexual and asexual organisms.
- b. *Students know* sexual reproduction produces offspring that inherit half their genes from each parent.
- c. *Students know* an inherited trait can be determined by one or more genes.
- d. *Students know* plant and animal cells contain many thousands of different genes and typically have two copies of every gene. The two copies (or alleles) of the gene may or may not be identical, and one may be dominant in determining the phenotype while the other is recessive.
- e. *Students know* DNA (deoxyribonucleic acid) is the genetic material of living organisms and is located in the chromosomes of each cell.

Biodiversity

Biodiversity developed through gradual processes over many generations. As a basis for understanding this concept:

- a. *Students know* both genetic variation and limiting environmental factors are causes of biodiversity of organisms.
- b. *Students know* how to construct a simple branching diagram to classify living groups of organisms by shared derived characteristics and how to expand the diagram to include fossil organisms.
- c. *Students know* that extinction of a species occurs when the environment changes and that the adaptive characteristics of a species are insufficient for its survival.

Structure and Function in Living Systems

The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function. As a basis for understanding this concept:

- a. *Students know* plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organism.
- b. *Students know* organ systems function because of the contributions of individual organs, tissues, and cells. The failure of any part can affect the entire system.
- c. *Students know* how bones and muscles work together to provide a structural framework for movement.
- d. *Students know* how the reproductive organs of the human female and male generate eggs and sperm and how sexual activity may lead to fertilization and pregnancy.
- e. *Students know* the function of the umbilicus and placenta during pregnancy.
- f. *Students know* the structures and processes by which flowering plants generate pollen, ovules, seeds, and fruit.
- g. *Students know* how to relate the structures of the eye and ear to their functions.

Investigation and Experimentation

7. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- a. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
- b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.
- c. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.
- d. Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e. g., motion of Earth's plates and cell structure).
- e. Communicate the steps and results from an investigation in written reports and oral presentations.

Grade 8

Physical Science

Motion

The velocity of an object is the rate of change of its position. As a basis for understanding this concept:

- a. *Students know* position is defined in relation to some choice of a standard reference point and a set of reference directions.
- b. *Students know* that average speed is the total distance traveled divided by the total time elapsed and that the speed of an object along the path traveled can vary.
- c. *Students know* how to solve problems involving distance, time, and average speed.
- d. *Students know* the velocity of an object must be described by specifying both the direction and the speed of the object.
- e. *Students know* changes in velocity may be due to changes in speed, direction, or both.
- f. *Students know* how to interpret graphs of position versus time and graphs of speed versus time for motion in a single direction.

Forces

Unbalanced forces cause changes in velocity. As a basis for understanding this concept:

- a. *Students know* a force has both direction and magnitude.
- b. *Students know* when an object is subject to two or more forces at once, the result is the cumulative effect of all the forces.
- c. *Students know* when the forces on an object are balanced, the motion of the object does not change.
- d. *Students know* how to identify separately the two or more forces that are acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.
- e. *Students know* that when the forces on an object are unbalanced, the object will change its velocity (that is, it will speed up, slow down, or change direction).
- f. *Students know* the greater the mass of an object, the more force is needed to achieve the same rate of change in motion.

g. *Students know* the role of gravity in forming and maintaining the shapes of planets, stars, and the solar system.

Structure of Matter

Each of the more than 100 elements of matter has distinct properties and a distinct atomic structure. All forms of matter are composed of one or more of the elements. As a basis for understanding this concept:

a. *Students know* the structure of the atom and know it is composed of protons, neutrons, and electrons.

b. *Students know* that compounds are formed by combining two or more different elements and that compounds have properties that are different from their constituent elements.

c. *Students know* atoms and molecules form solids by building up repeating patterns, such as the crystal structure of NaCl or long-chain polymers.

d. *Students know* the states of matter (solid, liquid, gas) depend on molecular motion.

e. *Students know* that in solids the atoms are closely locked in position and can only vibrate; in liquids the atoms and molecules are more loosely connected and can collide with and move past one another; and in gases the atoms and molecules are free to move independently, colliding frequently.

f. *Students know* how to use the periodic table to identify elements in simple compounds.

Reactions

5. Chemical reactions are processes in which atoms are rearranged into different combinations of molecules. As a basis for understanding this concept:

a. *Students know* reactant atoms and molecules interact to form products with different chemical properties.

b. *Students know* the idea of atoms explains the conservation of matter: In chemical reactions the number of atoms stays the same no matter how they are arranged, so their total mass stays the same.

c. *Students know* chemical reactions usually liberate heat or absorb heat.

d. *Students know* physical processes include freezing and boiling, in which a material changes form with no chemical reaction.

e. *Students know* how to determine whether a solution is acidic, basic, or neutral.

Periodic Table

7. The organization of the periodic table is based on the properties of the elements and reflects the structure of atoms. As a basis for understanding this concept:

- a. *Students know* how to identify regions corresponding to metals, nonmetals, and inert gases.
- b. *Students know* each element has a specific number of protons in the nucleus (the atomic number) and each isotope of the element has a different but specific number of neutrons in the nucleus.
- c. *Students know* substances can be classified by their properties, including their melting temperature, density, hardness, and thermal and electrical conductivity.

