Science Education Standards for Florida Public Schools

Standards of Excellence, Standards for Excellence

A Suggested Basis for Discussion and Revision

of Sunshine State Standards

2007-08

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A Project of Florida Citizens for Science, Inc.

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Dear Reader:

Florida Citizens for Science, Inc., (FCS) is a nonprofit educational organization focused on the improvement of science education in Florida's public schools and the promotion of science literacy in Florida. An objective of FCS is to support science-based curricula, textbooks, testing methods and appropriately trained teachers to provide students with the analytical skills and understanding necessary for the good of our communities, our state, our county and our world. We maintain that the proper focus of science education is the understanding of the natural world through observation, testing and analysis.

In light of the review and revision of public school science education standards planned later in 2007 and 2008 by the Florida Department of Education, the FCS Board of Directors determined that drafting a new set of science standards would be of service to the community at large. We intend that the draft standards that follow in this document be used as a starting point for discussion about both the impending revision process and the continuing evolution of the Florida Sunshine State Science Education Standards as we proceed in the 21st Century. While the standards are only one aspect of science education in Florida, they will influence all other aspects of science education—textbook selection, classroom teaching and high-stakes FCAT testing—for the next ten years.

We also hope that the adoption of rigorous, scientifically advanced public school standards will encourage the state colleges of education to strengthen their training of prospective science teachers.

The committee that undertook this significant work, chaired by Phyllis Park Saarinen, is composed of both teachers and non-teachers. The members of the FCS Board of Directors Standards Revision Committee and the Standards Review Subcommittee that reviewed the draft are listed below. You may note that the reviewers, some of whom made substantive changes in arrangement and content, are active and retired science teachers at the elementary, middle school, high school and college levels. As a group, they spent hundreds of hours on the review and have contributed significantly to the quality of this draft. Their experience in Florida schools is invaluable to the orientation and 'teachability' of these standards. We are grateful to them and acknowledge the importance of their contributions.

We have endeavored to compose the best possible standards by starting with the highest nationally rated standards currently adopted and successfully applied. We therefore drew upon California and Virginia standards, ranked first and second, respectively, in the Thomas B. Fordham Institute report "State of State Science 2005." We have used aspects of each of these sets of standards to ensure that the draft standards herein proposed for Florida include the following elements:

- Standards content is scientifically accurate and current.
- Grade level expectations are clear and concise.
- Emphasis is on the scientific process as a means of learning how to solve problems.
- Student learning proceeds from fact to conceptual theory and acknowledges students' intellectual development and mathematical skills.
- More rigorous material is included in honors courses.
- Laboratory safety is important to making science education a positive experience.

You may make copies of this document, including this letter, and distribute them to interested members of your community. FCS has no copyright interest in it.

Sincerely,

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INTRODUCTION

Well organized, comprehensive and intellectually rigorous science education standards are critical to providing science teachers with the structure, direction and content to improve science literacy and achievement among our children. Such standards, in conjunction with qualified, motivated and trained teachers, are essential to teaching students the skills and knowledge they will need to be scientifically literate citizens who are able to navigate an increasingly technologically sophisticated Twenty-First Century.

The demand is greater than ever for people who can communicate effectively, identify and analyze problems, and quickly learn new skills to solve these problems, both independently and as part of a team. These are the kinds of skills that go hand in hand with science education that teaches the methodology of science as well as the scientific consensus on how the natural world works.

Science, technology, and societal issues are strongly connected to community health, population, natural resources, environmental quality, natural and human-induced hazards, and other global challenges. The standards should be viewed as the foundation for understanding these issues.

Florida has set a priority on developing and attracting clean, science-based industries. We will be successful in growing toward this goal only if the people of the state understand and appreciate science and its ability to understand the natural world. These standards are the foundation for increasing the scientific literacy of all Florida residents and thus to support the growth of Florida's economy into a more secure and universally prosperous future.

While these standards set expectations for student learning, they provide the necessary flexibility to the teacher on how the standards should be taught. Teachers will use their skills, experience, talents and resources to design standards-based classroom lessons that meet the individual needs of their students.

Quality science standards should pose a challenge for some students and even teachers. However, meeting higher expectations leads to greater rewards and opportunities, not only for the student, but also for the teacher, the school system, and ultimately the whole state of Florida. By setting specific goals, quality science standards give teachers clear targets, students will know what is expected, and parents have information about what is expected and whether their children are learning the material. Parental involvement is vital to student success; understanding these standards allows parents to engage in meaningful dialogue about their students' progress. More than simply a checklist, the standards should provide a comprehensive look at what all students should know and be able to do at each grade level.

The Science Education Standards serve as the basis for statewide student assessments, the science curriculum framework, and the evaluation of instructional materials. Students should have the opportunity to learn science by receiving direct instruction, by reading textbooks and supplemental materials, by solving standards-based problems, and by doing laboratory

investigations and experiments. The Investigation and Experimentation standards are integral to, and directly and specifically support, the teaching of the content threads and disciplines.

HIGHLIGHTS OF THE STANDARDS

The standards include grade-level specific content for kindergarten through grade eight with the intention that knowledge builds upon the learning in the previous years. A significant feature is the focus on earth sciences in the sixth grade, life sciences in the seventh grade, and physical sciences in the eighth grade which progresses from facts generally observed or observable in the natural world to more conceptual material in the physical sciences. The standards for grades nine through twelve are divided into four content threads: physics, chemistry, biology/life sciences, and earth sciences. An Investigation and Experimentation thread describes a progressive set of expectations for each grade from kindergarten through grade eight, and one set of Investigation and Experimentation standards is given for grades nine through twelve.

As the student proceeds from elementary school to high school, the standards for each grade level lay the foundation for the concepts taught at the next grade level. The elementary school standards call for early introduction of science facts and terms. Quality textbooks and reading materials in science are now available to support students in mastering these standards as they develop their reading skills and vocabulary. The Investigation and Experimentation standards allow students to make a concrete association between science and the study of nature as well as provide them with many opportunities to take measurements and sharpen their basic mathematical skills.

The middle school science standards, with emphasis on various disciplines at each grade level, raise the bar substantially for students. Many teachers, schools, and districts will need to restructure their curriculum to meet these standards. The standards make the middle school curriculum more rigorous in response to a national call for excellence and prepare students for an in-depth study of science at the high school level.

The high school science standards require more than two years of science courses for students in order to achieve the breadth and depth described. The Science Education Standards reflect the desired content of science curriculum in Florida public schools. This content should be taught so that students have the opportunity to build connections that link science to technology and societal impacts. Material that is more advanced and may be taught in honors courses is indicated as Honors Extension.

K-12 SAFETY

In implementing the Science Education Standards, teachers must be certain that students know how to follow safety guidelines, demonstrate appropriate laboratory safety techniques, and use equipment safely while working individually and in groups. Safety must be given the highest priority in implementing the K–12 instructional program for science.

Correct and safe techniques, as well as wise selection of experiments, resources, materials, and field experiences appropriate to age levels, must be carefully considered with regard to the safety precautions for every instructional activity. Safe science classrooms require thorough planning,

careful management, and constant monitoring of student activities. Class enrollment should not exceed the capacity of the room.

Teachers must be knowledgeable of the properties, use, and proper disposal of all chemicals that may be judged as hazardous prior to their use in an instructional activity. Such information is referenced through Materials Safety Data Sheets (MSDS). The identified precautions involving the use of goggles, gloves, aprons, and fume hoods must be followed as prescribed.

While no comprehensive list exists to cover all situations, the following should be reviewed to avoid potential safety problems. Appropriate safety procedures should be used in the following situations:

• observing wildlife; handling living and preserved organisms; and coming in contact with natural hazards, such as poisonous/stinging plants, insects, ticks and spiders, and snakes;
• engaging in field activities in, near, or over bodies of water;
• handling glass tubing and other glassware, sharp objects, and labware;
• handling natural gas burners, Bunsen burners, and other sources of flame/heat;
• working in or with direct sunlight (sunburn and eye damage);
• using extreme temperatures and cryogenic materials;
• handling hazardous chemicals including toxins, carcinogens, and flammable and explosive materials;
• producing acid/base neutralization reactions/dilutions;
• producing toxic gases;
• generating/working with high pressures;
• working with biological cultures, including recombinant DNA, and their appropriate disposal;
• handling power equipment/motors;
• working with high voltage/exposed wiring; and
• working with lasers, ultraviolet light, and other types of electromagnetic radiation.

The use of human body fluids or tissues is generally prohibited for classroom lab activities. Further guidance from the following sources may be referenced:

• OSHA (Occupational Safety and Health Administration);
• ISEF (International Science and Engineering Fair Rules); and
• public health departments and local school division protocols.

INVESTIGATE AND UNDERSTAND

Most of the Science Education Standards begin with the phrase “students will investigate and understand.” This phrase suggests a more active role for the student than simply sitting in a classroom trying to absorb a set of facts like a sponge. The student learns by doing and

appreciates science not as just a set of facts, but as a journey of discovery that can last a lifetime.

