

OFFICE OF CHIEF ACADEMIC OFFICER
Summary of State Board of Education Agenda Items
January 19, 2017

OFFICE OF SECONDARY EDUCATION

03. Action: Begin the Administrative Procedures Act process: To revise the Mississippi College- and Career-Readiness Standards for Science [Goals 1 and 2 – MBE Strategic Plan]

The *Mississippi College- and Career-Readiness Standards (MS CCRS) for Science 2018* will replace the *2010 Mississippi Science Framework*. The new standards reflect national expectations with a focus on postsecondary success. All standards were reviewed and selected by Mississippi educators to address the needs of our students. The standards address three basic content strands of science – life science, physical science, and Earth and space science. This document will provide the basis for curriculum development for Grades K-12 science teachers, outlining what students should know and be able to do by the end of each grade level in preparation for college and career.

This item references Goals 1 and 2 of the *Mississippi Board of Education 2016-2020 Strategic Plan*.

Recommendation: Approval

Back-up material attached



MISSISSIPPI
DEPARTMENT OF
EDUCATION

Ensuring a bright future for every child

**2018
Mississippi
College- and
Career-
Readiness
Standards for
Science**

Effective Date: 2018-2019 School Year



2018 Mississippi College- and Career-Readiness Standards for Science

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Introduction

Mission Statement

The Mississippi Department of Education is dedicated to student success, which includes improving student achievement in science, equipping citizens to solve complex problems, and establishing fluent communication skills within a technological environment. The Mississippi College- and Career-Readiness Standards provide a consistent, clear understanding of what students are expected to know and be able to do by the end of each grade level or course. The standards are designed to be robust and relevant to the real world, reflecting the knowledge and skills that students need for success in college and careers and allowing students to compete in the global economy.

Purpose

In an effort to closely align instruction for students who are progressing toward postsecondary study and the workforce, the *2018 Mississippi College- and Career-Readiness Standards for Science* includes grade- and course-specific standards for K-12 science.

This document is designed to provide K-12 science teachers with a basis for curriculum development. In order to prepare students for careers and college, it outlines what knowledge students should obtain, and the types of skills students must master upon successful completion of each grade level. The *2018 Mississippi College- and Career-Readiness Standards (MS CCRS) for Science* replaces the *2010 Mississippi Science Framework*. These new standards reflect national expectations while focusing on postsecondary success, but they are unique to Mississippi in addressing the needs of our students and teachers. The standards' content centers around three basic content strands of science: life science, physical science, and Earth and space science. Instruction in these areas is designed for a greater balance between content and process. Teachers are encouraged to transfer more ownership of the learning process to students, who can then direct their own learning and develop a deeper understanding of science and engineering practices, critical analysis, and knowledge. Doing so will produce students that will become more capable, independent, and scientifically literate adults.

Implementation

The *2018 Mississippi College- and Career-Readiness Standards (MS CCRS) for Science* will be implemented during the 2018-2019 school year.



2018 Mississippi College- and Career-Readiness Standards for Science Overview

Research and Background Information

In today's modern world and complex society, our students are required to possess sufficient knowledge of science and engineering to become vigilant consumers of scientific and technological information. To meet the growing challenges facing our future workforce, the National Research Council (NRC) published a research-based report on teaching and learning science in a 2012 document titled *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). This document proposes a new approach to K-12 science education through the integration of science and engineering practices (SEPs), crosscutting concepts, disciplinary core ideas, and engineering design within the context of science instruction.

Core Elements in the Design of MS CCRS for Science

The *MS CCRS for Science* document was built by adapting and extending information from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012) and combining with Mississippi's previous science framework process strands (i.e., science as inquiry, unifying concepts and processes, science and technology, science in personal and social perspectives, and the history and nature of science). These concepts connect information across the science content strands (i.e., life science, physical science, and Earth and space science) with the disciplinary core ideas (e.g., ecology and interdependence, motions, forces, and energy, Earth systems and cycles) and are essential to both scientists and engineers because they identify common properties and processes found in practice.

The core elements are integrated across standards and performance objectives in each grade and course. A brief description of each core element is presented below.

1. **Nature of Science: Science and Engineering Practices (SEPs)** replaced the Inquiry Strand included in the *2010 Mississippi Science Framework*. Beyond integration within the standards, these practices must be mastered by students to produce a more scientifically literate citizenry and to develop students that are more excited about STEM (Science, Technology, Engineering, and Mathematics) topics and careers. Inquiry verbs, along with the SEPs, are woven throughout the standards, especially in the performance objectives. Each has a deliberate placement to indicate the depth of understanding expected for students.

The practices describe the behaviors that scientists engage in as they investigate and build models and theories about the natural world. They also describe the key set of engineering practices that engineers use as they design and build models and systems. These practices work together (overlap and interconnect) and are not separated in the study and investigation of science concepts. For example, the practice of *mathematical and computational thinking* may include some aspects of *analyzing and interpreting data*. The data often come from *planning and carrying out an investigation*. The writing task force for the *MS CCRS for Science* incorporated this language into the performance objectives to emphasize the importance of a student-centered science classroom and not a teacher-centered classroom. A list of these eight practices is listed below.

- a. **Ask Questions (science) and Define Problems (engineering)**
- b. **Develop and Use Models**
- c. **Plan and Conduct Investigations**
- d. **Analyze and Interpret Data**

-
- e. **Use Mathematical and Computational Thinking**
 - f. **Construct Explanations (science) and Design Solutions (engineering)**
 - g. **Engage in Scientific Argument from Evidence**
 - h. **Obtain, Evaluate, and Communicate Information**
2. **Crosscutting concepts:** These seven, binding concepts were adopted directly from the National Research Council’s *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2012) and should be woven into instruction for every grade and course. Crosscutting concepts are designed to help students see the unity of the sciences. Students often are confused when they study ecosystems for three weeks, then weather for two weeks, and finally motion and forces for several weeks. A concept is crosscutting if it communicates a scientific way of thinking about a subject and it applies to many different disciplines of science and engineering. Crosscutting concepts are sometimes called “the ties that bind.” The seven concepts are listed below.
- a. **Patterns**
 - b. **Cause and effect: Mechanism and explanation**
 - c. **Scale, proportion, and quantity**
 - d. **Systems and system models**
 - e. **Energy and matter: Flows, cycles, and conservation**
 - f. **Structure and function**
 - g. **Stability and change**
3. **Technology:** If Mississippi students are to compete on a global stage and exit high school prepared for college, career, and life, technology should be used in the classroom in a way that suits 21st-century learners and reflects the modern workplace. Technology is essential in teaching and learning of science; it influences and enhances students’ learning. Flexible access, customized delivery, and increased convenience for the user are core tenets. K-12 learners have fundamentally changed over the past few decades, and our classrooms should adapt to accommodate them. Dr. Ruben Puentedura’s SAMR (Substitution, Augmentation, Modification, and Redefinition) model is a resource that can be considered by teachers, administrators, and technology staff as they integrate meaningful and appropriate digital learning experiences into the classroom. At the basic level, technology enhances instruction.
4. **Science and society:** This core element assures exploration of science’s impacts on society and the feedback loop that must be cultivated and sustained to continue improvement of systems.
5. **History of science:** Because most modern-day scientific advancement derives from past discoveries, it is essential that students understand the breakthroughs that make today’s work possible.
6. **Engineering design process (EDP)** is the method of devising a system, component, or process to meet desired needs. Engineering standards are represented in some performance objectives with grade-banded, specific wording that prompts educators to approach learning and exploration using the engineering process. These performance objectives are marked with an *. It is important to note that the EDP is flexible. Most students will approach the process in various ways. The EDP is also a cycle—there is no official start or end point. Students can begin at any step, focus on just one step, move back and forth between steps, or repeat the cycle. Professional development and teacher resources will be developed for Mississippi teachers as EDP is incorporated into Mississippi standards.
-

Students should be provided a safe environment for failure without consequence, which is one of the most powerful drivers in learning. Providing ample opportunity for students to fail, learn, and try again, with appropriate levels of support, fosters a deeper level of understanding and greater student interest and engagement.

Other Important Core Elements

Mathematics is integrated throughout the science standards document because it is essential to the scientific process, requiring students to quantify, analyze, and present results. Students must be familiar with data analysis, critical thinking, and recording their own data; students must organize and analyze it before presenting their findings. Analysis of scientific studies and publications from a quantitative perspective is also very important.

English/language arts skills are also integrated into the science standards. Students will be required to read informational text for understanding as well as process and critique information. Students must be able to articulate a critical point of view using proper terminology. In addition, the K-4 science curriculum should be increasingly tied to language arts in order to lay the foundation for students to have access to science before fifth grade.

Content Strands and Disciplinary Core Ideas

Science (and engineering) fields can be divided into three content-strand domains based on relative content presented in strands, extending from kindergarten to eighth grade. Grouping content in this way allows for vertical alignment of competencies and objectives to better organize content distribution. Content strands are not included in the Grades 9-12 course organization, which allows for a more logical, sequential placement and flow of content. Content strands are subdivided into 10 disciplinary core ideas in which standards and performance objectives for science content can be placed in grades K-8.

K-8 content strands with the 10 disciplinary core ideas include:

Life Science

1. Hierarchical Organization
2. Reproduction and Heredity
3. Ecology and Interdependence
4. Adaptations and Diversity

Physical Science

5. Organization of Matter and Chemical Interactions
6. Motions, Forces, and Energy

Earth and Space Science

7. Earth's Structure and History
8. Earth and the Universe
9. Earth Systems and Cycles
10. Earth's Resources

Structure of the Standards Document

The organization and structure of this standards document are as follows:

- **Grade-band overview:** An overview that describes the general content and themes for the grade-level band or the high school courses. Outputs and outcomes are provided along with examples of, and references to, science and engineering practices and connecting concepts.
- **Grade-level or course overview:** An overview that describes the specific content and themes for each grade level and/or high school course. The K-8 standards are presented with each grade focused on a grade-level theme. High school courses provide an overview of the major ideas and strategies to use when planning instruction for the course.
- **Content strand:** Domains into which science fields can be divided based on relative content extending from kindergarten to eighth grade. In grades K through 8, the content strands are organized into three distinct areas: (1) life science, (2) physical science, and (3) Earth and space science. For the Grade 9-12 courses, the content areas are organized around the core ideas of each course.
- **Disciplinary core ideas:** Subdivision of the main content strands providing recurring ideas from the three content strands. The core ideas are the key organizing principles for the development of learning units. The K-8 vertical alignment is designed in a spiral arrangement, which places emphasis on one of the three content strands in each grade level. All content strands will be found in each grade level, but all disciplinary core ideas will not be found in every grade level in K-8 due to the spiral arrangement of content.
- **Conceptual understanding:** Statements of the core ideas for which student should demonstrate an understanding. Some grade level and/or course topics include more than one conceptual understanding with each guiding the intent of the standards.
- **Content standards:** Written below each disciplinary core ideas and conceptual understanding, the standards are a general statement of what students should know and be able to do as a result of instruction.
- **Performance objectives:** Detailed statements of content and skills to be mastered by the students. Performance objectives are specific statements of what students know and can do because of the science instruction at that level. These statements contain SEP and inquiry verb language.