Density and Buoyancy

8. All objects experience a buoyant force when immersed in a fluid. As a basis for understanding this concept:

- a. *Students know* density is mass per unit volume.
- b. *Students know* how to calculate the density of substances (regular and irregular solids and liquids) from measurements of mass and volume.
- c. *Students know* the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid the object has displaced.
- d. *Students know* how to predict whether an object will float or sink.

Heat (Thermal Energy)

3. Heat moves in a predictable flow from warmer objects to cooler objects until all the objects are at the same temperature. As a basis for understanding this concept:

- a. *Students know* energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.
- b. *Students know* that when fuel is consumed, most of the energy released becomes heat energy.
- c. *Students know* heat flows in solids by conduction (which involves no flow of matter) and in fluids by conduction and by convection (which involves flow of matter).
- d. *Students know* heat energy is also transferred between objects by radiation (radiation can travel through space).

Investigation and Experimentation

9. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- a. Plan and conduct a scientific investigation to test a hypothesis.
- b. Evaluate the accuracy and reproducibility of data.
- c. Distinguish between variable and controlled parameters in a test.
- d. Recognize the slope of the linear graph as the constant in the relationship $y = kx$ and apply this principle in interpreting graphs constructed from data.
- e. Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.
- f. Apply simple mathematic relationships to determine a missing quantity in a mathematic expression, given the two remaining terms (including speed = distance/time, density = mass/volume, force = pressure x area, volume = area x height).
- g. Distinguish between linear and nonlinear relationships on a graph of data.

The Science Curriculum for Grades Nine—Twelve

The science curriculum for kindergarten through grade eight provide the background for students to succeed with the science content standards for grades nine through twelve. Successful implementation of our standards-based kindergarten-through-grade-eight curriculum should enable more students to be successful in science courses in high school.

Appropriate to the rigor of the curriculum, each section covers a particular scientific discipline: physics, chemistry, biology/life sciences, and earth sciences. Along with meeting the subject-matter requirements for science, every student should learn the content in the full set of Investigation and Experimentation standards and have an opportunity to learn the slightly more advanced material in the standards that are marked with an asterisk in intro classes or advanced electives.

Technology can be used to teach some science standards and to assess students' understanding. Science education provides an opportunity to instruct students in gathering, graphing, tracking, and interpreting data through the use of technological tools, such as word processing, spreadsheets, and database development. Related concepts from science, mathematics, and language arts can be merged in the development of a science experiment and its subsequent analysis.

Safety is always the foremost consideration in the design of demonstrations, laboratories, and science experiments. The importance of safety is evident because scientists and engineers in universities and industries are required to follow strict health and safety regulations. Safety needs to be taught.

Here in Ronan School District #30, we have many local resources developed at SKC and in coordination with NASA Science Curriculum Project available for our use. These resources can provide additional appropriate resources for study for our students.

The following Montana Science Standards will be integrated into the curriculum in each course:

Standard 1—Students design, conduct, evaluate and communicate scientific investigations.

Standard 2—Students demonstrate knowledge of properties, forms, changes and interactions of physical and chemical systems.

Standard 3—Students demonstrate knowledge of characteristics, structures and function of living things, the process and diversity of life, and how living organisms interact with each other and their environment.

Standard 4—Students demonstrate knowledge of the composition, structures, processes and interactions of Earth’s systems and other objects in space.

Standard 5—Students understand how scientific knowledge and technological developments impact society.

Standard 6—Students understand historical developments in science and technology.

Physics

Many scientists and engineers consider physics the most basic of all sciences. It covers the study of motion, forces, energy, heat, waves, light, electricity, and magnetism. Physics focuses on the development of models deeply rooted in scientific inquiry, in which mathematics is used to describe and predict natural phenomena and to express principles and theories. Understanding physics requires the ability to use algebra, geometry, and trigonometry. This need for mathematics has kept all but a very few students in this country from studying physics. Other countries, however, have met this challenge by introducing the concepts of physics to students during a period of several years, starting in the earlier grade levels. Topics requiring little or no mathematics are introduced first, and students progress to more sophisticated and quantitative treatments as they learn more mathematics. The curriculum emulates this successful approach.

All students can learn high school physics. Many will have enough foundational skills and knowledge of mathematics from their science curriculum in earlier years to study motion, forces, heat, and light. In high school, students should develop a working knowledge of algebra, geometry, and simple trigonometry to understand and gain access to the power of physics. Some will need to learn or relearn algebra, geometry, and trigonometry skills while studying physics. The need for such mathematics review should lessen over time as Ronan's rigorous mathematics standards are implemented.

Standards that all students are expected to achieve in the course of their studies are unmarked. Standards that all students should have the opportunity to learn are marked with an asterisk ().*

Motion and Forces

1. Newton's laws predict the motion of most objects. As a basis for understanding this concept:
 - a. *Students know* how to solve problems that involve constant speed and average speed.
 - b. *Students know* that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law).
 - c. *Students know* how to apply the law $F = ma$ to solve one-dimensional motion problems that involve constant forces (Newton's second law).
 - d. *Students know* that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law).

- e. *Students know* the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth.
- f. *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed).
- g. *Students know* circular motion requires the application of a constant force directed toward the center of the circle.
- h. *Students know* how to solve two-dimensional trajectory problems.
- i. *Students know* how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components.
- j. *Students know* how to solve two-dimensional problems involving balanced forces (statics).
- k. *Students know* how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a = v^2/r$.
- l. *Students know* how to solve problems involving the forces between two electric charges at a distance (Coulomb's law) or the forces between two masses at a distance (universal gravitation).
- m.* *Students know* Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light or is small enough that quantum effects are important.