"Investigate" refers to scientific methodology and implies systematic use of the following inquiry skills:

- observing;
- classifying and sequencing;
- measuring;
- predicting;
- hypothesizing;
- inferring;
- defining, controlling, and manipulating variables in experimentation;
- designing, constructing, and interpreting models; and
- interpreting, analyzing, and evaluating data.

"Understand" refers to various levels of knowledge application. In the Science Education Standards these knowledge levels include the ability to:

- recall or recognize key terminology, facts and concepts;
- explain the concepts in one's own words, comprehend how the information is related to other key facts and concepts, and suggest additional interpretations of its meaning or importance;
- apply the facts and principles to new problems or situations, recognizing what information is required for a particular situation, using the information to explain new phenomena, and determining when there are exceptions;
- analyze the underlying details of important facts and principles, recognizing the key relations and patterns that are not always readily visible;
- arrange and combine important facts, principles, and other information to produce a new idea, plan, procedure, or product; and
- make judgments about information in terms of its accuracy, precision, consistency, or effectiveness.

Therefore, the use of "investigate and understand" allows each content standard to become the basis for a broad range of teaching objectives, which the local school division will develop and refine to meet the intent of the Science Education Standards.

Kindergarten

Through

Grade Five

Kindergarten

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 threads, 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.

Earth Sciences

Earth is composed of land, air, and water. As a basis for understanding this concept, students will investigate and understand:

a. Characteristics of mountains, rivers, oceans, valleys, deserts, and local landforms.
b. Changes in weather occur from day to day and across seasons, affecting the environment and its inhabitants.
c. How to identify resources from Earth that are used in everyday life, and understand that many resources can be conserved.

Life Sciences

Different types of plants and animals inhabit the earth. As a basis for understanding this concept, students will investigate and understand:

a. How to observe and describe similarities and differences in the appearance and behavior of plants and animals (e.g., seed-bearing plants, birds, fish, insects).
b. Stories sometimes give plants and animals attributes they do not really have.
c. How to identify major structures of common plants and animals (e.g., stems, leaves, roots, arms, wings, legs).

Physical Sciences

1. Materials come in different forms (states), including solids, liquids, and gases. Students will investigate and understand that:

a. Solids, liquids, and gases have different properties, and
b. The properties of substances can change when the substances are mixed, cooled, or heated.

2. Properties of materials can be observed, measured, and predicted. As a basis for understanding this concept, students will investigate and understand that:

a. Objects can be described in terms of the materials they are made of (e.g., clay, cloth, paper) and their physical properties (e.g., color, size, shape, weight, texture, flexibility, attraction to magnets, floating, sinking).
b. Water can be a liquid or a solid and can be made to change back and forth from one form to the other.
c. Water left in an open container evaporates (goes into the air) but water in a closed container does not.

GRADE ONE

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 threads, 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.
c. Record observations on a bar graph.
d. Describe the relative position of objects by using two references (e.g., above and next to, below and left of).
e. Make new observations when discrepancies exist between two descriptions of the same object or phenomenon.

Earth Sciences

Weather can be observed, measured, and described. As a basis for understanding this concept, students will investigate and understand:

a. How to use simple tools (e.g., thermometer, wind vane) to measure weather conditions and record changes from day to day and across the seasons.
b. Weather changes from day to day but trends in temperature or of rain (or snow) tend to be predictable during a season.
c. The Sun warms the land, air, and water of the planet Earth.
d. The Earth orbits the Sun, and the tilt of its axis results in seasonal change.

e. The Earth rotates on its axis, with the side away from the Sun shadowed in night.
f. The Moon orbits the Earth and always has the same side towards the Earth.

Life Sciences

Plants and animals meet their needs in different ways. As a basis for understanding this concept, students will investigate and understand:

a. Different plants and animals inhabit different kinds of environments and have external features that help them thrive in different kinds of places.
b. Both plants and animals need water and food, while most plants and animals need light.
c. Animals eat plants or other animals for food and may also use plants or even other animals for shelter and nesting.
d. How to infer what animals eat from the shapes of their teeth (e.g., sharp teeth for meat eaters and flat teeth for plant eaters).
e. Plants obtain water and nutrients from the soil through their roots, and make their food from sunlight using their green leaves.

Physical Sciences

The motion of objects can be observed and measured. As a basis for understanding this concept, students will investigate and understand that:

a. The position of an object can be described by locating it in relation to another object or to the background.
b. An object's motion can be described by recording the change in position of the object over time.
c. The way to change how something is moving is by giving it a push or a pull. The size of the change is related to the strength, or the amount of force, of the push or pull.
d. Tools and machines are used to apply pushes and pulls (forces) to make things move.
e. Objects fall to the ground unless something holds them up.
f. Magnets can be used to make some objects move without being touched.
g. Sound is made by vibrating objects and can be described by its pitch and volume.

GRADE TWO

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 instead of guessing.
b. Measure length, weight, temperature, and liquid volume with appropriate tools and express those measurements in standard metric system units.
c. Compare and sort common objects according to two or more physical attributes (e.g., color, shape, texture, size, weight).
d. Write or draw descriptions of a sequence of steps, events, and observations.
e. Construct bar graphs to record data, using appropriately labeled axes.
f. Use magnifiers or microscopes to observe and draw descriptions of small objects or small features of objects.
g. Follow oral instructions for a scientific investigation.

Earth Sciences

Earth is made of materials that have distinct properties and provide resources for human activities. As a basis for understanding this concept, students will investigate and understand:

a. How to compare the physical properties of different kinds of rocks and know that rock is composed of combinations of different minerals.
b. Smaller rocks come from the breakage and weathering of larger rocks.
c. Soil is made partly from weathered rock and partly from organic materials and that soils differ in their color, texture, capacity to retain water, and ability to support the growth of many kinds of plants.
d. Fossils provide evidence about the plants and animals that lived long ago and scientists learn about the past history of Earth by studying fossils.
e. Water, plants, rock and soil provide many resources for human use as food, fuel, and building materials.

Life Sciences

Plants and animals have recognizable life cycles. As a basis for understanding this concept, students will investigate and understand that:

a. Organisms reproduce offspring of their own kind and that the offspring resemble their parents

and one another.
b. Sequential stages of life cycles are different for different animals, such as butterflies, frogs, and mice.
c. Many characteristics of an organism are inherited from the parents. Some characteristics are caused or influenced by the environment.
d. There are variations among individuals of one kind within a given population.
e. Light, gravity, touch, or environmental stress can affect the germination, growth, and development of plants.
f. Flowers and fruits are associated with reproduction in plants

Physical Sciences

The motion of objects can be observed and measured. Students will investigate and understand that:

a. The position of an object can be described by locating it in relation to another object or to the background.
b. An object's motion can be described by recording the change in position of the object over time.
c. The way to change how something is moving is by giving it a push or a pull. The size of the change is related to the strength, or the amount of force, of the push or pull.
d. Tools and machines are used to apply pushes and pulls (forces) to make things move.
e. Objects fall to the ground unless something holds them up.
f. Magnets can be used to make some objects move without being touched.
g. Sound is made by vibrating objects and can be described by its pitch and volume.

GRADE THREE

Investigation and Experimentation

Scientific progress is made by asking 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 understand/recognize that the results of similar scientific investigations seldom turn out exactly the same due to differences in the things being investigated, the methods being used, or uncertainties in the observation.
b. Differentiate evidence from opinion and know that scientists do not rely on claims or conclusions unless they are supported by observations that can be confirmed.
c. Use numerical values in describing and comparing objects, events, and measurements.
d. Measure and estimate the weight and length of objects.
e. Predict the outcome of a simple investigation and compare the result with the prediction.

f. Collect data in an investigation and analyze those data to develop logical conclusions.

Earth Sciences

Objects in the sky move in regular and predictable patterns. As a basis for understanding this concept, students will investigate and understand:

a. Earth is one of several planets that orbit the Sun, and the Moon orbits the Earth.
b. The way in which the Moon's appearance changes during the four-week lunar cycle and why.
c. The position of the Sun in the sky changes during the course of the day and from season to season.
d. Seasons are due to the tilt of the Earth's axis and its movement around the Sun rather than to a change in the distance from the Sun.
e. The patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.
f. Telescopes magnify the appearance of some distant objects in the sky, including the Moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than the number that can be seen by the unaided eye. Distant objects can be seen better when viewed away from bright city lights and above the distorting nature of the atmosphere such as in space.

Life Sciences

Adaptations in physical structure or behavior may improve an organism's chance for survival. As a basis for understanding this concept, students will investigate and understand:

a. Plants and animals have structures that serve different functions in growth, survival, and reproduction.
b. Examples of diverse life forms in different environments, such as oceans, deserts, tundra, forests, grasslands, and wetlands.
c. Living things cause changes in the environment in which they live: some of these changes are detrimental to the organism or other organisms, and some are beneficial.
d. When the environment changes, some plants and animals survive and reproduce; others die or move to new locations.
e. Some kinds of organisms that once lived on Earth have completely disappeared, leaving only fossil remains, and that some of them resembled others that are alive today.
f. Adaptation to certain environments often results in similar physical structures and behaviors in different species.