Standards will appear in the following format:

Grade-Band Overview

Grade Level Theme (K-8)

Grade Level (K-8) or Course Overview (9-12)

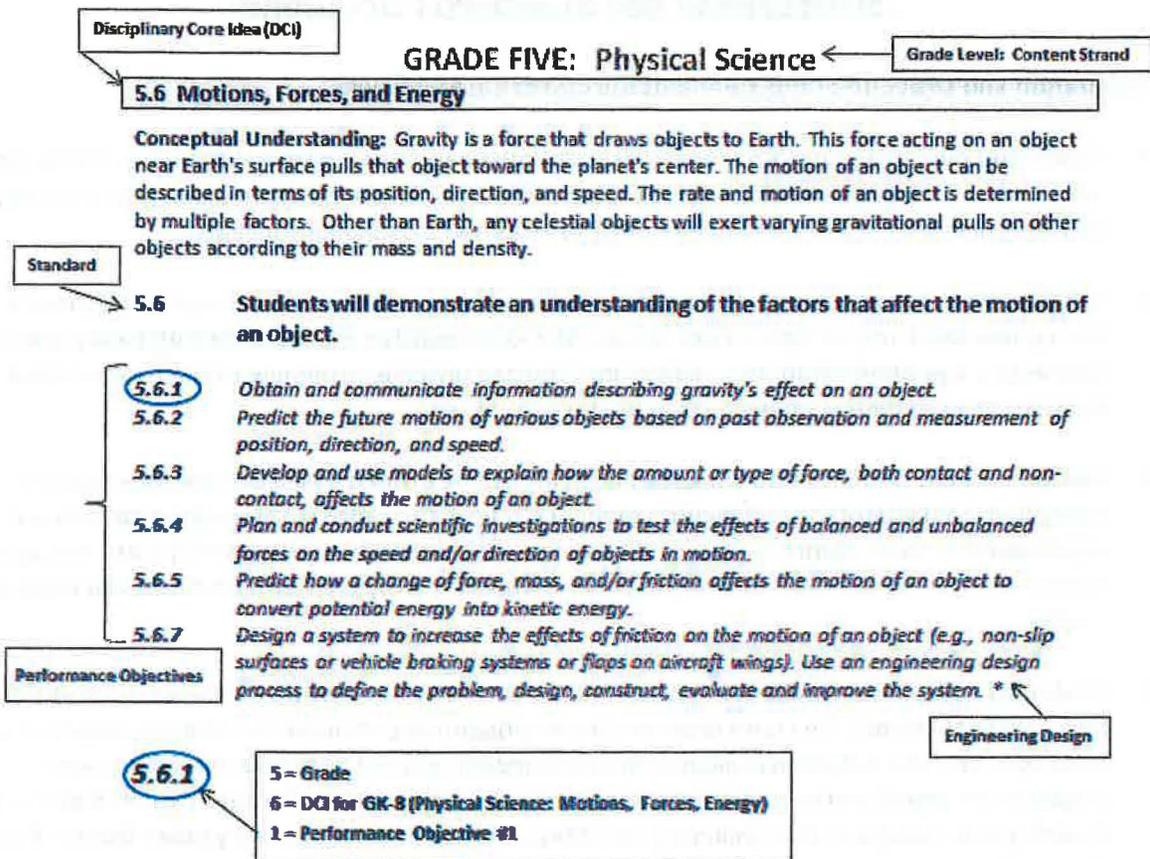
Grade Level: Content Strand (K-8); Course Name (9-12)

Disciplinary Core Idea (DCI)

Conceptual Understanding

Standard

Performance Objectives



Safety in the Science Classroom

The National Science Teachers Association (NSTA) encourages K–12 school leaders and teachers to promote and support the use of science activities in science instruction and work to avoid and reduce injury. NSTA provides the following guidelines for school leaders and teachers to develop safety programs that include the effective management of chemicals, implement safety training for teachers and others, and create school environments that are as safe as possible (NSTA 2013).

- 1) National Science Teacher Association's *Safety in the Science Classroom*, accessible at <http://www.nsta.org/docs/SafetyInTheScienceClassroom.pdf>.
- 2) An extensive list of safety resources is available at <http://www.nsta.org/safety/>.

Support Documents and Resources

The MDE will develop support documents after these standards have been approved by the State Board of Education. Local districts, schools, and teachers may use these documents to construct standards-based science curriculum, allowing them to customize content to fit their students' needs and match available instructional materials. The support documents will include suggested resources, instructional strategies, essential knowledge, and detailed information about the core elements (e.g., SEPs, crosscutting concepts).

Professional development efforts will be aligned with the standards and delivered in accord with teacher resources to help expand expertise in delivering student-centered lessons (e.g., inquiry-based learning, 5-E instructional models, or other best practices in STEM teaching). The most successful national models and programs will be referenced for a capacity-building effort that can develop a more effective culture of science education in Mississippi.

Investigate, Apply, and Understand

It is important that the pedagogical paradigm of Mississippi's science classroom reflects the nature of the content being learned. The essence of science is natural to children and includes discovery, observation, questioning, design, testing, failure, iteration, and hands-on application. Research-based approaches such as inquiry-based (IB), project-based, and discovery learning are all pedagogical pathways that make sense, especially in the science classroom. Mississippi's science teachers are encouraged to embrace the growth mindset and constantly seek to upgrade classroom approaches by experimenting and adopting methods that excite students to learn and become functional, autonomous learners and contributors. Students should be provided increased maneuverability in the classroom to formulate their own ideas to investigate and understand the scientific and engineering design processes.

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GRADES K-2 OVERVIEW

Students in Grades K-2 are naturally curious about their world and learn best through hands-on experiences. Teachers must consider the students' developmental level to provide appropriate learning experiences so that students will understand the nature of science. Therefore, investigations using the five senses should be an integral part of scientific inquiry. Recognizing and observing patterns are also important, and students should be given experiences with living things to help them build their scientific understanding. Learning opportunities should also facilitate the development of language-process skills and mathematical concepts, while the students develop the ability to observe and then communicate observations. Students need to be supplied with the appropriate materials and equipment necessary to complete scientific investigations.

Each grade is developed around a theme:

- Kindergarten – Change in the Natural World
- Grade 1 – Discovering Patterns and Constructing Explanations
- Grade 2 – Systems, Order, and Organization

In kindergarten, students are introduced to the concept of change. They learn to generate questions, conduct structured experiments, sort, classify, sequence, and predict to communicate those findings. In first grade, students build on the knowledge gained from kindergarten and make deeper connections by examining evidence, observing patterns, and formulating explanations. By second grade, students learn to organize and categorize their findings, which establish a foundation for logical thinking. They also use abstract reasoning and interpretation of observations to draw conclusions from their investigations.

The core science content utilizes hands-on classroom instruction to reinforce the seven crosscutting concepts (i.e., patterns; cause and effect; scale, portion, and quantity; systems and system models; energy and matter; structure and function; and stability and change).

SEPs are in life science, physical science, and Earth and space science. The SEPs are designed so that students may develop skills and apply knowledge to solve real-life problems. While presented as distinct skill sets, the eight practices intentionally overlap and interconnect as students explore the science concepts. Some examples of specific skills students should develop in grades K-2 are listed below.

1. Generate questions and investigate the differences between liquids and solids.
2. Develop and use models to predict weather conditions associated with seasonal patterns and changes.
3. Conduct an investigation to provide evidence that vibrations create sound (e.g., pluck a guitar string) and that sound can create vibrations (e.g., feeling sound through a speaker).
4. Analyze and interpret data from observations and measurements to describe local weather conditions (including temperature, wind, and forms of precipitation).
5. Compare the length and weight of solid objects and the volume of liquid objects using technology and mathematical representations. Measure, analyze and communicate findings.
6. Construct an explanation for the general pattern of change in daily temperatures by measuring and calculating the difference between morning and afternoon temperatures.
7. Obtain and evaluate informational texts and other media to generate and answer questions about water sources and human uses of clean water.

Curricula and instructions that integrate science and engineering practices should reflect the skills outlined above.

The Engineering Design Process (EDP) is a step-by-step method of devising a system, component, or process to meet desired needs. This is similar to the “scientific method” which is taught to young scientists. However, the EDP is a flexible process. Students can begin at any step, focus on just one step, move back and forth between steps, or repeat the cycle. Engineering standards are represented in some performance objectives with grade-banded, specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.** Professional development and teacher resources will be developed for teachers as EDP is incorporated into Mississippi standards.

Each K-2 standard allows students to be active doers of science rather than passive observers. This approach creates an opportunity for student learning and engages the pupil in the scientific investigation process.

KINDERGARTEN

Theme: Change in the Natural World

In kindergarten, students observe the changes in the natural world and identify how animals use their senses to recognize the changes. As language and vocabulary develops, students recognize that plants and animals change and report findings about the changes throughout the life cycle. Students conduct an investigation to determine the needs of plants to grow and use quantitative measurement to chart growth over time. Students learn that change occurs when plants and animals do not get the food, water, and space needed for growth. Students develop and use models to describe the seasonal changes in the environment. Students develop questions and conduct a structured investigation to determine how sunlight affects the temperature of sand, soil, rocks, and water. Using an engineer design process, students then construct a structure to reduce the temperature of a play area. Students recognize that scientists observe changes in the natural world and use investigations, charts, drawings, sketches, and models to communicate these changes. Students need to recognize that scientists observe the natural world and use investigations, charts, drawings, sketches, and models to communicate ideas.