Conservation of Energy and Momentum

2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects. As a basis for understanding this concept:
- a. *Students know* how to calculate kinetic energy by using the formula $E = (1/2)mv^2$.
- b. *Students know* how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) = mgh (h is the change in the elevation).
- c. *Students know* how to solve problems involving conservation of energy in simple systems, such as falling objects.

- d. *Students know* how to calculate momentum as the product mv .
- e. *Students know* momentum is a separately conserved quantity different from energy.
- f. *Students know* an unbalanced force on an object produces a change in its momentum.
- g. *Students know* how to solve problems involving elastic and inelastic collisions in one dimension by using the principles of conservation of momentum and energy.
- h.* *Students know* how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs.

Heat and Thermodynamics

3. Energy cannot be created or destroyed, although in many processes energy is transferred to the environment as heat. As a basis for understanding this concept:
- a. *Students know* heat flow and work are two forms of energy transfer between systems.
 - b. *Students know* that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy.
 - c. *Students know* the internal energy of an object includes the energy of random motion of the object's atoms and molecules, often referred to as *thermal energy*. The greater the temperature of the object, the greater the energy of motion of the atoms and molecules that make up the object.
 - d. *Students know* that most processes tend to decrease the order of a system over time and that energy levels are eventually distributed uniformly.
 - e. *Students know* that entropy is a quantity that measures the order or disorder of a system and that this quantity is larger for a more disordered system.
 - f.* *Students know* the statement "Entropy tends to increase" is a law of statistical probability that governs all closed systems (second law of thermodynamics).
 - g.* *Students know* how to solve problems involving heat flow, work, and efficiency in a heat engine and know that all real engines lose some heat to their surroundings.

Waves

4. Waves have characteristic properties that do not depend on the type of wave. As a basis for understanding this concept:

- a. *Students know* waves carry energy from one place to another.
- b. *Students know* how to identify transverse and longitudinal waves in mechanical media, such as springs and ropes, and on the earth (seismic waves).
- c. *Students know* how to solve problems involving wavelength, frequency, and wave speed.
- d. *Students know* sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates.
- e. *Students know* radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second).
- f. *Students know* how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization.

Electric and Magnetic Phenomena

5. Electric and magnetic phenomena are related and have many practical applications. As a basis for understanding this concept:

- a. *Students know* how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors.
- b. *Students know* how to solve problems involving Ohm's law.
- c. *Students know* any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) $\times I$ (current) = I^2R .
- d. *Students know* the properties of transistors and the role of transistors in electric circuits.
- e. *Students know* charged particles are sources of electric fields and are subject to the forces of the electric fields from other charges.
- f. *Students know* magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources.
- g. *Students know* how to determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil.
- h. *Students know* changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors.

i. *Students know* plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity.

j.* *Students know* electric and magnetic fields contain energy and act as vector force fields.

k.* *Students know* the force on a charged particle in an electric field is qE , where E is the electric field at the position of the particle and q is the charge of the particle.

l.* *Students know* how to calculate the electric field resulting from a point charge.

m.* *Students know* static electric fields have as their source some arrangement of electric charges.

n.* *Students know* the magnitude of the force on a moving particle (with charge q) in a magnetic field is $qvB \sin(a)$, where a is the angle between v and B (v and B are the magnitudes of vectors v and B , respectively), and students use the right-hand rule to find the direction of this force.

o.* *Students know* how to apply the concepts of electrical and gravitational potential energy to solve problems involving conservation of energy.

Chemistry

A sign in a university professor's office asks, "What in the world isn't chemistry?" Although meant to amuse, this question has a world of truth behind it. High school students come into contact with chemistry every day, often without realizing it. Discussions of daily interactions with chemistry often provide an entry into teaching the subject in high school. Although relating chemistry to daily life is helpful, this approach does not diminish the need for students to have a high level of readiness before entering the class. Of paramount importance is a firm grounding in algebra.

Chemistry is a sequential, hierarchical science that is descriptive and theoretical. It requires knowing the macroscopic properties of matter and the microscopic properties of matter's constituent particles. Although chemical demonstrations may engage students, going beyond a superficial appreciation of chemistry is a critical step.

Chemistry requires high-level problem-solving skills, such as designing experiments and solving word problems. For students to learn concepts of chemistry, they must learn new vocabulary, including the rules for naming simple compounds and ions. Students can discover chemistry's tremendous power to explain the nature of matter and its transformations when they study the periodic table of the elements.

Students who move beyond a trivial treatment of the discipline can explore the many useful, elegant, and even beautiful aspects of chemistry. Bringing students to this understanding is a great achievement.

Standards that all students are expected to achieve in the course of their studies are unmarked. Standards that all students should have the opportunity to learn are marked with an asterisk ().*

Atomic and Molecular Structure

1. The periodic table displays the elements in increasing atomic number and shows how periodicity of the physical and chemical properties of the elements relates to atomic structure. As a basis for understanding this concept:

- a. *Students know* how to relate the position of an element in the periodic table to its atomic number and atomic mass.
- b. *Students know* how to use the periodic table to identify metals, semimetals, non-metals, and halogens.
- c. *Students know* how to use the periodic table to identify alkali metals, alkaline earth metals and transition metals, trends in ionization energy, electronegativity, and the relative sizes of ions and atoms.