Physical Sciences

1. Energy and matter have multiple forms and can be changed from one form to another. Students will investigate and understand that:

a. Energy comes from the Sun to the Earth in the form of light.
b. Sources of stored energy take many forms, such as food, fuel, and batteries.
c. Machines and living things can convert stored energy into motion and heat.
d. Energy can be carried from one place to another by waves (such as water waves and sound waves), by electric currents, and by moving objects.
e. Matter has four forms: solid, liquid, and gas and plasma.
f. Evaporation, boiling and melting are changes that occur when the objects are heated.
g. When two or more substances are combined, a new substance may be formed with properties that are different from those of the original materials.
h. All matter is made of small particles called atoms, too small to see with the naked eye.
i. There are more than 100 different types of atoms, which are presented on the periodic table of the elements.

2. Light has a source and travels in a direction. Students will investigate and understand:

a. Light can be blocked to create shadows.
b. Light is reflected from mirrors and other surfaces.
c. The human eye sees only visible light, but there are other kinds of electromagnetic radiation like x-rays, ultraviolet light and infrared radiation.

GRADE FOUR

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 threads, students should develop their own questions and perform investigations. As a basis for understanding this concept, students will:

a. Differentiate observation from inference (interpretation) and understand that 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 of the results.
f. Follow a set of written instructions for a scientific investigation.

Earth Sciences

1. The properties of rocks and minerals reflect the processes that formed them. As a basis for

understanding this concept, students will investigate and understand:

a. Students know how to differentiate among igneous, sedimentary, and metamorphic rocks by referring to their properties and methods of formation (the rock cycle).
b. Students know how to identify common rock-forming minerals (including quartz, calcite, feldspar, mica, and hornblende) and ore minerals by using a table of diagnostic properties.

2. Waves, wind, water, and ice shape and reshape Earth's land surface. As a basis for understanding this concept, students will investigate and understand:

a. Some changes in the earth are due to slow processes, such as erosion, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.
b. Natural processes, including freezing and thawing and the growth of roots, can break rocks into smaller pieces.
c. Moving water erodes landforms, reshaping the land by taking it away from some places and depositing it as pebbles, sand, silt, and mud in other places (weathering, transport, and deposition).

Life Sciences

1. All organisms need energy and matter to live and grow. As a basis for understanding this concept, students will investigate and understand:

a. Plants are the primary source of matter and energy entering most food chains.
b. Producers and consumers (herbivores, carnivores, omnivores, and decomposers) are related in food chains and food webs, and often compete with each other for resources in an ecosystem.
c. Decomposers, including many fungi, insects, and microorganisms, recycle matter from dead plants and animals.

2. Living organisms depend on one another and on their environment for survival. As a basis for understanding this concept, students will investigate and understand:

a. Ecosystems can be characterized by their living and nonliving components.
b. In any particular environment, some kinds of plants and animals survive well, some survive less well, and some cannot survive at all.
c. Many plants depend on animals for pollination and seed dispersal, and all animals depend directly or indirectly on plants for food and shelter.
d. Most microorganisms do not cause disease, and many are beneficial.

Physical Sciences

Electricity and magnetism are related effects that have many useful applications in everyday life. As a basis for understanding this concept, students will investigate and understand:

a. How to design and build simple series and parallel circuits by using components such as wires, batteries, and bulbs.
b. How to build a simple compass and use it to detect magnetic effects, including Earth's magnetic field.
c. Electric currents produce magnetic fields and how to build a simple electromagnet.
d. The role of electromagnets in the construction of electric motors, electric generators, and simple devices, such as doorbells and earphones.
e. Electrically charged objects attract or repel each other.
f. Magnets have two poles (north and south) and like poles repel each other while unlike poles attract each other.
g. Electrical energy can be converted to heat, light, and the motion of objects.

GRADE FIVE

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., animals, rocks, plants, leaves) in accordance with appropriate criteria.
b. Develop testable questions.
c. Plan and conduct simple investigations based on a student-developed question, and write instructions that others can follow to carry out the procedure.
d. Identify the dependent and independent variables in an investigation.
e. Identify a single independent variable in a scientific investigation and explain how this variable can be used to answer questions 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.

Earth Sciences

1. Water on Earth moves between the oceans and land through the processes of evaporation and condensation. As a basis for understanding this concept, students will investigate and understand:

a. Most of Earth's water is present as salt water in the oceans, which cover two-thirds of Earth's surface.
b. When liquid water evaporates, it turns into water vapor in the air and can reappear as a liquid when cooled or as a solid if cooled below the freezing point of water.
c. Water vapor in the air moves from one place to another and can form fog or clouds, which are tiny droplets of water or ice, and can fall to Earth as rain, hail, sleet, or snow.
d. The amount of fresh water located in rivers, lakes, underground sources, and glaciers is limited and that its availability can be extended by recycling and decreasing the use of water.
e. The origin of the water used by their local communities.

2. Energy from the Sun heats Earth unevenly, causing air movements that result in changing weather patterns. As a basis for understanding this concept, students will investigate and understand:

a. Uneven heating of Earth causes air movements (convection currents).
b. The influence that the ocean has on the weather and the role that the water cycle plays in weather patterns.
c. The causes and effects of different types of severe weather.
d. How to use weather maps and data to predict local weather, and recognize that weather forecasts depend on many variables.
e. The Earth's atmosphere exerts a pressure that decreases with the distance above Earth's surface and at any point it exerts this pressure equally in all directions.
f. The Earth's atmosphere is composed of different gases, including oxygen, nitrogen, carbon dioxide and water vapor.
g. The relative concentrations of gases, especially carbon dioxide and water vapor, affect the Earth's temperature and climate.
h. Carbon dioxide, water vapor and some other gases store the Sun's energy in the atmosphere and affect the Earth's climate.
i. Different areas of the Earth's surface, such as water (oceans and lakes), ice, desert land and forests reflect the Sun's energy differently. Ice reflects the most energy while water absorbs the most energy and thus affects the Earth's climate most strongly.

Life Sciences

Plants and animals have structures for respiration, digestion, waste disposal, and transport of materials. As a basis for understanding this concept, students will investigate and understand:

a. Many multicellular organisms have specialized structures to support the transport of materials.
b. How blood circulates through the heart chambers, lungs, and body and how carbon dioxide (CO_2) and oxygen (O_2) are exchanged in the lungs and tissues.
c. The sequential steps of digestion and the roles of teeth and the mouth, esophagus, stomach, small intestine, large intestine, and colon in the function of the digestive system.
d. The role of the kidney in removing cellular waste from blood and converting it into urine, which is stored in the bladder.

e. How sugar, water, and minerals are transported in a vascular plant.
f. Plants use carbon dioxide (CO_2) and energy from sunlight to build molecules of sugar and to release oxygen.
g. Plant and animal cells break down sugar to obtain energy, a process resulting in carbon dioxide and water (respiration).

Physical Sciences

Elements and their combinations account for all the varied types of matter in the world. As a basis for understanding this concept, students will investigate and understand:

a. During chemical reactions the elements in the reactants rearrange to form compounds with new and different properties.
b. All elements are made of atoms, which may combine to form molecules.
c. Metals have properties in common, such as high electrical and thermal conductivity. Some metals, such as aluminum (Al), iron (Fe), nickel (Ni), copper (Cu), silver (Ag), and gold (Au), are pure elements; others, such as steel and brass, are composed of a combination of elemental metals.
d. Each element is made of one kind of atom and the elements are organized in the periodic table by their chemical properties (i.e., how they interact with other elements).
e. Scientists have developed instruments that can create discrete images of atoms and molecules that show that the atoms and molecules often occur in well-ordered arrays.
f. Differences in chemical and physical properties of substances are used to separate mixtures and identify compounds.
g. Properties of solid, liquid, and gaseous substances, such as sugar (C_6HO_6), water (H_2O), helium (He), oxygen (O_2), nitrogen (N_2), and carbon dioxide (CO_2).
h. Living organisms and most materials are composed of just a few elements.
i. The common properties of salts, such as sodium chloride (NaCl).

MIDDLE SCHOOL

Grade Six

Through

Grade Eight

GRADE SIX--Focus on Earth Sciences

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 hill slope.

Shaping Earth's Surface

1. **Plate tectonics accounts for important features of Earth's surface and major geologic events.** Students will investigate and understand:

a. Earth is composed of several layers: a cold, relatively inflexible lithosphere; a hot, convecting mantle; and a dense, metallic core.
b. Lithospheric plates the size of continents and oceans move at rates of centimeters per year. 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.
c. Earthquakes are sudden motions along breaks in the crust called faults, and volcanoes and fissures are locations where magma reaches the surface.
d. Major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.
e. Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.
f. How to explain the location of Florida in terms of plate tectonics.