KINDERGARTEN: Life Science

K.1 Hierarchical Organization

Conceptual Understanding: Objects in the environment can be classified as living and nonliving. Living things include plants and animals. All living things reproduce, grow, develop, respond to stimuli, and die; and nonliving things do not. Living things require air, food, water, and an environment in which to live. Acting as scientists, students will observe the natural world and use investigations, charts, drawings, sketches, and models as a way to communicate ideas.

K.1A Students will demonstrate an understanding of living and nonliving things.

K.1A.1 *With teacher guidance, conduct an investigation of living organisms and nonliving objects in various real world environments (e.g., playground, garden, school grounds) to define characteristics of living organisms that distinguish them from nonliving things.*

K.1A.2 *With teacher support, gain an understanding that scientists are humans who use observations to learn about the natural world. Obtain information from informational text or other media about scientists who have made important observations about living things (e.g. Carl Linnaeus, John James Audubon, Jane Goodall).*

Conceptual Understanding: All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water, and air. Animals (including humans) use their senses to learn about the world around them.

K.1B Students will demonstrate an understanding of how animals (including humans) use their physical features and their senses to learn about their environment.

K.1B.1 *Develop and use models to exemplify how animals use their body parts to (a) obtain food and other resources, (b) protect themselves, and (c) move from place to place.*

K.1B.2 *Analyze and interpret data to describe how animals use their senses to learn about the world around them.*

KINDERGARTEN: Life Science

K.2 Reproduction and Heredity

Conceptual Understanding: Plants and animals change in form as they go through stages in the life cycle. Young plants and animals are very much like their parents and other plants and animals of the same kind, but they can also vary in many ways.

K.2 Students will demonstrate an understanding of how living things change in form as they go through the general stages of a life cycle.

K.2.1 *Use informational text or other media to make observations about plants as they change during the life cycle (e.g., germination, growth, reproduction, and death) and use models (e.g., drawing, writing, dramatization, or technology) to communicate findings.*

K.2.2 *Construct explanations using observations to describe and model the life cycle (birth, growth, adulthood, death) of a familiar mammal (e.g., dog, squirrel, rabbit, deer).*

K.2.3 *With teacher guidance, conduct a structured investigation to observe and measure (comparison of lengths) the changes in various individuals of a single plant species from seed germination to adult plant. Record observations using drawing or writing.*

K.2.4 *Use observations to explain that young plants and animals are like but not exactly like their parents (i.e., puppies look similar, but not exactly like their parents).*

KINDERGARTEN: Life Science

K.3 Ecology and Interdependence

Conceptual Understanding: The environment consists of many types of living things including plants and animals. Living things depend on the land, water, and air to live and grow.

K.3A Students will demonstrate an understanding of what animals and plants need to live and grow.

K.3A.1 *With teacher guidance, conduct a structured investigation to determine what plants need to live and grow (water, light, and a place to grow). Use non-standard measurement to chart growth over time.*

K.3A.2 *Construct explanations using observations to describe and report what animals need to live and grow (food, water, shelter, and space).*

Conceptual Understanding: Interdependence exists between plants and animals within an environment. Living things can only survive in areas where their needs for air, water, food, and shelter are met.

K.3B Students will demonstrate an understanding of the interdependence of living things and the environment in which they live.

K.3B.1 *Observe and communicate that animals get food from plants or other animals. Plants make their own food and need light to live and grow.*

K.3B.2 *Create a model habitat which demonstrates interdependence of plants and animals using an engineering design process to define the problem, design, construct, evaluate, and improve the habitat.**

KINDERGARTEN: Life Science

K.4 Adaptations and Diversity

Conceptual Understanding: When animals do not get what they need to survive, they will die. Some types of plants and animals are now extinct because they were unable to adapt when the environment changed. There are similarities between some present-day animals and extinct animals.

K.4 Students will demonstrate an understanding that some groups of plants and animals are no longer living (extinct) because they were unable to meet their needs for survival.

K.4.1 Obtain information from informational text or other media to document and report examples of different plants or animals that are extinct.

K.4.2 Observe and report how some present-day animals resemble extinct animals (i.e., elephants resemble woolly mammoths).

KINDERGARTEN: Physical Science

K.5 Organization of Matter and Chemical Interactions

Conceptual Understanding: Matter exists in different states, including solid and liquid forms. Water can exist as a solid or a liquid. Solid objects can be described and sorted according to their attributes. Different properties are suited for different purposes.

K.5A Students will demonstrate an understanding of the solid and liquid states of matter.

K.5A.1 Generate questions and investigate the differences between liquids and solids and develop awareness that a liquid can become a solid and vice versa.

K.5A.2 Describe and compare the properties of different materials (e.g., wood, plastic, metal, cloth, paper) and classify these materials by their observable characteristics (visual, aural, or natural textural) and by their physical properties (weight, volume, solid or liquid, and sink or float).

Conceptual Understanding: Many objects can be built from a smaller set of pieces (e.g., blocks, construction sets). Most objects can be broken down into various component pieces and any piece of uniform matter (e.g., a sheet of paper, a block of wood,) can be subdivided into smaller pieces of the same material. If pieces of the original object are damaged or removed, the object may not have the same properties or work the same.

K.5B. Students will demonstrate an understanding of how solid objects can be constructed from a smaller set.

K.5B.1 Use basic shapes and spatial reasoning to model large objects in the environment using a set of small objects (e.g., blocks, construction sets).

K.5B.2 Analyze a large composite structure to describe its smaller components using drawing and writing.

K.5B.3 Explain why things may not work the same if some of the parts are missing.

KINDERGARTEN: Earth and Space Science**K.8 Earth and the Universe**

Conceptual Understanding: Seasonal changes occur as the Earth orbits the sun. These seasonal changes repeat in a pattern. Patterns of sunrise and sunset can be described and predicted.

K.8A Students will demonstrate an understanding of the pattern of seasonal changes on the Earth.

K.8A.1 *Construct an explanation of the pattern of the Earth's seasonal changes in the environment using evidence from observations.*

Conceptual Understanding: The sun is the source of heat and light for the solar system. This heat can impact Earth's natural resources. Living things depend upon the effects of the sun (warms the land, air, water, and helps plants grow) in order to survive.

K.8B Students will demonstrate an understanding that the Sun provides the Earth with heat and light.

K.8B.1 *With teacher guidance, generate and answer questions to develop a simple model, which describes observable patterns of sunlight on the Earth's surface (day and night).*

K.8B.2 *With teacher guidance, develop questions to conduct a structured investigation to determine how sunlight affects the temperature of the Earth's natural resources (e.g., sand, soil, rocks, and water).*

K.8B.3 *Develop a technology (i.e., umbrella, shade structure, or hat) which would reduce heat from the sun (temperature) using an engineering design process to define the problem, design, construct, evaluate, and improve the tool.**

KINDERGARTEN: Earth and Space Science**K.10 Earth's Resources**

Conceptual Understanding: Humans use Earth's resources for everything they do. Choices that humans make to live comfortably can affect the world around them. Recycling, reusing, and reducing consumption of natural resources is important in protecting our Earth's environment. Humans can make choices that reduce their impact on Earth's environment.

K.10 Students will demonstrate an understanding of how humans use Earth's resources.

K.10.1 *Participate in a teacher-led activity to gather, organize and record recyclable materials data on a chart or table using technology. Communicate results.*

K.10.2 *With teacher guidance, develop questions to conduct a structured investigation to determine ways to reduce, reuse and recycle Earth's resources and communicate results.*

K.10.3 *Create a product from the reused materials that will meet a human need (e.g., pencil holder, musical instrument, bird feeder). Use an engineering design process to define the problem, design, construct, evaluate, and improve the product.**

GRADE ONE

Theme: Discovering Patterns and Constructing Explanations

In Grade 1, students build on the language, vocabulary, and mathematical concepts developed in kindergarten to construct explanations stemming from patterns observed in the natural environment. Students conduct investigations to determine what plants need to live and grow. They test predictions, discover patterns in plant and animal life cycles, and construct explanations about plant needs for growth and survival. Students use an engineering design process to solve the problem of plant overcrowding in a garden. Students observe plant adaptations, such as trees shedding leaves, or leaves turning toward the sun, and establish the cause and effect relationship between adaptations and environmental changes. Students describe, compare, and analyze daily weather data to determine weather patterns in different seasons. They use an engineering design process to create a system to better plan and respond to severe weather. Students investigate light and sound to find materials that light passes through and materials that change sound. They construct a device that uses light and/or sound to communicate over a distance. Students develop investigations and make predictions about patterns in the natural world. Acting as scientists, students observe the natural world and use investigations, charts, drawings, sketches, and models to communicate ideas.

GRADE ONE: Life Science

1.1 Hierarchical Organization

Conceptual Understanding: All living things reproduce, grow, develop, respond to stimuli, and die. Living things require air, food, water, and an environment in which to live. Plants are living things, and each plant part (roots, stem, leaves, and fruit) helps them survive, grow, and reproduce.

1.1 Students will demonstrate an understanding of the basic needs and structures of plants.

- 1.1.1** *Construct explanations using first-hand observations or other media to describe the structures of different plants (i.e., root, stem, leaves, flowers, and fruit). Report findings using drawings, writing, or models.*
- 1.1.2** *Obtain information from informational text and other media to describe the function of each plant part (roots absorb water and anchor the plant, leaves make food, the stem transports water and food, petals attract pollinators, flowers produce seeds, and seeds produce new plants).*
- 1.1.3** *Design and conduct an experiment that shows the absorption of water and how it is transported through the plant. Report observations using drawings, sketches, or models.*
- 1.1.4** *Create a model which explains the function of each plant structure (roots, stem, leaves, petals, flowers, seeds).*
- 1.1.5** *With teacher support, gain an understanding that scientists are humans who use observations and experiments to learn about the natural world. Obtain information from informational text or other media about scientists who have made important observations about plants (e.g., Theophrastus, Gregor Mendel, George Washington Carver, Katherine Esau).*

GRADE ONE: Life Science

1.2 Reproduction and Heredity

Conceptual Understanding: Plants and animals change with each stage of life. Plants have predictable and observable characteristics at each developmental stage (germination, growth, reproduction, and seed dispersal). Most plants are stationary so they depend upon animals or the wind for seed dispersal. Plants and animals are similar to their parents and resemble other plants and animals of the same kind.

1.2 Students will demonstrate an understanding of how living things change in form as they go through the general stages of a life cycle.