- d. *Students know* how to use the periodic table to determine the number of electrons available for bonding.
- e. *Students know* the nucleus of the atom is much smaller than the atom yet contains most of its mass.
- f.* *Students know* how to use the periodic table to identify the lanthanide, actinide, and transactinide elements and know that the transuranium elements were synthesized and identified in laboratory experiments through the use of nuclear accelerators.
- g.* *Students know* how to relate the position of an element in the periodic table to its quantum electron configuration and to its reactivity with other elements in the table.
- h.* *Students know* the experimental basis for Thomson's discovery of the electron, Rutherford's nuclear atom, Millikan's oil drop experiment, and Einstein's explanation of the photoelectric effect.
- i.* *Students know* the experimental basis for the development of the quantum theory of atomic structure and the historical importance of the Bohr model of the atom.
- j.* *Students know* that spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with a frequency related to the energy spacing between levels by using Planck's relationship ($E = h\nu$).

Chemical Bonds

2. Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds from electrostatic forces between electrons and protons and between atoms and molecules. As a basis for understanding this concept:
- a. *Students know* atoms combine to form molecules by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds.
- b. *Students know* chemical bonds between atoms in molecules such as H_2 , CH_4 , NH_3 , H_2CCH_2 , N_2 , Cl_2 , and many large biological molecules are covalent.
- c. *Students know* salt crystals, such as $NaCl$, are repeating patterns of positive and negative ions held together by electrostatic attraction.
- d. *Students know* the atoms and molecules in liquids move in a random pattern relative to one another because the intermolecular forces are too weak to hold the atoms or molecules in a solid form.
- e. *Students know* how to draw Lewis dot structures.

f.* *Students know* how to predict the shape of simple molecules and their polarity from Lewis dot structures.

g.* *Students know* how electronegativity and ionization energy relate to bond formation.

h.* *Students know* how to identify solids and liquids held together by Van der Waals forces or hydrogen bonding and relate these forces to volatility and boiling/melting point temperatures.

Conservation of Matter and Stoichiometry

3. The conservation of atoms in chemical reactions leads to the principle of conservation of matter and the ability to calculate the mass of products and reactants. As a basis for understanding this concept:

a. *Students know* how to describe chemical reactions by writing balanced equations.

b. *Students know* the quantity *one mole* is set by defining one mole of carbon 12 atoms to have a mass of exactly 12 grams.

c. *Students know* one mole equals 6.02×10^{23} particles (atoms or molecules).

d. *Students know* how to determine the molar mass of a molecule from its chemical formula and a table of atomic masses and how to convert the mass of a molecular substance to moles, number of particles, or volume of gas at standard temperature and pressure.

e. *Students know* how to calculate the masses of reactants and products in a chemical reaction from the mass of one of the reactants or products and the relevant atomic masses.

f.* *Students know* how to calculate percent yield in a chemical reaction.

g.* *Students know* how to identify reactions that involve oxidation and reduction and how to balance oxidation-reduction reactions.

Gases and Their Properties

4. The kinetic molecular theory describes the motion of atoms and molecules and explains the properties of gases. As a basis for understanding this concept:

a. *Students know* the random motion of molecules and their collisions with a surface create the observable pressure on that surface.

b. *Students know* the random motion of molecules explains the diffusion of gases.

- c. *Students know* how to apply the gas laws to relations between the pressure, temperature, and volume of any amount of an ideal gas or any mixture of ideal gases.
- d. *Students know* the values and meanings of standard temperature and pressure (STP).
- e. *Students know* how to convert between the Celsius and Kelvin temperature scales.
- f. *Students know* there is no temperature lower than 0 Kelvin.
- g. *Students know* the kinetic theory of gases relates the absolute temperature of a gas to the average kinetic energy of its molecules or atoms.
- h. *Students know* how to solve problems by using the ideal gas law in the form $PV = nRT$.
- i. *Students know* how to apply Dalton's law of partial pressures to describe the composition of gases and Graham's law to predict diffusion of gases.

Acids and Bases

5. Acids, bases, and salts are three classes of compounds that form ions in water solutions. As a basis for understanding this concept:

- a. *Students know* the observable properties of acids, bases, and salt solutions.
- b. *Students know* acids are hydrogen-ion-donating and bases are hydrogen-ion-accepting substances.
- c. *Students know* strong acids and bases fully dissociate and weak acids and bases partially dissociate.
- d. *Students know* how to use the pH scale to characterize acid and base solutions.
- e. *Students know* the Arrhenius, Bronsted-Lowry, and Lewis acid-base definitions.
- f. *Students know* how to calculate pH from the hydrogen-ion concentration.
- g.* *Students know* buffers stabilize pH in acid-base reactions.

Solutions

6. Solutions are homogenous mixtures of two or more substances. As a basis for understanding this concept:

- a. *Students know* the definitions of *solute* and *solvent*.

- b. *Students know* how to describe the dissolving process at the molecular level by using the concept of random molecular motion.
- c. *Students know* temperature, pressure, and surface area affect the dissolving process.
- d. *Students know* how to calculate the concentration of a solute in terms of grams per liter, molarity, parts per million, and percent composition.
- e.* *Students know* the relationship between the molality of a solute in a solution and the solution's depressed freezing point or elevated boiling point.
- f.* *Students know* how molecules in a solution are separated or purified by the methods of chromatography and distillation.