2. **The Rock Cycle: topography is reshaped by the weathering of rock and soil and by the transportation and deposition of sediment (erosion).** Students will investigate and understand:

a. Flowing water and wind are the dominant processes in shaping the landscape, including Florida's landscape.
b. Eroded soil is deposited in low points, such as lakes and oceans, as sediment. Over time and with increasing pressure and heat from the weight of the building sediment, the soil compacts and becomes sedimentary rock.
c. Sedimentary rock is usually layered, with the oldest layers on the bottom.
d. Evidence from geologic layers and radioactive dating indicates Earth is approximately 4.6 billion years old
e. Rivers and streams are dynamic systems that erode, transport sediment, change course, and flood their banks in natural and recurring patterns.
f. Beaches are dynamic systems in which the sand is supplied by rivers and moved along the coast by the action of waves.
g. Earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.
h. Florida's rock is primarily limestone, made of the shells of ancient ocean animals, sand and clay.

Energy in the Earth System

Many phenomena on Earth's surface are affected by the transfer of energy through radiation and convection currents in the atmosphere and oceans. Students will investigate and understand:

a. The sun is the major source of energy for phenomena on Earth's surface; it powers winds, ocean currents, and the water cycle.
b. Solar energy reaches Earth through radiation, mostly in the form of visible light.
c. Heat from Earth's interior reaches the surface via conduction and convection, producing ocean spreading ridges and hot spot volcanism (e.g., the Hawaiian sea mount volcanoes).
d. Convection currents distribute heat in the atmosphere and oceans.
e. Differences in pressure, heat, air movement, and humidity result in changes of weather.
f. The composition of the Earth's atmosphere affects how much solar energy the atmosphere absorbs.
g. Energy is distributed across pressure differences in the atmosphere by wind and atmospheric pressure pulses (or sound) and in the oceans by wave action.
h. Energy is transferred between atmosphere and water bodies through heat exchange and motion (wind and waves).

Natural Resources

Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their formation. Students will investigate and understand:

a. 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.
b. The usefulness of energy sources depends on how the sources are converted to usable forms (e.g., petroleum is refined to gasoline) and the consequences of both the conversion process (e.g., air pollution from refineries) and the use process (e.g., excess carbon dioxide and its relationship to global climate).
c. The natural origin of the materials used to make common objects.

Solar System

The solar system consists of planets and other bodies that orbit the Sun in predictable paths. As a basis for understanding this concept, students will investigate and understand:

a. The Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.
b. The Sun generates energy through nuclear fusion, a process in which four hydrogen nuclei combine to form one helium nucleus.
c. The Sun's energy reaches the Earth and other bodies of the solar system as different types of radiation, some of it experienced as light and heat.
b. The solar system includes the planet Earth, the Moon, the Sun, at least seven other planets and their satellites or moons, and smaller objects, such as asteroids, comets and dwarf planets.
c. The path of a planet around the Sun and of moons around planets is due to gravitational attraction and the planet's or moon's angular momentum.

GRADE 7 – Focus on Life Sciences

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. 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 internet) to collect information and evidence as part of a research project.
c. Organize data into tables showing repeated trials and means, draw conclusions from the data, become familiar with the concept of independent and dependent variables.
d. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.

e. Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).
f. Communicate the steps and results from an investigation in written reports and oral presentations.

Ecology

Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. Students will investigate and understand:

a. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis and then from organism to organism through food webs.
b. Matter is transferred over time from one organism to others in the food web and between organisms and the physical environment.
c. Populations of organisms can be categorized by the functions they serve in an ecosystem.
d. Different kinds of organisms may play similar ecological roles in similar biomes.
e. The number and types of organisms an ecosystem can support depends on the resources available, including quantities of light and water, the range of temperatures, and soil composition.
f. The impact of human population growth and use of resources on the environment, and human dependence on the environment.

Earth and Life History

1. **Evidence from rocks allows us to understand the evolution of life on Earth.** Students will investigate and understand:

a. The history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids. These catastrophic events have a major impact on the history of life on earth.
b. Fossils, which are found in sedimentary rocks, are made from organisms that existed when the sediments were deposited. Fossils demonstrate that life on this planet has existed for more than 3 billion years.
c. Fossils provide evidence of how life and environmental conditions have changed.
d. How movements of Earth's continental and oceanic plates through time, with associated changes in climate and geographic connections, have affected the past and present distribution of organisms.
e. How to explain significant developments and extinctions of plant and animal life on the geologic time scale.

2. **Biological evolution accounts for the diversity of species developed through gradual processes over many generations.** Students will investigate and understand:

a. Biological evolution is defined as a change in frequency of specific genes (alleles) through time. It is both observable and testable.

b. Both genetic variation and environmental factors are causes of evolution and diversity of organisms.
c. The reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution.
d. How independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.
e. 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.
f. Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient for its survival.

Cells and Genetics

1. **All living organisms are composed of cells, from just one to many trillions, whose details usually are visible only through a microscope.** Students will investigate and understand:

a. Cells function similarly in all living organisms.
b. The characteristics that distinguish plant cells from animal cells, including chloroplasts and cell walls.
c. The characteristics that distinguish prokaryotic cells from eukaryotic cells.
d. The nucleus is the repository for genetic information in plant and animal cells.
e. Within cells smaller structures called organelles exist that perform special functions. Mitochondria are organelles that liberate energy for the work that cells do. Chloroplasts are organelles found in plant cells that capture energy from sunlight for photosynthesis.
f. Cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.
g. As multicellular organisms develop, their cells differentiate.

2. **A typical cell of any organism contains genetic instructions that specify its traits. Those traits may be modified by environmental influences.** Students will investigate and understand:

a. The differences between the life cycles and reproduction methods of sexual and asexual organisms.
b. Sexual reproduction produces offspring that inherit half their genes from each parent, resulting in offspring that are different from but similar to both parents. This is the origin of variation that is critical to natural selection and emphasizes the primary advantage of sexual reproduction.
c. An inherited trait can be determined by one or more genes.

d. 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. DNA (deoxyribonucleic acid) is the genetic material of living organisms and is located in the chromosomes of each cell.
f. RNA (ribonucleic acid) serves as a template for the translation of genes into proteins.

Structure and Function in Living Systems

The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function. Students will investigate and understand:

a. Plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organism.
b. Individual organs, tissues, and cells are critical to the functioning of the organism as a whole. The failure of any part can affect the entire system.
c. How bones and muscles work together to provide a structural framework for movement.
d. How the reproductive organs of female and male mammals generate eggs and sperm and how the union of gametes may lead to fertilization and pregnancy.
e. The function of the umbilicus and placenta during pregnancy.
f. The structures and processes by which flowering plants generate pollen, ovules, seeds, and fruit.
g. How to relate the structures of the eye and ear to their functions: for an object to be seen, light emitted by or reflected from it must be detected by the eye. Retinal cells of the eye react differently to different wavelengths contained in white light. For a sound to be heard, vibrations in a fluid medium must impact the eardrum.
h. Contractions of the heart generate blood pressure and heart valves prevent backflow of blood in the circulatory system.
i. Physical principles underlie biological structures and functions: joints in the body (wrist, shoulder, thigh) compare with structures used in machines and simple devices (hinge, ball-and-socket, and sliding joints).
j. Levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system.

GRADE EIGHT—Focus on Physical Sciences

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. 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=mx + b 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.
e. Apply simple mathematic relationships to determine a missing quantity in a mathematical expression, given the two remaining terms (including speed = distance/time, density = mass/volume, force = pressure x area, volume = area x height).
f. Distinguish between linear and nonlinear relationships on a graph of data.

The Nature of Energy

1. **The velocity of an object is the rate of change of its position in a certain direction.** Students will investigate and understand:

a. Position is defined in relation to some choice of a standard reference point and a set of reference directions.
b. 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. How to solve problems involving distance, time, and average speed.
d. The velocity of an object must be described by specifying both the direction and the speed of the object.
e. Changes in velocity may be due to changes in speed, direction, or both.
f. How to interpret graphs of position versus time and graphs of speed versus time for motion in a single direction.

2. **Unbalanced forces cause changes in velocity.** Students will investigate and understand:

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

3. **Heat moves in a predictable flow from warmer objects to cooler objects until all the objects are at the same temperature.** Students will investigate and understand:

a. 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. When fuel is consumed, most of the energy released becomes heat.

c. Heat flows in solids by conduction (which involves no flow of matter) and in fluids and gases by conduction and by convection (which involves flow of matter).
d. Heat is also transferred between objects by radiation (radiation can travel through empty space as well as through matter).

The Nature of Matter

1. **All objects experience a buoyant force when immersed in a fluid.** Students will investigate and understand:

a. Density is mass divided by volume (mass per unit volume).
b. How to calculate the density of substances (regular and irregular solids and liquids) from measurements of mass and volume.
c. 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. How to predict whether an object will float or sink.

2. **Each of the more than 100 identified elements of matter has distinct properties and a distinct atomic structure.** Students will investigate and understand:

a. The structure of the atom and know it is composed of protons, neutrons, and electrons.
b. Compounds are formed by combining two or more different elements and that compounds have properties that are different from their constituent elements.
c. Atoms and molecules form solids by building up repeating patterns, such as the crystal structure of NaCl or long-chain polymers.
d. The states of matter (solid, liquid, gas or plasma) depend on the amount of molecular motion and the strength of attraction between molecules.
e. 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. A plasma is a collection of high energy and free-moving electrons and ions (charged matter).