1.2.1 *Investigate, using observations and measurements, flowering plants (pumpkins, peas, marigolds, or sunflowers) as they change during the life cycle (i.e., germination, growth, reproduction, and seed dispersal). Use drawings, writing, or models to communicate findings.*

1.2.2 *Obtain, evaluate, and communicate information through labeled drawings, the life cycle (egg, larva, pupa, adult) of pollinating insects (e.g., bees, butterflies).*

1.2.3 *Create a device to help humans disperse seeds in order to grow new plants. Use an engineering design process to define the problem, design, construct, evaluate, and improve a device.**

GRADE ONE: Life Science

1.3 Ecology and Interdependence

Conceptual Understanding: The needs of plants must be met to survive. Sunlight, water, nutrients, and space to grow are necessary for plant growth and repair.

1.3A Students will demonstrate an understanding of what plants need from the environment for growth and repair.

1.3A.1 *Conduct structured investigations to make and test predictions about what plants need to live, grow, and repair including water, nutrients, sunlight, and space. Develop explanations, compare results, and report findings.*

Conceptual Understanding: Animals, such as insects, depend on other living organisms for food. Many plants depend on insects or other animals for pollination or to move their seeds around so the plant can survive.

1.3B Students will demonstrate an understanding of the interdependence of flowering plants and pollinating insects.

1.3B.1 *Identify the body parts of a pollinating insect (e.g., bee, butterfly) and describe how insects use these parts to gather nectar or disburse pollen. Report findings using drawings, writing, or models.*

1.3B.2 *Create a hand pollinator that will disperse pollen to help seeds grow when natural forms of pollination are unavailable. Use an engineering design process to define the problem, design, construct, evaluate, and improve the hand pollinator.**

GRADE ONE: Life Science

1.4 Adaptations and Diversity

Conceptual Understanding: Plants respond to stimuli (e.g., turn their leaves to the sun, use tendrils to grab and support) to adapt to changes in the environment. There are distinct environments in the world that support certain types of plants. Plants have features that help them survive in their environment.

1.4 Students will demonstrate an understanding of the ways plants adapt to their environment in order to survive.

1.4.1 *Explore the cause and effect relationship between plant adaptations and environmental changes (i.e., leaves turning toward the sun, leaves changing color, leaves wilting, or trees shedding leaves).*

1.4.2 *Describe how the different characteristics of plants help them to survive in distinct environments (e.g., rain forest, desert, grasslands, forests).*

1.4.3 *Create a trellis that will make use of plant structures (e.g., tendrils) to support vertical growth and solve the problem of plant overcrowding in a garden. Use an engineering design process to define the problem, design, construct, evaluate, and improve the structure.**

GRADE ONE: Physical Science

1.6 Motions, Forces, and Energy

Conceptual Understanding: Some objects allow light to pass through them and some objects do not allow any light to pass through them, creating shadows. Very hot objects give off light. Objects reflect light, and objects can only be seen when light is reflected off them. Mirrors and prisms can be used to change the direction of a light beam-

1.6A Students will demonstrate an understanding that light is required to make objects visible.

1.6A.1 *Construct explanations using first-hand observations or other media to describe how reflected light makes an object visible.*

1.6A.2 *Use evidence from observations to explain how shadows form and change with the position of the light source.*

Conceptual Understanding: Vibrations of matter can create sound, and sound can make an object vibrate. Humans use sound and light to communicate over long distances.

1.6B Students will demonstrate an understanding of sound.

1.6B.1 *Conduct an investigation to provide evidence that vibrations create sound (e.g., pluck a guitar string) and that sound can create vibrations (e.g., feeling sound through a speaker).*

1.6B.2 *Create a device that uses light and/or sound to communicate over a distance (e.g., signal lamp with a flashlight). Use an engineering design process to define the problem, design, construct, evaluate, and improve the device.**

GRADE ONE: Earth and Space Science

1.9 Earth's Systems and Cycles

Conceptual Understanding: Weather is a combination of temperature, sunlight, wind, snow, or rain in a particular place at a particular time. People measure weather conditions (temperature, precipitation) to describe and record the weather and to notice patterns over time. Temperature and precipitation can change with the seasons. Some kinds of severe weather (hurricane, tornado, flood, and drought) are more likely to occur in certain regions. Meteorologists forecast severe weather so that communities can prepare for and respond appropriately.

1.9A Students will demonstrate an understanding of the patterns of weather by describing, recording, and analyzing weather data to answer questions about daily and seasonal weather patterns.

1.9A.1 *Analyze and interpret data from observations and measurements to describe local weather conditions (including temperature, wind, and forms of precipitation).*

1.9A.2 *Develop and use models to predict weather conditions associated with seasonal patterns and changes.*

1.9A.3 *Construct an explanation for the general pattern of change in daily temperatures by measuring and calculating the difference between morning and afternoon temperatures.*

1.9A.4 *Obtain and communicate information about severe weather conditions to explain why certain safety precautions are necessary.*

Conceptual Understanding: The Earth is made of different materials, including rocks, soil, and water (nonliving things). Plants and animals, including humans, depend on the Earth's land, water, and air to live and grow. Animals, including humans, can change the environment (e.g., shape of the land, the flow of water).

1.9B Students will demonstrate an understanding of models (drawings or maps) to describe how water and land are distributed on Earth.

1.9B.1 *Locate, classify, and describe bodies of water (oceans, rivers, lakes, and ponds) on the Earth's surface using maps, globes, or other media.*

1.9B.2 *Generate and answer questions to explain the patterns and location of frozen and liquid bodies of water on earth using maps, globes, or other media.*

1.9B.3 *With teacher guidance, plan and conduct a structured investigation to determine how the movement of water can change the shape of the land on earth.*

GRADE ONE: Earth and Space Science

1.10 Earth's Resources

Conceptual Understanding: Water is essential to life on earth. Humans and other living things are dependent on clean water to survive. Water is an Earth material, and like all of Earth's resources, the amount of water is limited. Continued health and survival of humans are dependent on solutions that maintain clean water sources.

- 1.10** **Students will demonstrate an understanding of human dependence on clean and renewable water resources.**
- 1.10.1** *Obtain and evaluate informational texts and other media to generate and answer questions about water sources and human uses of clean water.*
- 1.10.2** *Communicate solutions that will reduce the impact of humans on the use and quality of water in the local environment.*
- 1.10.3** *Create a tool that will collect free water to meet a human need (e.g., household drinking water, watering plants/animals, cleaning). Use an engineering design process to define the problem, design, construct, evaluate, and improve the structure.**

GRADE TWO

Theme: Systems, Order, and Organization

In Grade 2, students organize plants and animals according to their physical characteristics and recognize that living things are part of a larger system. Students construct models showing the characteristics of animals that help them survive in their environments, and construct scientific arguments explaining how animals can make major and minor changes in the environment. Students conduct investigations to find and report evidence where plants and animals compete or cooperate with other plants in a system before identifying the adaptations that help them survive in that environment. Students investigate the relationship between friction and the motion of an object by changing the strength, direction, and speed of pushes and pulls. Students use an engineering design process to construct a ramp that will reduce or increase friction to solve a problem, such as rolling a baby carriage safely down a steep ramp.

GRADE TWO: Life Science

2.1 Hierarchical Organization

Conceptual Understanding: Animals have unique physical and behavioral characteristics that enable them to survive in their environment. Animals can be classified based on physical characteristics.

2.1 Students will demonstrate an understanding of the classification of animals based on physical characteristics.

2.1.1 *Compare and sort groups of animals with backbones (vertebrates) from groups of animals without backbones (invertebrates).*

2.1.2 *Classify vertebrates (mammals, fish, birds, amphibians, and reptiles) based on their physical characteristics.*

2.1.3 *Compare and contrast physical characteristics that distinguish classes of vertebrates (i.e., reptiles compared to amphibians).*

2.1.4 *Construct a scientific argument for classifying animals using structural characteristics of bats, penguins, snakes, salamanders, dolphins, and duck-billed platypuses.*

GRADE TWO: Life Science

2.2 Reproduction and Heredity

Conceptual Understanding: Plants and animals experience different life cycles as they grow and develop. Plants and animals exhibit predictable characteristics at each developmental stage throughout the life cycle.

2.2 Students will demonstrate an understanding of how living things change in form as they go through the general stages of a life cycle.

2.2.1 *Use observations and measurements of trees (i.e. pecan, oak, pine) in different stages of the life cycle to construct explanations of how trees change over time. Communicate findings.*

2.2.2 *Construct explanations using first-hand observations or other media to describe the life cycle of a frog (birth, growth/development, reproduction, and death). Communicate findings.*

GRADE TWO: Life Science

2.3 Ecology and Interdependence

Conceptual Understanding: Animals thrive in environments where their needs (air, water, food, and shelter) are met. The environment where plants and animals live sometimes changes slowly and sometimes changes rapidly. If living things are unable to adapt to changes in the environment, they may not survive.

2.3A Students will demonstrate an understanding of the interdependence of living things and the environment in which they live.

2.3A.1 *Evaluate and communicate findings from informational text or other media to describe how animals change and respond to rapid or slow changes in their environment (fire, pollution, changes in tide, availability of food/water).*

2.3A.2 *Construct scientific arguments to explain how animals can make major changes (e.g., beaver dams obstruct streams, or large deer populations destroying crops) and minor changes to their environments (e.g., ant hills, crawfish burrows, mole tunnels). Communicate findings.*

Conceptual Understanding: All animals and plants need food to provide energy for activity and raw materials for growth. Animals and plants have physical features and behaviors that help them survive in their environment. All living things in an environment interact with each other in different ways and for different reasons.

2.3B Students will demonstrate an understanding of the interdependence of living things.

2.3B.1 *Evaluate and communicate findings from informational text or other media to describe and to compare how animals interact with other animals and plants in the environment (i.e., predator-prey relationships, herbivore, carnivore, omnivore).*

2.3B.2 *Conduct an investigation to find evidence where plants and animals compete or cooperate with other plants and animals for food or space. Present findings (i.e., using technology or models).*

GRADE TWO: Life Science

2.4 Adaptations and Diversity

Conceptual Understanding: Living things need air, food, water, and space to survive. Different environments support different types of plants and animals. Animals have adaptations allowing them to grow and survive in the climate of their specific environment.