Chemical Thermodynamics

7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:

- a. *Students know* how to describe temperature and heat flow in terms of the motion of molecules (or atoms).
- b. *Students know* chemical processes can either release (exothermic) or absorb (endothermic) thermal energy.
- c. *Students know* energy is released when a material condenses or freezes and is absorbed when a material evaporates or melts.
- d. *Students know* how to solve problems involving heat flow and temperature changes, using known values of specific heat and latent heat of phase change.
- e.* *Students know* how to apply Hess's law to calculate enthalpy change in a reaction.
- f.* *Students know* how to use the Gibbs free energy equation to determine whether a reaction would be spontaneous.

Reaction Rates

8. Chemical reaction rates depend on factors that influence the frequency of collision of reactant molecules. As a basis for understanding this concept:

- a. *Students know* the rate of reaction is the decrease in concentration of reactants or the increase in concentration of products with time.
- b. *Students know* how reaction rates depend on such factors as concentration, temperature, and pressure.

- c. *Students know* the role a catalyst plays in increasing the reaction rate.
- d.* *Students know* the definition and role of activation energy in a chemical reaction.

Chemical Equilibrium

9. Chemical equilibrium is a dynamic process at the molecular level. As a basis for understanding this concept:

- a. *Students know* how to use LeChatelier's principle to predict the effect of changes in concentration, temperature, and pressure.
- b. *Students know* equilibrium is established when forward and reverse reaction rates are equal.
- c.* *Students know* how to write and calculate an equilibrium constant expression for a reaction.

Organic Chemistry and Biochemistry

10. The bonding characteristics of carbon allow the formation of many different organic molecules of varied sizes, shapes, and chemical properties and provide the biochemical basis of life. As a basis for understanding this concept:

- a. *Students know* large molecules (polymers), such as proteins, nucleic acids, and starch, are formed by repetitive combinations of simple subunits.
- b. *Students know* the bonding characteristics of carbon that result in the formation of a large variety of structures ranging from simple hydrocarbons to complex polymers and biological molecules.
- c. *Students know* amino acids are the building blocks of proteins.
- d.* *Students know* the system for naming the ten simplest linear hydrocarbons and isomers that contain single bonds, simple hydrocarbons with double and triple bonds, and simple molecules that contain a benzene ring.
- e.* *Students know* how to identify the functional groups that form the basis of alcohols, ketones, ethers, amines, esters, aldehydes, and organic acids.
- f.* *Students know* the R-group structure of amino acids and know how they combine to form the polypeptide backbone structure of proteins.

Nuclear Processes

11. Nuclear processes are those in which an atomic nucleus changes, including

radioactive decay of naturally occurring and human-made isotopes, nuclear fission, and nuclear fusion. As a basis for understanding this concept:

a. *Students know* protons and neutrons in the nucleus are held together by nuclear forces that overcome the electromagnetic repulsion between the protons.

b. *Students know* the energy release per gram of material is much larger in nuclear fusion or fission reactions than in chemical reactions. The change in mass (calculated by $E = mc^2$) is small but significant in nuclear reactions.

c. *Students know* some naturally occurring isotopes of elements are radioactive, as are isotopes formed in nuclear reactions.

d. *Students know* the three most common forms of radioactive decay (alpha, beta, and gamma) and know how the nucleus changes in each type of decay.

e. *Students know* alpha, beta, and gamma radiation produce different amounts and kinds of damage in matter and have different penetrations.

f.* *Students know* how to calculate the amount of a radioactive substance remaining after an integral number of half lives have passed.

g.* *Students know* protons and neutrons have substructures and consist of particles called quarks.

Biology/Life Sciences

Living organisms appear in many variations, yet there are basic similarities among their forms and functions. For example, all organisms require an outside source of energy to sustain life processes; all organisms demonstrate patterns of growth and, in many cases, senescence, the process of becoming old; and the continuity of all species requires reproduction. All organisms are constructed from the same types of macromolecules (proteins, nucleic acids, lipids) and inherit a deoxyribonucleic acid (DNA) genome from a parent or parents. DNA is always transcribed to yield ribonucleic acid (RNA), which is translated through the use of a nearly universal genetic code. Environmental factors frequently regulate and influence the expression of specific genes.

Biology textbooks typically start with a review of chemistry and energetics; therefore, students will be able to make good use of their study of the curriculum for “Chemistry of Living Systems” in the middle school grade. The principles of cellular biology, including respiration and photosynthesis, are usually taught next, followed by instruction in molecular and Mendelian genetics. Population genetics follow naturally from the study of genetics and lead to a discussion of diversity of form and physiology. Ecology can be an introduction or culmination to these topics in biology.

Standards that all students are expected to achieve in the course of their studies are unmarked. Standards that all students should have the opportunity to learn are marked with an asterisk ().*

Cell Biology

1. The fundamental life processes of plants and animals depend on a variety of chemical reactions that occur in specialized areas of the organism's cells. As a basis for understanding this concept:
 - a. *Students know* cells are enclosed within semipermeable membranes that regulate their interaction with their surroundings.
 - b. *Students know* enzymes are proteins that catalyze biochemical reactions without altering the reaction equilibrium and the activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings.
 - c. *Students know* how prokaryotic cells, eukaryotic cells (including those from plants and animals), and viruses differ in complexity and general structure.
 - d. *Students know* the central dogma of molecular biology outlines the flow of information from transcription of ribonucleic acid (RNA) in the nucleus to translation of proteins on ribosomes in the cytoplasm.