3. **The organization of the periodic table is based on the properties of the elements and reflects the structure of atoms.** Students will investigate and understand:

a. The symbols for elements and how to identify elements in the periodic table.
b. How to identify regions of the periodic table corresponding to metals, nonmetals, and inert gases.
c. 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.
d. Substances can be classified by their properties, including their melting temperature, density, hardness, and thermal and electrical conductivity.

4. **Chemical reactions are processes in which bonds between atoms are broken and reformed into different combinations of molecules.** Students investigate and understand:

a. Reactant atoms and molecules interact to form products with different chemical properties.
b. In chemical reactions the number of atoms stays the same no matter how they are arranged, so their total mass stays the same. This explains the conservation of matter.
c. Chemical reactions usually liberate or absorb heat.
d. Physical processes include freezing and boiling, in which a material changes form with no chemical reaction.
e. How to determine whether a solution is acidic, basic, or neutral.

5. **Principles of chemistry underlie the functioning of biological systems.** Students will investigate and understand:

a. Carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.
b. Living organisms are made of molecules consisting largely of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.
c. Living organisms have many different kinds of molecules, including small ones, such as water and salt, and very large ones, such as carbohydrates, fats, proteins, and DNA.

Astronomy

The structure and composition of the universe can be learned from studying stars and galaxies and their development. Students will investigate and understand:

a. Galaxies are clusters of billions of stars and may have different shapes.
b. The Sun is one of hundreds of millions of stars in the Milky Way galaxy.
c. There are more galaxies in the universe than there are stars in the Milky Way.
d. All stars are made of similar chemical elements, although they may differ in age, size, temperature, color and distance from the Earth.
e. How to use astronomical units and light years as measures of distances between the Sun, stars, and Earth.
f. Stars, which emit thermal radiation (similar to an incandescent light bulb), are the most common source of light from bright objects in outer space.
g. The Moon and planets shine by reflected sunlight, not by their own light.
h. The orbits of objects in the solar system are maintained by gravity. The planets, which are the largest objects in the solar system other than the Sun, travel on nearly circular (but elliptical) orbits. Planets are known to exist around other stars.

HIGH SCHOOL

GRADES NINE

THROUGH

TWELVE

EARTH SCIENCES

Investigation and Experimentation

The earth science standards connect the study of the Earth's composition, structure, processes, and history; its atmosphere, fresh water, and oceans; and its environment in space. The standards emphasize historical contributions in the development of scientific thought about the Earth and space. The standards stress the interpretation of maps, charts, tables, and profiles; the use of technology to collect, analyze, and report data; and the utilization of science skills in systematic investigation. Problem solving and decision making are an integral part of the standards, especially as they relate to the costs and benefits of utilizing the Earth's resources. Major topics of study include plate tectonics, the rock cycle, Earth history, the oceans, the atmosphere, weather and climate, and the solar system and universe.

The earth science standards focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence.

The students will plan and conduct investigations in which:

a. Volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools.
b. Technologies including computers, probeware, and global positioning systems (GPS), are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions.
c. Scales, diagrams, maps, charts, graphs, tables, and profiles are constructed and interpreted.
d. Variables are manipulated with repeated trials.
e. Scientific viewpoint is constructed and defended (the nature of science).

The students will demonstrate scientific reasoning and logic by:

a. Analyzing how science explains and predicts the interactions and dynamics of complex Earth systems.
b. Recognizing that evidence is required to evaluate hypotheses and explanations.
c. Comparing different scientific explanations for a set of observations about the Earth.
d. Explaining that observation and logic are essential for reaching a conclusion.
e. Evaluating evidence for scientific theories.

The students will investigate and understand how to read and interpret maps, globes, models, charts, and imagery. Key concepts include:

a. Maps (bathymetric, geologic, topographic, and weather) and star charts.
b. Imagery (aerial photography and satellite images).

c. Direction and measurements of distance on any map or globe.
d. Location by latitude and longitude and topographic profiles.

Earth's Place in the Universe

Astronomy and planetary exploration reveal the solar system's structure, scale, and change over time. Students will investigate and understand:

a. 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. The evidence from Earth and moon rocks indicates that the solar system was formed from a nebular cloud of dust and gas approximately 4.54 billion years ago.
c. The evidence from geological studies of Earth and other planets suggest that the early Earth was very different from Earth today.
d. The planets are much closer to Earth than the stars are.
e. The Sun is an average main sequence star and is powered by nuclear reactions, primarily the fusion of hydrogen to form helium.
f. 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. The evidence for the existence of planets orbiting other stars.

Earth-based and space-based astronomy reveal the structure, scale, and changes in stars, galaxies, and the universe over time. Students will investigate and understand:

a. The solar system is located in an outer edge of the disc-shaped Milky Way galaxy, which spans 100,000 light years.
b. Galaxies are made of hundreds of millions or billions of stars and comprise most of the visible mass of the universe.
c. Our galaxy is not unique, and there are more galaxies in the universe than stars in our galaxy.
d. The evidence indicating that all elements with an atomic number greater than that of lithium have been formed by nuclear fusion in stars.
e. The evidence indicating that all elements with an atomic number greater than iron were created in a system that has completed at least one stellar cycle.
f. Stars differ in their life cycles and that visual, radio, and X-ray telescopes may be used to collect data that reveal those differences.
g. Accelerators boost subatomic particles to energy levels that simulate conditions within stars and during the early history of the universe before stars formed.
h. The evidence indicating that the color, brightness, and evolution of a star are determined by a balance between gravitational collapse and nuclear fusion.
i. Because the speed of light is finite, astronomical objects are viewed as they appeared in the past. The further away an object, the further back into the past we are looking.
j. How the redshift from distant galaxies and the cosmic background radiation provide evidence for the "big bang" model that suggests that the universe has been expanding for 12-15 billion years.

Dynamic Earth Processes

Plate tectonics operating over geologic time have changed the patterns of land, sea, and mountains on Earth's surface. Students will investigate and understand:

a. Features of the ocean floor (magnetic patterns, age, and sea-floor topography) provide evidence of plate tectonics.
b. The principal structures that form at the three different kinds of plate boundaries.
c. How to explain the properties of rocks based on the physical and chemical conditions in which they formed, including plate tectonic processes.
d. Why and how earthquakes occur and the scales used to measure their intensity and magnitude.
e. There are several types of volcanoes that vary in their eruptive style and geomorphic expression.
f. The explanation for the location and properties of volcanoes due to spreading centers, hot spots and convergent plate boundaries.
g. The evidence contained in continental rocks that yield a history of life and tectonics on earth.
h. The structure of the Earth's interior.

Energy in the Earth System

Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. Students will investigate and understand:

a. The relative amount of incoming solar energy compared with Earth's internal energy and the energy used by society.
b. The fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.
c. The different atmospheric gases that absorb the Earth's thermal radiation and the mechanism and significance of the greenhouse effect.
d. The differing greenhouse conditions on Earth, Mars, and Venus; the origins of those conditions; and the climatic consequences of each.

Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. Students will investigate and understand:

a. How differential heating of Earth results in circulation patterns in the atmosphere and oceans that globally distribute the heat.
b. The relationship between the rotation of Earth and the circular motions of ocean currents and air in pressure centers.
c. The origin and effects of temperature inversions.
d. 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.
e. Rainforests and deserts on Earth are distributed in bands at specific latitudes.
f. The interaction of wind patterns, ocean currents, and mountain ranges results in the global

pattern of latitudinal bands of rain forests and deserts.
g. 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.

Climate is the long-term average of a region's weather and depends on many factors. Students will investigate and understand:

a. Weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere.

b. The effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.

c. 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. 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

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. Students will investigate and understand:

a. The water cycle of evaporation/transpiration, condensation/precipitation, including the role of groundwater in Florida and artificial reservoirs.
b. The carbon cycle of photosynthesis and respiration and the nitrogen cycle.
c. 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.
d. The movement of matter among reservoirs is driven by Earth's internal and external sources of energy.
e. The behavior of climate as a complex system subject to thresholds and tipping points, positive and negative feedback loops, and delayed feedback.

Honors Extension. Students will investigate and understand:

f. The relative residence times and flow characteristics of carbon, oxygen and strontium in and out of their different reservoirs.

Structure and Composition of the Atmosphere

Life has changed Earth's atmosphere, and changes in the atmosphere affect conditions for life. Students will investigate and understand:

a. The thermal structure and chemical composition of the atmosphere.

b. How the composition of Earth's atmosphere has evolved over geologic time.
c. The effect of outgassing, the variations of carbon dioxide concentration, and the origin of atmospheric oxygen.
d. 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.