2.4 Students will demonstrate an understanding of the ways animals adapt to their environment in order to survive.

2.4.1 *Evaluate and communicate findings from informational text or other media to describe adaptations that help living things (e.g., ducks use webbed feet to swim in lakes and ponds, cacti have waxy coatings and spines to grow in the desert) survive in distinct environments (e.g., polar lands, saltwater and freshwater, desert, rainforest, woodlands).*

2.4.2 *Create a device based on an animal adaptation that would help a human survive in a specific environment (e.g., shoes like a snowshoe hare's or a helmet like a turtle's shell). Use an engineering design process to define the problem, design, construct, evaluate, and improve the device.**

GRADE TWO: Physical Science

2.5 Organization of Matter and Chemical Interactions

Conceptual Understanding: Matter exists in different states, including solid, liquid, and gas forms. Solids have a definite shape and volume and can be measured by length, and weight. Liquids have a definite volume but not a definite shape (Boundary: Volume is introduced for liquid measure only.) A gas has neither definite shape nor volume. Changes to matter can result from changes in temperature. Some changes may or may not be reversible (i.e., melting or freezing versus burning a cake).

2.5 Students will demonstrate an understanding of the properties of matter.

- 2.5.1** *Conduct a structured investigation to collect, represent, and analyze categorical data to classify matter as solid, liquid, or gas. Report findings and describe a variety of materials according to observable physical properties (e.g., size, color, texture, opacity, solubility).*
- 2.5.2** *Compare the length and weight of solid objects and the volume of liquid objects using technology and mathematical representations. Measure, analyze and communicate findings.*
- 2.5.3** *Construct scientific arguments to support claims that some changes to matter caused by heating can be reversed, and some changes cannot be reversed.*

GRADE TWO: Physical Science

2.6 Motions, Forces, and Energy

Conceptual Understanding: An object at rest will stay at rest unless it is pushed or pulled by an unbalanced force. Pushes and pulls can have different strengths, directions, or speeds. Friction occurs when two objects make contact. Friction can change the motion of an object, the speed of an object, and can also create heat. Friction can be increased or decreased.

2.6 Students will demonstrate an understanding of how the motion of objects is affected by pushes, pulls, and friction on an object.

- 2.6.1** *Conduct a structured investigation to collect, represent, and analyze data from observations and measurements to demonstrate the effects of pushes and pulls with different strengths and directions. Communicate findings (e.g., models or technology).*
- 2.6.2** *Generate and answer questions about the relationship between (1) friction and the motion of objects and (2) friction and the production of heat.*
- 2.6.3** *Develop a plan to reduce friction to solve a human problem (e.g., improve the ride on a playground slide or make a toy car or truck go faster). Use an engineering design process to define the problem, design, construct, evaluate, and improve the plan.**

GRADE TWO: Earth and Space Science

2.8 Earth and the Universe

Conceptual Understanding: Patterns of the Sun, Moon, and stars can be observed, described, and predicted. The sun is the source of heat and light for the solar system. Seasonal changes occur as the Earth orbits the Sun because of the tilt of the Earth on its axis. At night, one can see light from stars and sunlight being reflected from the moon. Telescopes make it possible to observe the Moon and the planets in greater detail. Space exploration continues to help humans understand more about the universe.

- 2.8** Students will demonstrate an understanding of the appearance, movements, and patterns of the sun, moon, and stars.
- 2.8.1** *Recognize that there are many stars that can be observed in the night sky and the Sun is the Earth's closest star.*
- 2.8.2** *With teacher guidance, observe, describe, and predict the seasonal patterns of sunrise and sunset. Collect, represent, and interpret data from internet sources to communicate findings.*
- 2.8.3** *Observe and compare the details in images of the moon and planets using the naked eye, telescopes, and data from space exploration.*
- 2.8.4** *With teacher support, gain an understanding that scientists are humans who use observations and experiments to learn about space. Obtain information from informational text or other media about scientists who have made important discoveries about objects in space (e.g., Galileo Galilei, Johannes Kepler, George Ellery Hale, Jill Tarter) or the development of technologies (e.g., various telescopes and detection devices, computer modeling, and space exploration).*
- 2.8.5** *Use informational text and other media to observe, describe and predict the visual patterns of motion of the Sun (sunrise, sunset) and Moon (phases).*
- 2.8.6** *Create a product that will demonstrate the observable pattern of motion of the Sun or Moon. Use an engineering design process to define the problem, design, construct, evaluate, and improve the product.**

GRADE TWO: Earth and Space Science

2.10 Earth's Resources

Conceptual Understanding: Earth is made of different materials, including rocks, sand, soil, and water. An Earth material is a resource that comes from Earth. Earth materials can be classified by their observable properties. Human life and health are heavily dependent on these materials. Understanding how to best conserve these resources will continue to be a major challenge for humans.

- 2.10** Students will demonstrate an understanding of how humans use Earth's resources.
- 2.10.1** *Analyze and interpret data from observations and measurements to compare the properties of Earth materials (including rocks, soils, sand, and water).*
- 2.10.2** *Conduct an investigation to identify and classify everyday objects that are resources from the Earth (e.g., drinking water, granite countertops, clay dishes, wood furniture, or gas grill).*
- 2.10.3** *Obtain and communicate information to summarize how earth materials are used in different ways (e.g., soil and water to grow plants; rocks to make roads, walls or buildings; or sand to make glass).*
- 2.10.4** *Obtain and communicate information to explain the process and consequences of soil erosion.*
- 2.10.5** *With teacher guidance, investigate possible solutions to prevent or repair soil erosion.*

GRADES 3-5 OVERVIEW

Upper elementary is a pivotal time to enhance students' scientific literacy and active engagement in science and engineering practices. Students use their experiences from structured investigations in kindergarten through Grade 2 to begin planning their own investigations to answer scientific questions. Because science foundations created at this level are key in developing students for college and career readiness, the cultivation of opportunities for inquiry-based activities and experiences that emphasize the problem solving and the engineering design process is critical.

The standards for Grades 3-5 have been developed around the following crosscutting concepts or themes:

- Grade 3 – Interactions Within an Environment
- Grade 4 – Energy and Change
- Grade 5 – Interdependence of Systems

In Grade 3, students are expected to engage in the engineering design process and conduct research and communicate their understanding of each standard in a variety of ways. In Grade 4, students will observe, research, and conduct investigations to discover patterns related to energy and change in the world around them. In Grade 5, students will model, provide evidence to support arguments, and obtain and display data about relationships among a variety of systems. Because of this yearlong study, students will gain content knowledge and tools to provide evidence and support arguments about the ways systems across content areas are interconnected and interdependent.

The core science content utilizes hands-on classroom instruction to reinforce the seven crosscutting concepts (i.e., patterns; cause and effect; scale, portion, and quantity; systems and system models; energy and matter; structure and function; and stability and change).

SEPs are in life science, physical science, and Earth and space science. The SEPs are designed so that students may develop skills and apply knowledge to solve real-life problems. While presented as distinct skill sets, the eight practices intentionally overlap and interconnect as students explore the science concepts. Some examples of specific skills students should develop in Grades 3-5 are listed below.

1. Ask questions to predict how natural or man-made changes in a habitat cause plants and animals to respond in different ways, including hibernating, migrating, responding to light, death, or extinction (e.g., sea turtles, the dodo bird, or nocturnal species).
2. Develop and use models to explain the unique and diverse life cycles of organisms other than humans (e.g., flowering plants, frogs, or butterflies) including commonalities (e.g., birth, growth, reproduction, or death).
3. Plan and conduct scientific investigations to classify different materials as either an insulator or conductor of electricity.
4. Analyze and interpret data to describe and predict how natural processes (e.g., weathering, erosion, deposition, earthquakes, tsunamis, hurricanes, or storms) affect Earth's surface.
5. Collect, analyze, and interpret data from measurements of the physical properties of matter including solid, liquid, and gas (volume, shape, movement, and spacing of particles).
6. Construct explanations about regional climate differences using maps and long-term data from various regions.
7. Construct scientific arguments to support claims about the importance of astronomy in navigation and exploration, including the use of telescopes, compasses, and star charts.

8. Obtain and evaluate scientific information regarding the characteristics of different ecosystems and the organisms they support (e.g., salt and fresh water, deserts, grasslands, forests, rain forests, or polar tundra lands).

Curricula and instructions that integrate science and engineering practices should reflect the skills outlined above.

The Engineering Design Process (EDP) is a step-by-step method of devising a system, component, or process to meet desired needs. This is similar to the “scientific method” which is taught to young scientists. However, the EDP is a flexible process. Students can begin at any step, focus on just one step, move back and forth between steps, or repeat the cycle. Engineering standards are represented in some performance objectives with grade-banded, specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.** Professional development and teacher resources will be developed for teachers as EDP is incorporated into Mississippi standards.

Each standard in Grades 3, 4, and 5 allows students to be active doers of science rather than passive observers of science. This approach creates an opportunity for student learning and engages the pupil in the scientific investigation process. Therefore, students need to be supplied with the appropriate resources and materials to complete scientific investigations.

GRADE THREE

Theme: Interactions within an Environment

In Grade 3, students will increase their use of science and engineering practices for obtaining, recording, charting, and analyzing data in the study of a variety of environments. The crosscutting concept can be seen in life science through an organism's ability to grow, develop, survive, obtain food/energy, and reproduce within a given environment. In physical science, the concept is developed through a study of matter and its properties and their interactions based on environmental changes and surroundings. The study of Earth science in third grade investigates surface features affected by one or more of Earth's spheres and human impacts on the environment. Students are expected to engage in the engineering design process and conduct research and communicate their understanding of each standard in a variety of ways. Because of this yearlong study, students will gain content knowledge and tools to provide evidence and support arguments about the ways matter and organisms interact and are affected by the environment.

GRADE THREE: Life Science

3.1 Hierarchical Organization

Conceptual Understanding: Plants and animals have physical characteristics and features that allow them to receive information from the environment. Structural adaptations within groups of plants and animals allow them to better survive and reproduce in an environment.

3.1 Students will demonstrate an understanding of internal and external structures in animals and how they relate to their growth, survival, behavior, and reproduction within an environment.

3.1.1 *Examine evidence to communicate information that the internal and external structures of animals (e.g., heart, stomach, bone, lung, brain, skin, ears, appendages) function to support survival, growth, behavior, and reproduction.*

3.1.2 *Examine evidence to communicate information that the internal and external structures of plant (e.g., thorns, leaves, stems, roots, or colored petals) function to support survival, growth, behavior, and reproduction.*

3.1.3 *Obtain and communicate examples of physical features or behaviors of vertebrates and invertebrates and how these characteristics help them survive in particular environments, (e.g., animals hibernate, migrate, or estivate to stay alive when food is scarce or temperatures are not favorable).*

GRADE THREE: Life Science

3.2 Reproduction and Heredity

Conceptual Understanding: Scientists have identified and classified many types of plants and animals. Some characteristics and traits that organisms have are inherited, and some result from interactions with the environment.