- e. *Students know* the role of the endoplasmic reticulum and Golgi apparatus in the secretion of proteins.
- f. *Students know* usable energy is captured from sunlight by chloroplasts and is stored through the synthesis of sugar from carbon dioxide.
- g. *Students know* the role of the mitochondria in making stored chemical-bond energy available to cells by completing the breakdown of glucose to carbon dioxide.
- h. *Students know* most macromolecules (polysaccharides, nucleic acids, proteins, lipids) in cells and organisms are synthesized from a small collection of simple precursors.
- i. *Students know* how eukaryotic cells are given shape and internal organization by a cytoskeleton or cell wall or both.
- j.* *Students know* how chemiosmotic gradients in the mitochondria and chloroplast store energy for ATP production.

Genetics

2. Mutation and sexual reproduction lead to genetic variation in a population. As a basis for understanding this concept:

- a. *Students know* meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.
- b. *Students know* only certain cells in a multicellular organism undergo meiosis.
- c. *Students know* how random chromosome segregation explains the probability that a particular allele will be in a gamete.
- d. *Students know* new combinations of alleles may be generated in a zygote through the fusion of male and female gametes (fertilization).
- e. *Students know* why approximately half of an individual's DNA sequence comes from each parent.
- f. *Students know* the role of chromosomes in determining an individual's sex.
- g. *Students know* how to predict possible combinations of alleles in a zygote from the genetic makeup of the parents.

3. A multi-cellular organism develops from a single zygote, and its phenotype depends on its genotype, which is established at fertilization. As a basis for understanding this concept:

a. *Students know* how to predict the probable outcome of phenotypes in a genetic cross from the genotypes of the parents and mode of inheritance (autosomal or X-linked, dominant or recessive).

b. *Students know* the genetic basis for Mendel's laws of segregation and independent assortment.

c. *Students know* how to predict the probable mode of inheritance from a pedigree diagram showing phenotypes.

d.* *Students know* how to use data on frequency of recombination at meiosis to estimate genetic distances between loci and to interpret genetic maps of chromosomes.

4. Genes are a set of instructions encoded in the DNA sequence of each organism that specify the sequence of amino acids in proteins characteristic of that organism. As a basis for understanding this concept:

a. *Students know* the general pathway by which ribosomes synthesize proteins, using tRNAs to translate genetic information in mRNA.

b. *Students know* how to apply the genetic coding rules to predict the sequence of amino acids from a sequence of codons in RNA.

c. *Students know* how mutations in the DNA sequence of a gene may or may not affect the expression of the gene or the sequence of amino acids in an encoded protein.

d. *Students know* specialization of cells in multi-cellular organisms is usually due to different patterns of gene expression rather than to differences of the genes themselves.

e. *Students know* proteins can differ from one another in the number and sequence of amino acids.

f.* *Students know* why proteins having different amino acid sequences typically have different shapes and chemical properties.

5. The genetic composition of cells can be altered by incorporation of exogenous DNA into the cells. As a basis for understanding this concept:

a. *Students know* the general structures and functions of DNA, RNA, and protein.

b. *Students know* how to apply base-pairing rules to explain precise copying of DNA

during semiconservative replication and transcription of information from DNA into mRNA.

c. *Students know* how genetic engineering (biotechnology) is used to produce novel biomedical and agricultural products.

d.* *Students know* how basic DNA technology (restriction digestion by endonucleases, gel electrophoresis, ligation, and transformation) is used to construct recombinant DNA molecules.

e.* *Students know* how exogenous DNA can be inserted into bacterial cells to alter their genetic makeup and support expression of new protein products.

Ecology

6. Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept:

a. *Students know* biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats.

b. *Students know* how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.

c. *Students know* how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.

d. *Students know* how water, carbon, and nitrogen cycle between abiotic resources and organic matter in the ecosystem and how oxygen cycles through photosynthesis and respiration.

e. *Students know* a vital part of an ecosystem is the stability of its producers and decomposers.

f. *Students know* at each link in a food web some energy is stored in newly made structures but much energy is dissipated into the environment as heat. This dissipation may be represented in an energy pyramid.

g.* *Students know* how to distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change.

Diversity

7. The great diversity of organisms has resulted in life forms that have filled every available niche. Classification: Biological classifications are based on how organisms

are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities that reflect their relationships. Species is the next fundamental unit of classification.

The frequency of an allele in a gene pool of a population depends on many factors and may be stable or unstable over time. As a basis for understanding this concept:

- a. *Students know* why natural selection acts on the phenotype rather than the genotype of an organism.
- b. *Students know* why alleles that are lethal in a homozygous individual may be carried in a heterozygote and thus maintained in a gene pool.
- c. *Students know* new mutations are constantly being generated in a gene pool.
- d. *Students know* variation within a species increases the likelihood that at least some members of a species will survive under changed environmental conditions.
- e.* *Students know* the conditions for Hardy-Weinberg equilibrium in a population and why these conditions are not likely to appear in nature.
- f.* *Students know* how to solve the Hardy-Weinberg equation to predict the frequency of genotypes in a population, given the frequency of phenotypes.