Florida Geology

The geology of Florida underlies the state's wealth of natural resources, including its water resources. Students will investigate and understand:

a. The geologic development of Florida and why it is composed primarily of limestone.
b. Florida's topography and the impact of sea level on the state.
c. The resources of major economic importance in Florida and their relation to Florida's geology.
d. The relationship between Florida's geology, sea level, water resources, and sinkhole formation.
e. The importance of water to society; the relationship between supply, residential need (defined by the World Health Organization as 30 gal per person per day) and current levels of demand for water in Florida; the role of agricultural and industrial water use; and the importance of conservation.

LIFE SCIENCES

Investigation and Experimentation

The biology standards are designed to provide students with a detailed understanding of living systems. Emphasis is on the skills necessary to examine alternative scientific explanations, actively conduct controlled experiments, analyze and communicate information, and gather and use information in scientific literature. The history of biological thought and the evidence that supports it are explored, providing the foundation for investigating biochemical life processes, cellular organization, mechanisms of inheritance, dynamic relationships among organisms, and the change in organisms through time.

The importance of scientific research that validates or challenges ideas is emphasized at this level. The biology standards focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence.

Students will plan and conduct investigations in which:

a. Observations of living organisms are recorded in the lab and, where possible, in the field;
b. Hypotheses are formulated based on direct observations and information from scientific literature;
c. Variables are defined and investigations are designed to test hypotheses;
d. Graphing and arithmetic calculations are used as tools in data analysis;
e. Conclusions are formed based on recorded quantitative and qualitative data;
f. Sources of error inherent in experimental design are identified and discussed;
g. Validity of data is determined;
h. Chemicals and equipment are used in a safe manner;
i. Appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results;
j. Scientific literature is used as a guide for designing the research project;
k. Differentiation is made between a scientific hypothesis and theory;
l. Alternative scientific explanations and models are recognized and analyzed;
m. A scientific viewpoint is constructed and defended (the nature of science).

Students will investigate and understand the history of biological concepts. Key concepts include:

a. Evidence supporting the cell theory;
b. Scientific explanations of the diversification of organisms through time (biological evolution);
c. Evidence supporting the germ theory of infectious disease;

d. Development of the structural model of DNA;
e. The collaborative efforts of scientists, past and present.

Cell Biology

Fundamental life processes depend on a variety of chemical reactions that occur in specialized areas of cells. Students will investigate and understand:

a. Cells are enclosed within semipermeable membranes that regulate their interaction with their surroundings.
b. How prokaryotic cells, eukaryotic cells (including those from plants and animals), and viruses differ in complexity and general structure.
c. The role of anaerobic respiration in living things.
d. 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.
e. The central idea of molecular biology describes the process of transcription of ribonucleic acid (RNA) from DNA to proteins on ribosomes.
f. The role of the endoplasmic reticulum and Golgi apparatus in the secretion of proteins.
g. Usable energy from sunlight is captured by chloroplasts and used to synthesize glucose from carbon dioxide and water.
h. The role of the mitochondria in making stored chemical energy in the form of ATP available to cells by completing the breakdown of glucose to carbon dioxide.
i. Most macromolecules (polysaccharides, nucleic acids, proteins, lipids) in cells and organisms are synthesized from a small collection of simple precursors.

Honors Extension. Students will investigate and understand:

j. How chemiosmotic gradients in the mitochondria and chloroplast store energy for ATP production.
k. How eukaryotic cells are given shape and internal organization by a cytoskeleton or cell wall or both.

Genetics

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. Students will investigate and understand:

a. The general structures and functions of DNA, RNA and protein.
b. How to apply base-pairing rules to explain precise copying of DNA during semi-conservative replication and transcription of information from DNA into mRNA.
c. The general pathway by which ribosomes synthesize proteins, using tRNAs to translate genetic information in mRNA.

d. How to apply the genetic coding rules to predict the sequence of amino acids from a sequence of codons in RNA.
e. 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.
f. Specialization of cells in multicellular organisms is usually due to different patterns of gene expression rather than to differences of the genes themselves.
g. Proteins can differ from one another in the number and sequence of amino acids, and typically have different shapes and chemical properties.
h. How genetic engineering (biotechnology) is used to produce novel biomedical and agricultural products.

Honors Extension. Students will investigate and understand:

i. How basic DNA technology (restriction digestion by endonucleases, gel electrophoresis, ligation, and transformation) is used to construct recombinant DNA molecules.
j. How DNA from other organisms can be inserted into bacterial cells to alter their genetic make-up and support expression of new protein products.

Mutation and sexual reproduction lead to genetic variation in a population. Students will investigate and understand:

a. Changing the DNA sequence (mutation) by nucleotide addition, deletion or substitution can alter a gene.
b. Gene mutations occur spontaneously at low rates. Only mutations in germ cells (ovum and sperm) can create a variation that affects an organism's offspring. If mutations occur in other cells, they are passed on only to descendant cells of the same organism.
c. Gene mutations can result in uncontrolled cell division, or cancer. Exposure of cells to certain chemicals or radiation increases mutation rates and can increase the probability of cancer.
d. 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.
e. Crossing over during meiosis results in chromosomes with some combination of DNA from both parents.
f. Only certain cells in a multicellular organism undergo meiosis.
g. How random chromosome segregation explains the probability that a particular allele will be in a gamete.
h. New combinations of alleles may be generated in a zygote through the fusion of male and female gametes (fertilization).
i. Why approximately half of an individual's DNA sequence comes from each parent.
j. The role of chromosomes in determining an individual's sex.
k. How to predict possible combinations of alleles in a zygote from the genetic makeup of the parents.

A multi-cellular organism develops from a single zygote, and its phenotype depends primarily on its genotype, which is established at fertilization. Students will investigate and understand:

a. How to predict the probable outcome of phenotypes in a genetic cross from the genotypes of the parents and mode of inheritance (autosomal or sex-linked, dominant or recessive, codominant, or multiple alleles).
b. Solve genetics problems involving each of the inheritance patterns listed above.
c. The genetic basis for selected human genetic disorders including cystic fibrosis, sickle cell anemia, hemophilia and color-blindness.
d. The genetic basis for Mendel's laws of segregation and independent assortment.

Honors Extension. Students will investigate and understand:

e. How to predict the probable mode of inheritance from a pedigree diagram showing phenotypes.
f. How to use data on frequency of recombination at meiosis to estimate genetic distances between loci and to interpret genetic maps of chromosomes.

Ecology

Stability in an ecosystem is a balance between competing effects. Students will investigate and understand:

a. Biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats.
b. How to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.
c. How fluctuations in population size in an ecosystem are influenced by the relative rates of birth, immigration, emigration, and death.
d. How water, carbon, and nitrogen cycle between abiotic resources and organic matter in the ecosystem, how oxygen cycles through photosynthesis and respiration, and how energy flows through food webs. .
e. A vital part of an ecosystem is the stability of its producers and decomposers.
f. 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.

Honors Extension. Students will investigate and understand:

g. 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.

Evolution

The frequency of an allele in a gene pool of a population depends on many factors and may be stable or unstable over time. Students will investigate and understand:

a. Why natural selection acts on the phenotype rather than the genotype of an organism.
b. Why alleles that are lethal in a homozygous individual may be carried in a heterozygote and thus maintained in a gene pool.
c. Many new mutations are constantly generated in a gene pool.
d. Variation within a species increases the likelihood that at least some members of a species will survive under changed environmental conditions.

Honors Extension. Students will investigate and understand:

e. The conditions for Hardy-Weinberg equilibrium in a population and why these conditions are not likely to appear in nature.
f. How to solve the Hardy-Weinberg equation to predict the frequency of genotypes in a population, given the frequency of phenotypes.

Evolution is the result of genetic changes that occur in constantly changing environments. Students will investigate and understand:

a. How natural selection determines the differential survival of groups of organisms.
b. A great diversity of species increases the chance that at least some organisms survive major changes in the environment.
c. The effects of genetic drift and inbreeding on the diversity of organisms in a population.
d. Reproductive or geographic isolation affects speciation.
e. How to analyze fossil evidence and homologous structures with regard to biological diversity, episodic speciation, and mass extinction.
f. The connection between paleontological observations and evolutionary biology.

Honors Extension. Students will investigate and understand:

g. 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 evolutionary relationships.
h. How several independent molecular clocks, calibrated against each other and combined with evidence from the fossil record, can help to estimate how long ago various groups of organisms diverged evolutionarily from one another.

Physiology

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. Students will investigate and understand:

a. How the complementary activity of major body systems provides cells with oxygen and nutrients and removes toxic waste products such as carbon dioxide.
b. How the nervous system mediates communication between different parts of the body and the body's interactions with the environment.
c. How feedback loops in the nervous and endocrine systems regulate conditions in the body.
d. The functions of the nervous system and the role of neurons in conducting electrochemical information.
e. The roles of sensory neurons, interneurons, and motor neurons in sensation, thought, and response.

Honors Extension. Students will investigate and understand:

f. The individual functions and sites of secretion of digestive enzymes (amylases, proteases, nucleases, lipases), stomach acid, and bile salts.
g. 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. The cellular and molecular basis of muscle contraction, including the roles of actin, myosin, Ca^{+2}, and ATP.
i. How hormones (including digestive, reproductive, osmoregulatory) provide internal feedback mechanisms for homeostasis at the cellular level and in whole organisms.