3.2 Students will demonstrate an understanding that through reproduction, the survival and physical features of plants and animals are inherited traits from parents but can also be influenced by the environment.

- 3.2.1 *Identify traits and describe how traits are passed from parent(s) to offspring in plants and animals.*
- 3.2.2 *Describe and provide examples of plant and animal offspring from a single parent (e.g., bamboo, fern, or starfish) as being an exact replica with identical traits as the parent.*
- 3.2.3 *Describe and provide examples of offspring from two parents as containing a combination of inherited traits from both parents.*
- 3.2.4 *Obtain and communicate data to provide evidence that plants and animals have traits inherited from parents and that variations of these traits exist in groups of similar organisms (e.g., flower colors in pea plants or fur color and pattern in animal offspring).*
- 3.2.5 *Research to justify the concept that traits can be influenced by the environment (e.g., stunted growth in normally tall plants due to insufficient water, changes in an arctic fox's fur color due to light and/or temperature, or flamingo plumage).*

GRADE THREE: Life Science

3.4 Adaptations and Diversity

Conceptual Understanding: When the environment or habitat changes, some plants and animals survive and reproduce, some move to new locations, and some die. Scientists can obtain historical information from fossils to provide evidence of both the organism and environments in which they lived.

- 3.4 **Students will demonstrate an understanding of how adaptations allow animals to satisfy life needs and respond both physically and behaviorally to their environment.**
- 3.4.1 *Obtain data from informational text to explain how changes in habitats (both those that occur naturally and those caused by organisms) can be beneficial or harmful to the organisms that live there.*
- 3.4.2 *Ask questions to predict how natural or man-made changes in a habitat cause plants and animals to respond in different ways, including hibernating, migrating, responding to light, death, or extinction (e.g., sea turtles, the dodo bird, or nocturnal species).*
- 3.4.3 *Analyze and interpret data to explain how variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing (e.g., plants with larger thorns being less likely to be eaten by predators or animals with better camouflage colorations being more likely to survive and bear offspring).*
- 3.4.4 *Define and improve a solution to a problem created by environmental changes and any resulting impacts on the types of density and distribution of plant and animal populations living in the environment (e.g., replanting sea oats in coastal areas or developing or preserving wildlife corridors and green belts). Use an engineering design process to define the problem, design, construct, evaluate, and improve the environment.**
- 3.4.5 *Construct scientific argument using evidence from fossils of plants and animals that lived long ago to infer the characteristics of early environments (e.g., marine fossils on dry land, tropical plant fossils in arctic areas, or fossils of extinct organisms in any environment).*

GRADE THREE: Physical Science

3.5 Organization of Matter and Chemical Interactions

Conceptual Understanding: Matter is made up of particles that are too small to be seen. Even though the particles are very small, the movement and spacing of these particles determine the basic properties of matter. Matter exists in several different states and is classified based on observable and measurable properties. Matter can be changed from one state to another when heat (i.e., thermal energy) is added or removed.

3.5 Students will demonstrate an understanding of the physical properties of matter to explain why matter can change states between a solid, liquid, or gas dependent upon the addition or removal of heat.

3.5.1 *Plan and conduct scientific investigations to determine how changes in heat (i.e., an increase or decrease) change matter from one state to another (e.g., melting, freezing, condensing, boiling, or evaporating).*

3.5.2 *Develop and use models to communicate the concept that matter is made of particles too small to be seen that move freely around in space (e.g., inflation and shape of a balloon, wind blowing leaves, or dust suspended in the air).*

3.5.3 *Plan and conduct investigations that particles speed up or slow down with addition or removal of heat.*

GRADE THREE: Physical Science

3.6 Motions, Forces, and Energy

Conceptual Understanding: Magnets are a specific type of solid that can attract and repel certain other kinds of materials, including other magnets. There are some materials that are neither attracted to nor repelled by magnets. Because of their special properties, magnets are used in various ways. Magnets can exert forces—a push or a pull—on other magnets or magnetic materials, causing energy transfer between them, even when the objects are not touching.

3.6 Students will demonstrate an understanding of magnets and the effects of pushes, pulls, and friction on the motion of objects.

3.6.1 *Compare and contrast the effects of different strengths and directions of forces on the motion of an object (e.g., gravity, polarity, attraction, repulsion, or strength).*

3.6.2 *Plan an experiment to investigate the relationship between a force applied to an object (e.g., friction, gravity) and resulting motion of the object.*

3.6.3 *Research and communicate information to explain how magnets are used in everyday life.*

3.6.4 *Define and solve a simple design problem by applying scientific ideas about magnets (e.g., can opener, door latches, paperclip holders, finding studs in walls, magnetized paint). Use an engineering design process to define the problem, design, construct, evaluate, and improve the magnet.**

GRADE THREE: Earth and Space Science

3.7 Earth's Structure and History

Conceptual Understanding: Since its formation, the Earth has undergone a great deal of geological change driven by its composition and systems. Scientists use many methods to learn more about the history and age of Earth. Earth materials include rocks, soils, water, and gases. Rock is composed of different combinations of minerals. Smaller rocks come from the breakage and weathering of bedrock and larger rocks. Soil is made partly from weathered rock, partly from plant remains, and contains many living organisms.

3.7A Students will demonstrate an understanding of the various processes involved in the rock cycle, superposition of rock layers, and fossil formation.

3.7A.1 *Plan and conduct controlled scientific investigations to identify the processes involved in forming the three major types of rock, and investigate common techniques used to identify them.*

3.7A.2 *Develop and use models to demonstrate the processes involved in the development of various rock formations, including superposition, and how those formations can fracture and move over time.*

3.7A.3 *Ask questions to generate testable hypotheses regarding the formation and location of fossil types, including their presence in some sedimentary rock.*

Conceptual Understanding: Earth has an active mantle, which interacts with the Earth's crust to drive plate tectonics and form new rocks. Resulting surface features change through interactions with water, air, and living things. Waves, wind, water, and ice shape and reshape the Earth's land surface by eroding rock and soil in some areas and depositing them in other areas. Scientists use many methods to learn more about the history and age of Earth.

3.7B Students will demonstrate an understanding of the composition of Earth and the processes which change Earth's landforms.

3.7B.1 *Obtain and evaluate scientific information (e.g. using technology) to describe the four major layers of Earth and the varying compositions of each layer.*

3.7B.2 *Develop and use models to describe the characteristics of Earth's continental landforms and classify landforms as volcanoes, mountains, valleys, canyons, planes, and islands.*

3.7B.3 *Develop and use models of weathering, erosion, and deposition processes which explain the appearance of various Earth features (e.g., the Grand Canyon, Arches National Park in Utah, Plymouth Bluff in Columbus, or Red Bluff in Marion County, Mississippi).*

3.7B.4 *Compare and contrast constructive (e.g., deposition, volcano) and destructive (e.g., weathering, erosion, earthquake) processes of the Earth.*

GRADE THREE: Earth and Space Science

3.9 Earth's Systems and Cycles

Conceptual Understanding: The Earth's land can be situated above or submerged below water. Water in the atmosphere changes states according to energy levels driven by the sun and its interactions with various Earth components, both living and non-living. The downhill movement of water as it flows to the ocean shapes the appearance of the land.

- 3.9** Students will demonstrate an understanding of how the Earth's systems (i.e., geosphere, hydrosphere, atmosphere, and biosphere) interact in multiple ways to affect Earth's surface materials and processes.
- 3.9.1** *Develop models to communicate the characteristics of the Earth's major systems, including the geosphere, hydrosphere, atmosphere, and biosphere.*
- 3.9.2** *Construct explanations of how different landforms and surface features result from the location and movement of water on Earth's surface (e.g., watersheds, drainage basins, deltas, or rivers).*
- 3.9.3** *Use graphical representations to communicate the distribution of freshwater and saltwater on Earth (e.g., oceans, lakes, rivers, glaciers, groundwater, or polar ice caps).*

GRADE THREE: Earth and Space Science

3.10 Earth's Resources

Conceptual Understanding: Earth is made of materials that provide resources for human activities, and their use affects the environment in multiple ways. Some resources are renewable and others are not.

- 3.10** Students will demonstrate an understanding that all materials, energy, and fuels that humans use are derived from natural sources.
- 3.10.1** *Identify some of Earth's resources that are used in everyday life such as water, wind, soil, forests, oil, natural gas, and minerals and classify as renewable or nonrenewable.*
- 3.10.2** *Obtain and communicate information to exemplify how humans attain, use, and protect renewable and nonrenewable Earth resources.*
- 3.10.3** *Use maps and historical information to identify natural resources in the state connecting (a) how resources are used for human needs and (b) how the use of those resources impacts the environment.*
- 3.10.4** *Design a process for cleaning a polluted environment (e.g., simulating an oil spill in the ocean or a flood in a city and creating a solution for containment and/or cleanup). Use an engineering design process to define the problem, design, construct, evaluate, and improve the environment.**

GRADE FOUR

Theme: Energy and Systems

In Grade 4, students will observe, research, and conduct investigations to discover patterns related to energy and change in the world around them. The crosscutting concept can be seen in life science through the study of human body systems, including their functions, interactions, and reliance upon other systems within the body. In physical science, the concept is developed through a study of energy in the forms of heat, light, sound, and electricity, as well as the conservation and transfer of energy from one form to another. The study of Earth science in fourth grade investigates the driving force of energy as it relates to the water cycle and changes in patterns of weather and climate. Students are expected to engage in engineering design practices, conduct research, and communicate their understanding of each standard in a variety of ways. Because of this yearlong study, students will gain research and process skills to build content knowledge that will support arguments about the ways energy and change relate to the world around us.

GRADE FOUR: Life Science

4.1 Hierarchical Organization

Conceptual Understanding: All organisms need energy for growth and development. Animals have specialized structures and systems for obtaining and processing energy. These structures and systems cannot function properly without adequate nourishment. Living organisms can be adversely affected by environmental conditions or disease.

4.1 Students will demonstrate an understanding of the organization, functions, and interconnections of the major human body systems.