8. Evolution is the result of genetic changes that occur in constantly changing environments. As a basis for understanding this concept:

- a. *Students know* how natural selection determines the differential survival of groups of organisms.
- b. *Students know* a great diversity of species increases the chance that at least some organisms survive major changes in the environment.
- c. *Students know* the effects of genetic drift on the diversity of organisms in a population.
- d. *Students know* reproductive or geographic isolation affects speciation.
- e. *Students know* that fossil evidence provides support for changing biological diversity, episodic speciation, and mass extinction.
- f.* *Students know* how to use comparative embryology, DNA or protein sequence comparisons, and other independent sources of data to create a branching diagram (cladogram) that shows probable relationships.

Physiology

9. As a result of the coordinated structures and functions of organ systems, the internal environment of the human body remains relatively stable (homeostatic) despite changes in the outside environment. As a basis for understanding this concept:

a. *Students know* how the complementary activity of major body systems provides cells with oxygen and nutrients and removes toxic waste products such as carbon dioxide.

b. *Students know* how the nervous system mediates communication between different parts of the body and the body's interactions with the environment.

c. *Students know* the functions of the nervous system and the role of neurons in transmitting electrochemical impulses.

d.* *Students know* how feedback loops in the nervous and endocrine systems regulate conditions in the body.

e.* *Students know* the roles of sensory neurons, interneurons, and motor neurons in sensation, thought, and response.

f.* *Students know* the individual functions and sites of secretion of digestive enzymes (amylases, proteases, nucleases, lipases), stomach acid, and bile salts.

g.* *Students know* the homeostatic role of the kidneys in the removal of nitrogenous wastes and the role of the liver in blood detoxification and glucose balance.

h.* *Students know* the cellular and molecular basis of muscle contraction, including the roles of actin, myosin, Ca^{+2} , and ATP.

i.* *Students know* how hormones (including digestive, reproductive, osmoregulatory) provide internal feedback mechanisms for homeostasis at the cellular level and in whole organisms.

10. Organisms have a variety of mechanisms to combat disease. As a basis for understanding the human immune response:

a. *Students know* the role of the skin in providing nonspecific defenses against infection.

b. *Students know* the role of antibodies in the body's response to infection.

c. *Students know* how vaccination protects an individual from infectious diseases.

d. *Students know* there are important differences between bacteria and viruses with respect to their requirements for growth and replication, the body's primary defenses against bacterial and viral infections, and effective treatments of these infections.

e. *Students know* why an individual with a compromised immune system (for example, a person with AIDS) may be unable to fight off and survive infections by microorganisms that are usually benign.

f.* *Students know* the roles of phagocytes, B-lymphocytes, and T-lymphocytes in the immune system.

Earth Sciences

In looking outward and deep into space and time, astronomers have discovered a vast and ancient universe. The study of earth sciences helps students find their place in this universe by showing where their unique world fits in with the grand scheme of the cosmos. Students of the earth sciences gain an understanding of the physical and chemical processes that formed Earth and continue to operate on this planet. As students study these science standards, they will also learn more about the geologic factors that make Montana special.

Standards that all students are expected to achieve in the course of their studies are unmarked. Standards that all students should have the opportunity to learn are marked with an asterisk ().*

Earth's Place in the Universe

1. Astronomy and planetary exploration reveal the solar system's structure, scale, and change over time. As a basis for understanding this concept:

- a. *Students know* how the differences and similarities among the sun, the terrestrial planets, and the gas planets may have been established during the formation of the solar system.
- b. *Students know* the evidence from Earth and moon rocks indicates that the solar system was formed from a nebular cloud of dust and gas approximately 4.6 billion years ago.
- c. *Students know* the evidence from geological studies of Earth and other planets suggest that the early Earth was very different from Earth today.
- d. *Students know* the evidence indicating that the planets are much closer to Earth than the stars are.
- e. *Students know* the Sun is a typical star and is powered by nuclear reactions, primarily the fusion of hydrogen to form helium.
- f. *Students know* the evidence for the dramatic effects that asteroid impacts have had in shaping the surface of planets and their moons and in mass extinctions of life on Earth.
- g.* *Students know* the evidence for the existence of planets orbiting other stars.

2. Earth-based and space-based astronomy reveal the structure, scale, and changes in stars, galaxies, and the universe over time. As a basis for understanding this concept:

- a. *Students know* the solar system is located in an outer edge of the disc-shaped Milky Way galaxy, which spans 100,000 light years.
- b. *Students know* galaxies are made of billions of stars and comprise most of the visible mass of the universe.
- c. *Students know* the evidence indicating that all elements with an atomic number greater than that of lithium have been formed by nuclear fusion in stars.
- d. *Students know* that stars differ in their life cycles and that visual, radio, and X-ray telescopes may be used to collect data that reveal those differences.
- e.* *Students know* accelerators boost subatomic particles to energy levels that simulate conditions in the stars and in the early history of the universe before stars formed.
- f.* *Students know* the evidence indicating that the color, brightness, and evolution of a star are determined by a balance between gravitational collapse and nuclear fusion.
- g.* *Students know* how the red-shift from distant galaxies and the cosmic background radiation provide evidence for the "big bang" model that suggests that the universe has been expanding for 10 to 20 billion years.