Organisms have a variety of mechanisms to combat disease. Students will investigate and understand:

a. The role of the skin in providing nonspecific defenses against infection.
b. The role of antibodies in the body's response to infection.
c. How vaccination protects an individual from infectious diseases.
d. 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. 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.

Honors Extension. Students will investigate and understand:

f. The roles of phagocytes, B-lymphocytes, and T-lymphocytes in the immune system.

CHEMISTRY

Investigation and Experimentation

Chemistry is the physical science that describes matter, i.e., its composition, structure, physical and chemical transformations, and the energies associated with these transformations. Three descriptive dimensions are routinely intertwined:

1. Macro-scale observations describe and classify matter and energy on the human sensory level; for example, phases, homogeneity (physical properties such as color, density, volatility), and chemical reactivity, alone and in combination with other substances.

2. Nano-scale models describe and classify matter and energy beyond the human sensory level; for example, atoms, subatomic particles, interparticle bonds and bond making/breaking, reaction energies, rates and chemical equilibrium. Energy is the currency of change, and spontaneous reactions achieve lower energy states and greater stability.

3. Chemical symbolism represents both the macro- and nano-scale perspectives.

The chemistry standards are designed to provide students with a detailed understanding of the interaction of matter and energy. This interaction is investigated through the use of laboratory techniques, manipulation of chemical quantities, and problem-solving applications. Scientific methodology is employed in experimental and analytical investigations, and concepts are illustrated with practical applications that should include examples from environmental, nuclear, organic, and biochemistry content areas. Technology, including graphing calculators, computers, and probeware, are employed where feasible.

Students will understand and use safety precautions with chemicals and equipment. The standards emphasize qualitative and quantitative study of substances and the changes that occur in them. In meeting the chemistry standards, students will be encouraged to share their ideas, use the language of chemistry, discuss problem-solving techniques, and communicate effectively.

The chemistry standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence.

Students will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include:

a. Designated laboratory techniques;
b. Safe use of chemicals and equipment;

c. Proper response to emergency situations;
d. Manipulation of multiple variables, using repeated trials;
e. Accurate recording, organization, and analysis of data through repeated trials;
f. Mathematical and procedural error analysis;
g. Mathematical manipulations (SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, dimensional analysis);
h. Use of appropriate technology including computers, graphing calculators, and probeware, for gathering data and communicating results; and
i. Construction and defense of a scientific viewpoint (the nature of science).

Atomic Theory and the Periodic Law

Atomic and Molecular Structure

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. Students will investigate and understand:

a. The role of Dalton, Mendeleev, and Meyer in the development of atomic theory and the Periodic Law.
b. How to relate the position of an element in the periodic table to its atomic number and atomic mass.
c. How to use the periodic table to identify metals, metalloids, and nonmetals.
d. How to use the periodic table to identify alkali metals, alkaline earth metals and transition metals, as well as trends in ionization energy, electronegativity, and the relative sizes of ions and atoms.
e. How to use the periodic table to determine the number of electrons available for bonding.
f. The nucleus of the atom is much smaller than the atom yet contains most of its mass.

Honors Extension. Students will investigate and understand:

g. 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.
h. The experimental basis for Thomson's discovery of the electron, Rutherford's nuclear atom, Millikan's oil drop experiment, and Planck's and Einstein's explanations of the photoelectric effect.
i. The patterns for allowed (quantized) energy level of electrons within atoms and their relationship to the Periodic Table and the chemical reactivity of the elements.
j. The experimental basis for the development of the quantum theory of atomic structure and the historical importance of the Bohr model of the atom.
k. Spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with an energy content quantified by Planck's relationship (E-hy).
l. The wave-particle duality of electromagnetic radiation to include frequency, wavelength, and

the quantized nature of the photon.
m. Electromagnetic radiation as a tool, as a probe into the nature of atoms/molecules and their constituent particles.

Chemical Bonds

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. Chemical change requires breaking bonds and forming new bonds to form new substances while maintaining the elemental identity of each atom. Students will investigate and understand:

a. Atoms combine to form molecules by sharing electrons to form nonmetallic covalent bonds or by exchanging electrons to form metallic ionic bonds (cations + and anions -.
b. Chemical bonds between atoms in molecules such as H_2, CH_4, NH_3, $HCCH_2$, N_2, Cl_2, and many large biological molecules are covalent.
c. Salt crystals, such as NaCl, are repeating patterns of positive and negative ions held together by electrostatic attraction.
d. 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. How to draw Lewis dot structures.

Honors Extension. Students will investigate and understand:

f. How to predict the shape of simple molecules and their polarity from Lewis dot structures.
g. The use of valence shell electron pair repulsion theory (VSEPR) to predict molecular shape from Lewis electron structures.
h. How electronegativity and ionization energy relate to bond formation.
i. 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 Mass and Stoichiometry

The conservation of atoms in chemical reactions leads to the principle of conservation of mass and the ability to calculate the mass of products and reactants. Students will investigate and understand:

a. How to describe chemical reactions by writing balanced equations.
b. The quantity one mole is set by defining one mole of carbon 12 atoms to have a mass of exactly 12 grams.
c. One mole containes Avogadro's number 6.02×10^{23} particles (atoms or molecules).
d. How to determine a compound's empirical formula from elemental mass data.
e. 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.
f. How balanced equations (stoichiometric equations) indicate the molar relationships of the reactants consumed and the products produced.
g. 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.

Honors Extension. Students will investigate and understand:

h. A mole as the formula mass expressed in grams.
i. How to calculate percent theoretical yield as a reflection of non-ideal reality in reaction efficiencies.
j. How to identify reactions that involve oxidation and reduction and how to balance oxidation-reduction reactions.

Gases and Their Properties

The kinetic molecular theory describes the gas phase motion of atoms and molecules as a means to explain the properties of gases under certain conditions. Students will investigate and understand:

a. The random motion of molecules and their collisions with a surface create the observable pressure on that surface.
b. The random motion of molecules explains the diffusion of gases.
c. 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. The values and meanings of standard temperature and pressure (STP).
e. How to convert between the Celsius and Kelvin temperature scales.
f. There is no temperature lower than 0 Kelvin.

Honors Extension. Students will investigate and understand:

g. The kinetic theory of gases relates the absolute temperature of a gas to the average kinetic energy of its molecules or atoms.
h. How to solve problems by using the ideal gas law in the form PV□=□nRT.
i. How to apply Dalton's law of partial pressures to describe the composition of gases and Graham's law to predict diffusion of gases.
j. Avogadro's Hypothesis and molar volume at STP.
k. The Law of Combining Volumes as a component of gaseous reaction stoichiometry.

Acids and Bases

Acids, bases, and salts are three classes of compounds that form ions in water solutions. Students will investigate and understand:

a. The observable properties of acids, bases, and salt solutions.
b. Acids are hydrogen-ion-donating and bases are hydrogen-ion-accepting substances.
c. Strong acids and bases fully dissociate and weak acids and bases partially dissociate.
d. How to use the pH scale to characterize acid and base solutions.

Honors Extension. Students will investigate and understand:

e. The Arrhenius, Brønsted-Lowry, and Lewis acid–base definitions.
f. Strong electrolytes as ionic compound solutions yield high ion concentrations.
g. Weak electrolytes dissolve as molecules which then react with water (hydrolysis) and yield partial ionization producing a low concentration of ions.
h. Non-electrolytes dissolve completely as neutral molecules and yield no ions.
i. How to calculate pH from the hydrogen-ion concentration.
j. Buffers stabilize pH in acid–base reactions.

Solutions

Solutions are homogeneous mixtures of two or more substances. Students will investigate and understand:

a. The definitions of solute and solvent.
b. How to describe the dissolving process at the molecular level by using the concept of random molecular motion.
c. Temperature, pressure, and surface area affect the dissolving process.
d. How to calculate the concentration of a solute in terms of grams per liter, molarity, parts per million, and percent composition
e. How to use the concentration expressions of molarity, molality, and mole fraction.

Honors Extension. Students will investigate and understand:

f. The relationship between the molality of a solute in a solution and the solution's depressed freezing point or elevated boiling point.
g. How molecules in a solution are separated or purified by the methods of chromatography and distillation.

Chemical Thermodynamics

Energy is exchanged or transformed in all chemical reactions and physical changes of matter. Students will investigate and understand:

a. How to describe temperature and heat in terms of the motion of molecules (or atoms).
b. If the total strength of all new bonds formed in a reaction exceeds the total strength of the bonds broken, heat energy is released in an exothermic reaction.
c. If the total strength of all bonds broken exceeds the strength of all new bonds formed, heat

energy must be absorbed in an endothermic reaction.
d. Energy is released when a material condenses or freezes and is absorbed when a material evaporates or melts.
e. How to solve problems involving heat flow and temperature changes, using known values of specific heat and latent heat of phase change.