- 4.1.1** *Use technology or other resources to research and discover general system function (e.g., machines, water cycle) as they relate to human organ systems and identify organs that work together to create organ systems.*
- 4.1.2** *Obtain and communicate data to describe patterns that indicate the nature of relationships between human organ systems, which interact with one another to control digestion, respiration, circulation, excretion, movement, coordination, and protection from infection.*
- 4.1.3** *Construct models of organ systems (e.g. circulatory, digestive, respiratory, muscular, skeletal, nervous) to demonstrate both the unique function of the system and how multiple organs and organ systems work together to accomplish more complex functions.*
- 4.1.4** *Research and communicate how noninfectious diseases (e.g. diabetes, heart disease) and infectious diseases (e.g. cold, flu) serve to disrupt the function of the body system.*
- 4.1.5** *Using informational text, investigate how scientific fields, medical specialties, and research methods help us find new ways to maintain a healthy body and lifestyle (e.g. diet, exercise, vaccines, and mental health).*

GRADE FOUR: Life Science

4.2 Reproduction and Heredity

Conceptual Understanding: Scientists have identified and classified many types of plants and animals. Each plant or animal has a unique pattern of growth and development called a life cycle. All of Earth's cycles are driven by energy which can be traced back to the sun.

4.2 Students will demonstrate an understanding of life cycles, including familiar plants and animals (e.g., reptiles, amphibians, or birds).

4.2.1 Compare and contrast life cycles of familiar plants and animals.

4.2.2 Develop and use models to explain the unique and diverse life cycles of organisms other than humans (e.g., flowering plants, frogs, or butterflies) including commonalities (e.g., birth, growth, reproduction, or death).

GRADE FOUR: Physical Science

4.6 Motions, Forces, and Energy

Conceptual Understanding: As different forms of energy, heat and electricity can be produced in different ways and are transferred and conducted from one form or object to another. Some materials can be conductors or insulators of heat energy. Electricity can be transferred from place to place by electric currents to produce motion, sound, heat, or light.

4.6A Students will demonstrate an understanding of the common sources and uses of heat and electric energy and the materials used to transfer heat and electricity.

4.6A.1 Obtain and communicate information to compare how different processes (including burning, friction, and electricity) serve as sources of heat energy.

4.6A.2 Plan and conduct scientific investigations to classify different materials as either an insulator or conductor of electricity.

4.6A.3 Develop models demonstrating how heat and electrical energy can be transformed into other forms of energy (e.g., motion, sound, heat, or light).

4.6A.4 Develop models that demonstrate the path of an electric current in a complete, simple circuit (e.g., lighting a light bulb or making a sound).

4.6A.5 Use informational text and technology resources to communicate technological breakthroughs made by historical figures in electricity (e.g. Alessandro Volta, Michael Faraday, Nicola Tesla, Thomas Edison, incandescent light bulbs, batteries, Light Emitting Diodes).

4.6A.6 Design a device that converts any form of energy from one form to another form (e.g., construct a musical instrument that will convert vibrations to sound by controlling varying pitches, a solar oven that will convert energy from the sun to heat energy, or a simple circuit that can be used to complete a task). Use an engineering design process to define the problem, design, construct, evaluate, and improve the device.*

Conceptual Understanding: Light, as a form of energy, has specific properties, including brightness. Light travels in a straight line until it strikes an object. The way light behaves when it strikes an object depends on the object's properties.

4.6B Students will demonstrate an understanding of the properties of light as forms of energy.

4.6B.1 Construct scientific evidence to support the claim that white light is made up of different colors. Include the work of Sir Isaac Newton to communicate results.

4.6B.2 Obtain and communicate information to explain how the visibility of an object is related to light.

- 4.6B.3** *Develop and use models to communicate how light travels and behaves when it strikes an object, including reflection, refraction, and absorption.*
- 4.6B.4** *Plan and conduct scientific investigations to explain how light behaves when it strikes transparent, translucent, and opaque materials.*

Conceptual Understanding: Sound, as a form of energy, is produced by vibrating objects (matter) and has specific properties, including pitch and volume. Sound travels through air and other materials and is used to communicate information in various forms of technology.

4.6C **Students will demonstrate an understanding of the properties of sound as a form of energy.**

- 4.6C.1** *Plan and conduct scientific investigations to test how different variables affect the properties of sound (i.e., pitch and volume).*
- 4.6C.2** *In relation to how sound is perceived by humans, analyze and interpret data from observations and measurements to report how changes in vibration affect the pitch and volume of sound.*
- 4.6C.3** *Obtain and communicate information about scientists who pioneered in the science of sound, (e.g., Alexander Graham Bell, Robert Boyle, Daniel Bernoulli, and Guglielmo Marconi).*

GRADE FOUR: Earth and Space Science

4.9 Earth's Systems and Cycles

Conceptual Understanding: Earth's atmosphere is a mixture of gases, including water vapor and oxygen. Water, which is found almost everywhere on Earth, including the atmosphere, changes form and cycles between Earth's surface to the air and back again. This cycling of water is driven by energy from the sun. The movement of water in the water cycle is a major process that influences weather conditions. Clouds form during this cycle and various types of precipitation result.

4.9A **Students will demonstrate an understanding of how the water cycle is propelled by the sun's energy.**

- 4.9A.1** *Develop and use models to explain how the sun's energy drives the water cycle. (e.g., evaporation, condensation, precipitation, transpiration, runoff, and groundwater).*

Conceptual Understanding: Scientists record patterns in weather conditions over time and across the globe to make predictions about what kind of weather might occur next. Climate describes the range of an area's typical weather conditions and the extent to which those conditions vary over long periods of time.

4.9B **Students will demonstrate an understanding of weather and climate patterns.**

- 4.9B.1** *Analyze and interpret data (e.g., temperature, precipitation, wind speed/direction, relative humidity, or cloud types) to predict changes in weather over time.*
- 4.9B.2** *Construct explanations about regional climate differences using maps and long-term data from various regions.*
- 4.9B.3** *Design weather instruments utilized to measure weather conditions (e.g., barometer, hygrometer, rain gauge, anemometer, or wind vane). Use an engineering design process to define the problem, design, construct, evaluate, and improve the weather instrument.**

Conceptual Understanding: Earth’s oceans and landforms can be affected in various ways by natural processes in one or more of Earth’s spheres (i.e., atmosphere, biosphere, geosphere, and hydrosphere). Humans cannot eliminate natural hazards caused by these processes but can take steps to reduce their impacts. Human activities can affect the land and oceans in positive and negative ways.

4.9C Students will demonstrate an understanding of how natural processes and human activities affect the features of Earth’s landforms and oceans.

4.9C.1 *Analyze and interpret data to describe and predict how natural processes (e.g., weathering, erosion, deposition, earthquakes, tsunamis, hurricanes, or storms) affect Earth’s surface.*

4.9C.2 *Develop and use models to explain the effect of the movement of water on the ocean shore zone, including beaches, barrier islands, estuaries, and inlets.*

4.9C.3 *Construct scientific arguments from evidence to support claims that human activities, such as conservation efforts or pollution, affect the land, oceans, and atmosphere of Earth.*

4.9C.4 *Research and explain how systems (i.e., the atmosphere, geosphere, and/or hydrosphere), interact and support life in the biosphere.*

4.9C.5 *Obtain and communicate information about severe weather phenomena (e.g., thunderstorms, hurricanes, or tornadoes) to explain steps humans can take to reduce the impact of severe weather events.*

GRADE FOUR: Earth and Space Science

4.10 Earth’s Resources

Conceptual Understanding: Energy and fuels are derived from natural sources and human use of these materials affects the environment in multiple ways. Due to limited natural resources, humans are exploring the use of abundant solar, water, wind, and geothermal energy resources to develop innovative, high-tech renewable energy systems.

4.10 Students will demonstrate an understanding of the various sources of energy used for human needs along with their effectiveness and possible impacts.

4.10.1 *Organize simple data sets to compare energy and pollution output of various traditional, non-renewable resources (e.g. coal, crude oil, wood).*

4.10.2 *Use technology or informational text to investigate, evaluate, and communicate various forms of clean energy generation.*

GRADE FIVE

Theme: Interdependence of Systems

In Grade 5, students will model processes, provide evidence to support arguments, and obtain and display data about relationships among a variety of systems. The crosscutting concept can be seen in life science through the transfer of energy from the sun into all parts of a food web and ecosystem. In physical science, the concept is developed through a study of matter and an examination of forces and motion through the lens of gravity's effect on an object. The study of Earth and space science in fifth grade investigates the Earth in the universe, relationships between the bodies of our solar system, and human interaction with the Earth. Students are expected to engage in the engineering design process and conduct research to communicate their understanding of each standard in a variety of ways. Because of this yearlong study, students will gain content knowledge and tools to provide evidence and support arguments about the ways systems across content areas are interconnected and interdependent.

GRADE FIVE: Life Science

5.3 Ecology and Interdependence

Conceptual Understanding: All organisms need energy to live and grow. Energy is obtained from the sun. Cells transform the energy that organisms need to perform essential life functions through a complex sequence of reactions in which chemical energy is transferred from one system of interacting molecules to another.

5.3A Students will demonstrate an understanding of photosynthesis and the transfer of energy from the sun into chemical energy necessary for plant growth and survival.

5.3A.1 *Research and communicate the basic process of photosynthesis that is used by plants to convert light energy into chemical energy that can be stored and released to fuel an organism's activities.*

5.3A.2 *Analyze environments that do not receive direct sunlight and devise explanations as to how photosynthesis occurs, either naturally or artificially.*

Conceptual Understanding: A major role an organism serves in an ecosystem can be described by the way in which it obtains its energy. Energy is transferred within an ecosystem by producers, consumers, or decomposers. A healthy ecosystem is one in which a diverse population of life forms can meet their needs in a relatively stable web of life.

5.3B Students will demonstrate an understanding of a healthy ecosystem with a stable web of life and the roles of living things within a food chain and/or food web, including producers, primary and secondary consumers, and decomposers.

5.3B.1 *Obtain and evaluate scientific information regarding the characteristics of different ecosystems and the organisms they support (e.g., salt and fresh water, deserts, grasslands, forests, rain forests, or polar tundra lands).*

5.3B.2 *Develop and use a food chain model to classify organisms as producers, consumers, or decomposers. Trace the energy flow to explain how each group of organisms obtains energy.*

- 5.3B.3** *Design and interpret models of food webs to justify what effects the removal or the addition of a species (i.e., introduced or invasive) would have on a specific population and/or the ecosystem as a whole.*
- 5.3B.4** *Communicate scientific or technical information that explains human positions in food webs and our potential impacts on these systems.*

GRADE FIVE: Physical Science

5.5 Organization of Matter and Chemical Interactions

Conceptual Understanding: Matter can be segregated into tiny particles that are too small to see, but can be detected by other methods. These tiny particles are referred to as atoms, which can be combined to form molecules. Substances of the same type exhibit specific properties that can be observed and measured.