Dynamic Earth Processes

3. Plate tectonics operating over geologic time has changed the patterns of land, sea, and mountains on Earth's surface. As the basis for understanding this concept:

- a. *Students know* features of the ocean floor (magnetic patterns, age, and sea-floor topography) provide evidence of plate tectonics.
- b. *Students know* the principal structures that form at the three different kinds of plate boundaries.
- c. *Students know* how to explain the properties of rocks based on the physical and chemical conditions in which they formed, including plate tectonic processes.
- d. *Students know* that the rock cycle describes how sedimentary metamorphic and igneous rocks form and are converted from one type to another.
- e. *Students know* why and how earthquakes occur and the scales used to measure their intensity and magnitude.
- f. *Students know* there are two kinds of volcanoes: one kind with violent eruptions producing steep slopes and the other kind with voluminous lava flows producing gentle slopes.

g.* *Students know* the explanation for the location and properties of volcanoes that are due to hot spots and the explanation for those that are due to subduction.

Energy in the Earth System

4. Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. As a basis for understanding this concept:

a. *Students know* the relative amount of incoming solar energy compared with Earth's internal energy and the energy used by society.

b. *Students know* the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.

c. *Students know* the different atmospheric gases that absorb the Earth's thermal radiation and the mechanism and significance of the greenhouse effect.

d.* *Students know* the differing greenhouse conditions on Earth, Mars, and Venus; the origins of those conditions; and the climatic consequences of each.

5. Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept:

a. *Students know* how differential heating of Earth results in circulation patterns in the atmosphere and oceans that globally distribute the heat.

b. *Students know* the relationship between the rotation of Earth and the circular motions of ocean currents and air in pressure centers.

c. *Students know* the origin and effects of temperature inversions.

d. *Students know* terrestrial biomes on Earth are distributed in bands at specific latitudes.

e. **Students know* properties of ocean water, such as temperature and salinity, can be used to explain the layered structure of the oceans, the generation of horizontal and vertical ocean currents, and the geographic distribution of marine organisms.

f.* *Students know* the interaction of wind patterns, ocean currents, and mountain ranges results in the global pattern of latitudinal bands of terrestrial biomes.

g.* *Students know* features of the ENSO (El Niño southern oscillation) cycle in terms of sea-surface and air temperature variations across the Pacific and some climatic results of this cycle.

6. Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept:

- a. *Students know* weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere.
- b. *Students know* the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.
- c. *Students know* how Earth's climate has changed over time, corresponding to changes in Earth's geography, atmospheric composition, and other factors, such as solar radiation and plate movement.
- d.* *Students know* how computer models are used to predict the effects of the increase in greenhouse gases on climate for the planet as a whole and for specific regions.

Biogeochemical Cycles

7. Each element on Earth moves among reservoirs, which exist in the solid earth, in oceans, in the atmosphere, and within and among organisms as part of biogeochemical cycles. As a basis for understanding this concept:

- a. *Students know* the global carbon cycle: the different physical and chemical forms of carbon in the atmosphere, oceans, biomass, fossil fuels, and the movement of carbon among these reservoirs.
- b. *Students know* the movement of matter among reservoirs is driven by Earth's internal and external sources of energy.
- c.* *Students know* the relative residence times and flow characteristics of carbon in and out of its different reservoirs.

Structure and Composition of the Atmosphere

8. Life has changed Earth's atmosphere, and changes in the atmosphere affect conditions for life. As a basis for understanding this concept:

- a. *Students know* the thermal structure and chemical composition of the atmosphere.
- b. *Students know* how the composition of Earth's atmosphere has evolved over geologic time and know the effect of outgassing, the variations of carbon dioxide concentration, and the origin of atmospheric oxygen.
- c. *Students know* the location of the ozone layer in the upper atmosphere, its role in absorbing ultraviolet radiation, and the way in which this layer varies both naturally and in response to human activities.

Montana Geology

9. The geology of Montana underlies the state's wealth of natural resources as well as its natural hazards. As a basis for understanding this concept:

- a. *Students know* the resources of major economic importance in Montana and their relation to Montana's geology.
- b. *Students know* the principal natural hazards in different Montana regions and the geologic basis of those hazards.
- c. Students know that weathering and erosion are responsible for constantly changing landscapes over time. Erosion by glaciers and running water have shaped Montana's current landscape.
- d. *Students know* the importance of water to society, the origins of Montana's fresh water, and the relationship between supply and need.
- e. Students know how to read and interpret topographic, geologic, and weather maps.
- f.* *Students know* how to analyze published geologic hazard maps of Montana and know how to use the map's information to identify evidence of geologic events of the past and predict geologic changes in the future.

Investigation and Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

- a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
- b. Identify and communicate sources of unavoidable experimental error.
- c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.
- d. Formulate explanations by using logic and evidence.
- e. Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions.

- f. Distinguish between hypothesis and theory as scientific terms.
- g. Recognize the usefulness and limitations of models and theories as scientific representations of reality.
- h. Analyze the locations, sequences, or time intervals that are characteristic of natural phenomena (e.g., relative ages of rocks, locations of planets over time, and succession of species in an ecosystem).
- i. Recognize the issues of statistical variability and the need for controlled tests.
- j. Recognize the cumulative nature of scientific evidence.
- k. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.
- l. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in Montana.
- m. Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent (e. g., the Piltdown Man fossil or unidentified flying objects) and that the theory is sometimes wrong (e.g., the Ptolemaic model of the movement of the Sun, Moon, and planets).