Honors Extension. Students will investigate and understand:

f. How to apply Hess's law to calculate enthalpy of reaction or heat of reaction expressed as ΔH_r and relate ΔH_r to the molar quantities of reagents in the stoichiometric equation.
g. The validity, utility and application of Hess's Law.
h. How to use enthalpies of formation, ΔH_f , to calculate ΔH_r.
i. Entropy and its significance in energy changes of chemical and physical change.
j. How to use the Gibbs Free Energy Equation $\Delta G = \Delta H - T\Delta S$, and the meaning of reaction spontaneity.
k. ΔG and the position of equilibrium

Reaction Rates (Kinetics)

Chemical reaction rates depend on factors that influence the frequency of collision of reactant molecules. Students will investigate and understand:

a. The rate of reaction is the decrease in concentration of reactants or the increase in concentration of products with time.
b. How reaction rate depends on such factors as concentration, temperature, and pressure and is a direct effect of collision frequency and orientation.
c. The exponential increase in reaction rate as the absolute temperature increases
d. The nature and behavior of catalysts.

Honors Extension. Students will investigate and understand:

e. The energy of activation, E_{act}, and its negative exponential impact on reaction rate (reaction rate decreases exponentially as E_{act} increases).

Chemical Equilibrium

Chemical equilibrium is a dynamic process at the molecular level. Students will investigate and understand:

a. At equilibrium the forward rate and reverse rate are equal, and the relative proportions of reactants and products are constant.
b. The position of equilibrium is directly related to ΔG_r.
c. The position of equilibrium can be changed by adding/removing reagents and/or changing pressure or temperature.

d. How to use Le Chatelier's principle to predict equilibrium position shifts when the system is disturbed.

Honors Extension. Students will investigate and understand:

e. How to write and calculate an equilibrium constant expression for a reaction.

Organic Chemistry and Biochemistry

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. Students will investigate and understand:

a. Large molecules (polymers), such as proteins, nucleic acids, and starch, are formed by repetitive combinations of simple subunits.
b. 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. Amino acids are the building blocks of proteins.

Honors Extension. Students will investigate and understand:

d. 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. How to identify the functional groups that form the basis of alcohols, ketones, ethers, amines, esters, aldehydes, and organic acids.
f. The R-group structure of amino acids and how they combine to form the polypeptide backbone structure of proteins.

Nuclear Processes

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. Students will investigate and understand:

a. Protons and neutrons in the nucleus are held together by nuclear forces that overcome the electromagnetic repulsion between the protons.
b. 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. Some naturally occurring isotopes of elements are radioactive, as are isotopes formed in nuclear reactions.
d. The three most common forms of radioactive decay (alpha, beta, and gamma) and how the nucleus changes in each type of decay.

e. Alpha, beta, and gamma radiation produce different amounts and kinds of damage in matter and have different penetrations.

Honors Extension. Students will investigate and understand:

f. How to calculate the amount of a radioactive substance remaining after an integral number of half-lives have passed.
g. Protons and neutrons have substructures and consist of particles called quarks.

PHYSICS

Investigation and Experimentation

The physics standards emphasize a more complex understanding of experimentation, the analysis of data, and the use of reasoning and logic to evaluate evidence. The use of mathematics, including algebra and trigonometry, is important, but conceptual understanding of physical systems remains a primary concern. Students build on basic physical science principles by exploring in depth the nature and characteristics of energy and its dynamic interaction with matter.

Key areas covered by the standards include force and motion, energy transformations, wave phenomena and the electromagnetic spectrum, light, electricity, fields, and non-Newtonian physics. The standards stress the practical application of physics in other areas of science and technology and how physics affects our world.

The physics standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence.

Each topic (e.g., Motion and Forces) has a section of more advanced material labeled *Honors Extension*, which is for use in honors level physics courses.

The student will plan and conduct investigations in which:

a. The components of a system are defined;
b. Instruments are selected and used to extend observations and measurements of mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge;
c. Information is recorded and presented in an organized format;
d. Metric units are used in all measurements and calculations;
e. The limitations of the experimental apparatus and design are recognized;
f. The limitations of measured quantities are recognized through the appropriate use of significant figures or statistically-based error ranges;
g. Data gathered from non-SI instruments are incorporated through appropriate conversions; and
h. Appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results.

The student will investigate and understand how to analyze and interpret data. Key concepts include:

a. A description of a physical problem is translated into a mathematical statement in order to find a solution;

b. Relationships between physical quantities are determined using appropriate curve-fitting or other statistical methods to evaluate experimentally obtained data;
c. The slope of a linear relationship is calculated and includes appropriate units;
d. Interpolated, extrapolated, and analyzed trends are used to make predictions; and
e. Unusual results are investigated in terms of experimental errors, methodological errors or potentially new physical phenomena.

The student will investigate and understand how to demonstrate scientific reasoning and logic. Key concepts include:

a. Analysis of scientific sources to develop and refine research hypotheses;
b. Analysis of how science explains and predicts relationships;
c. Evaluation of evidence for scientific theories;
d. Examination of how new discoveries result in modification of existing theories or establishment of new paradigms; and
e. Construction and defense of a scientific viewpoint (the nature of science).

The student will investigate and understand how applications of physics affect the world. Key concepts include:

a. Examples from the real world; and
b. Exploration of the roles and contributions of science and technology.

Motion and Forces

Newton's laws predict the motion of most objects. Students will investigate and understand:

a. How to solve problems that involve constant speed and average speed.
b. When forces are balanced, no acceleration occurs; thus an object continues to move at a constant velocity or stays at rest (Newton's first law).
c. How to apply the law F = ma to solve one-dimensional motion problems that involve constant forces (Newton's second law).
d. 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 on the first object (Newton's third law).
e. The relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth and other celestial bodies.
f. 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. Uniform circular motion requires the application of a constant force directed toward the center of the circle.

Honors Extension. Students will investigate and understand:

h. Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light, when special relativity plays a part, or is small enough

that quantum effects are important.

i. How to solve two-dimensional trajectory problems.

j. To resolve two or three-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components.

k. To solve two-dimensional problems involving balanced forces (statics).

l. To solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a = v^2/r$.

m. 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) and to understand the physical similarities/differences between the charge/mass relationships.

n. The problems in applying gravitational theory at the quantum level (the so-called Grand Unified Theory).

Conservation of Energy and Momentum

The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects. Students will investigate and understand:

a. How to calculate kinetic energy by using the formula $E = (1/2)mv^2$.

b. 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. How to solve problems involving conservation of energy in simple systems, such as falling objects.

d. How to calculate momentum as the product mv. where v is the velocity.

e. Momentum is a separately conserved quantity different from energy.

f. An unbalanced force on an object produces a change in its momentum as time changes.

g. How to solve problems involving elastic and inelastic collisions in one dimension by using the principles of conservation of momentum and energy.

Honors Extension. Students will investigate and understand:

h. 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

Energy cannot be created or destroyed, although in many processes energy is transferred to the environment as heat. Students will investigate and understand:

a. Heat and work are two forms of energy transfer between systems.

b. The work done by a heat engine that is working in a cycle is the difference between the heat into the engine at high temperature and the heat out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy.

c. 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. All processes that convert energy to work do so at less than (or equal to) 100% efficiency and therefore tend either (i) to decrease the order of a system over time, or (ii) decrease the available energy of a system over time. Energy in an isolated system is eventually distributed uniformly.

e. Entropy is (i) a quantity that measures the efficiency of a process in the conversion of energy to work; the lower the efficiency, the higher the entropy quantity; or (ii) a measure of the energy that is dispersed in a system or in a process.

Honors Extension. Students will investigate and understand:

f. The statement "Entropy tends to increase" is a law of statistical probability that governs all isolated systems (second law of thermodynamics).

g. 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

Waves have characteristic properties that do not depend on the type of wave. Students will investigate and understand:

a. Waves carry energy from one place to another.

b. How to identify transverse and longitudinal waves in mechanical media, such as springs and ropes, and on the earth (seismic waves).

c. How to solve problems involving wavelength, frequency, and wave speed.

d. Sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates.

e. Radio waves, visible light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately $3x10^8$ m/s (186,000 miles/second).

Honors Extension. Students will investigate and understand:

f. How to identify the characteristic behavior of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization.

Electric and Magnetic Phenomena

Electric and magnetic phenomena are related and have many practical applications. Students will investigate and understand:

a. How to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors.

b. How to solve problems involving Ohm's law.

c. 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) x I (current) = I^2R.
d. The properties of transistors and the role of transistors in electric circuits.
e. Charged particles are sources of electric fields and are subject to the forces of the electric fields from other charges.
f. 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. How to determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil.
h. Changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors.
i. Plasma, the fourth state of matter, contains ions or free electrons or both and conducts electricity.

Honors Extension. Students will investigate and understand:

j. Electric and magnetic fields contain energy and act as vector force fields.
k. The magnitude of 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. How to calculate the electric field resulting from a point charge.
m. Static electric fields have as their source some arrangement of electric charges.
n. The magnitude of the force on a moving particle (with charge q) in a magnetic field B is qvB sin(a), where a is the angle between velocity 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. How to apply the concepts of electrical and gravitational potential energy to solve problems involving conservation of energy.