5.5A Students will demonstrate an understanding of the physical properties of matter.

- 5.5A.1** *Obtain and evaluate scientific information to describe basic physical qualities of atoms and molecules.*
- 5.5A.2** *Collect, analyze, and interpret data from measurements of the physical properties of matter including solid, liquid, and gas (volume, shape, movement, and spacing of particles).*

Conceptual Understanding: Substances of the same type can be classified by their similar, observable properties. Substances can be combined in a variety of ways. A mixture is formed when two or more kinds of matter are physically combined. Solutions are a special type of mixture in which one substance is distributed evenly into another substance. When the physical properties of the components in a mixture are not changed, they can be separated in different physical ways.

5.5B Students will demonstrate an understanding of mixtures and solutions.

- 5.5B.1** *Analyze matter through observations and measurements to classify materials (e.g., powders, metals, minerals, or liquids) based on their properties (e.g., color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, solubility, or density).*
- 5.5B.2** *Obtain and evaluate scientific information to describe what happens to the properties of substances in mixtures and solutions.*
- 5.5B.3** *Analyze and interpret data to communicate that the concentration of a solution is determined by the relative amount of solute versus solvent in various mixtures.*
- 5.5B.4** *Investigate how different variables (e.g., temperature change, stirring, particle size, or surface area) affect the rate at which a solute will dissolve.*
- 5.5B.5** *Design an effective system (e.g., sifting, filtration, evaporation, magnetic attraction, or floatation) for separating various mixtures. Use an engineering design process to define the problem, design, construct, evaluate, and improve the system.**
- 5.5B.6** *Make and test predictions about how the density of an object affects whether the object sinks or floats when placed in a liquid.*
- 5.5B.7** *Design a vessel that can safely transport a dense substance (e.g., honey or maple syrup) through water at various distances and under variable conditions. Use an engineering design process to define the problem, design, construct, evaluate, and improve the vessel.**

Conceptual Understanding: Physical properties can be observed and measured without changing the composition of matter. A physical change occurs when the matter's physical appearance is altered while leaving the composition of the matter unchanged. When two or more substances are mixed together, a new substance with different properties can sometimes be formed, but the total amount (i.e., mass) of the substances is conserved (i.e., total mass stays the same). In a chemical change, the composition of the original matter is altered to create a new substance. A different compound is present at the completion of the chemical change.

5.5C Students will demonstrate an understanding of the difference between physical and chemical changes.

5.5C.1 *Analyze and communicate the results of chemical changes that result in the formation of new materials (e.g., decaying, burning, rusting, or cooking).*

5.5C.2 *Analyze and communicate the results of physical changes to a substance that results in a reversible change (e.g., changes in states of matter with the addition or removal of energy, changes in size or shape, or combining/separating mixtures or solutions).*

5.5C.3 *Analyze and interpret data to support claims that when two substances are mixed, the total weight of matter is conserved.*

GRADE FIVE: Physical Science

5.6 Motions, Forces, and Energy

Conceptual Understanding: Gravity is a force that draws objects to Earth. This force acting on an object near Earth's surface pulls that object toward the planet's center. The motion of an object can be described in terms of its position, direction, and speed. Multiple factors determine the rate and motion of an object. Other than Earth, any celestial objects will exert varying gravitational pulls on other objects according to their mass and density.

5.6 Students will demonstrate an understanding of the factors that affect the motion of an object.

5.6.1 *Obtain and communicate information describing gravity's effect on an object.*

5.6.2 *Predict the future motion of various objects based on past observation and measurement of position, direction, and speed.*

5.6.3 *Develop and use models to explain how the amount or type of force, both contact and non-contact, affects the motion of an object.*

5.6.4 *Plan and conduct scientific investigations to test the effects of balanced and unbalanced forces on the speed and/or direction of objects in motion.*

5.6.5 *Predict how a change of force, mass, and/or friction affects the motion of an object to convert potential energy into kinetic energy.*

5.6.7 *Design a system to increase the effects of friction on the motion of an object (e.g., non-slip surfaces or vehicle braking systems or flaps on aircraft wings). Use an engineering design process to define the problem, design, construct, evaluate, and improve the system.**

GRADE FIVE: Earth and Space Science

5.8 Earth and the Universe

Conceptual Understanding: Astronomy is the study of celestial objects in our solar system and beyond. A solar system includes one or more suns (stars) and all other objects orbiting in that system. Planets in our night sky change positions and are not always visible from Earth as they orbit our sun. Stars that can be seen in the night sky lie beyond our solar system and appear in patterns called constellations. Constellations can be used for navigation and appear to move together across the sky because of Earth's rotation and revolution around the sun.

5.8A Students will demonstrate an understanding of the locations of objects in the solar system.

5.8A.1 *Develop and use scaled models of Earth's solar system to demonstrate the size, composition (i.e., rock or gas), location, and order of the planets as they orbit the Sun.*

5.8A.2 *Use evidence to argue why the sun appears brighter than other stars.*

5.8A.3 *Describe how constellations appear to move from Earth's perspective throughout the seasons (e.g., Ursa Major, Ursa Minor, and Orion).*

5.8A.4 *Construct scientific arguments to support claims about the importance of astronomy in navigation and exploration, including the use of telescopes, compasses, and star charts.*

Conceptual Understanding: Earth orbits around the sun as the moon orbits around Earth. The revolution and rotation of Earth on a tilted axis provide evidence of patterns that can be observed, studied, and predicted.

5.8B Students will demonstrate an understanding of the principles that govern moon phases, day and night, appearance of objects in the sky, and seasonal changes.

5.8B.1 *Analyze and interpret data from observations and research (e.g., from NASA, NOAA, or the USGS) to explain patterns in the location, movement, and appearance of the moon throughout a month and over the course of a year.*

5.8B.2 *Develop and use a model of the Earth-Sun-Moon system to analyze the cyclic patterns of lunar phases, solar and lunar eclipses, and seasons.*

5.8B.3 *Develop and use models to explain the factors (e.g., tilt, revolution, and angle of sunlight) that result in Earth's seasonal changes.*

5.8B.4 *Obtain information and analyze how our understanding of the solar system has evolved over time (e.g., Earth-centered model of Aristotle and Ptolemy compared to the Sun-centered model of Copernicus and Galileo).*

GRADE FIVE: Earth and Space Science

5.10 Earth's Resources

Conceptual Understanding: Human activities can impact natural processes and availability of resources. To reduce impacts on the environment (including humans), various best practices can be used. New and improved conservation practices are constantly being developed and tested.

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- 5.10** Students will demonstrate an understanding of the effects of human interaction with Earth and how Earth’s natural resources can be protected and conserved.
- 5.10.1** *Collect and organize scientific ideas that individuals and communities can use to conserve Earth’s natural resources and systems (e.g., implementing watershed management practices to conserve water resources, utilizing no-till farming to improve soil fertility, reducing emissions to abate air pollution, or recycling to reduce landfill waste).*
- 5.10.2** *Design a process for better preparing communities to withstand manmade or natural disasters (e.g., removing oil from water or soil, systems that reduce the impact of floods, structures that resist hurricane forces). Use an engineering design process to define the problem, design, construct, evaluate, and improve the disaster plan.**

GRADES 6-8 OVERVIEW

Critical to middle school students is the foundation needed to be successful in high school science. In Grades 6-8, students use an integrated science curriculum to develop and plan controlled investigations and create more explicit and detailed models and explanations. Students must have opportunities to develop the skills necessary to engage in scientific and technical reasoning that are necessary for success in college, careers, and citizenship.

As a result of using an integrated science model, the development of themes for each grade became necessary to assure continuity of thought processes.

- Grade 6 – Structure and Function
- Grade 7 – Systems and Cycles
- Grade 8 – Cause and Effect

In Grade 6, students need more tangible concepts, but by Grade 8, the complexity of the content increases to abstract cause and effect relationships. Explaining patterns and making predictions based on an understanding of cause and effect allows students to conceptualize and describe the relationships among natural phenomena. By building complexity into the standards, student skill sets are further strengthened as they prepare for high school courses.

The core science content utilizes hands-on classroom instruction to reinforce the seven crosscutting concepts (i.e., patterns; cause and effect; scale, portion, and quantity; systems and system models; energy and matter; structure and function; and stability and change).

SEPs are in life science, physical science, and Earth and space science. The SEPs are designed so that students may develop skills and apply knowledge to solve real-life problems. While presented as distinct skill sets, the eight practices intentionally overlap and interconnect as students explore the science concepts. Some examples of specific skills students should develop in Grades 6-8 are listed below.

1. Ask questions to explain how density of matter (observable in various objects) is affected by a change in heat and/or pressure.
2. Develop and use models to show relationships among the increasing complexity of multicellular organisms (cells, tissues, organs, organ systems, organisms) and how they serve the needs of the organism.
3. Conduct simple investigations about the performance of waves to describe their behavior (e.g., refraction, reflection, transmission, and absorption) as they interact with various materials (e.g., lenses, mirrors, and prisms).
4. Analyze and interpret data to explain how the processes of photosynthesis, cellular respiration, and transpiration work together to meet the needs of plants and animals.
5. Use mathematical computation and diagrams to calculate the sum of forces acting on various objects.
6. Construct an explanation for how climate is determined in an area using global and surface features (e.g. latitude, elevation, shape of the land, distance from water, global winds, and ocean currents).
7. Engage in scientific argument based on current evidence to determine whether climate change happens naturally or is being accelerated through the influence of man.
8. Obtain and evaluate scientific information to explain the relationship between seeing color and the transmission, absorption, or reflection of light waves by various materials.

Curricula and instructions that integrate science and engineering practices should reflect the skills outlined above.

The Engineering Design Process (EDP) is a step-by-step method of devising a system, component, or process to meet desired needs. This is similar to the “scientific method” which is taught to young scientists. However, the EDP is a flexible process. Students can begin at any step, focus on just one step, move back and forth between steps, or repeat the cycle. Engineering standards are represented in some performance objectives with grade-banded, specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.** Professional development and teacher resources will be developed for teachers as EDP is incorporated into Mississippi standards.

The use of science and engineering practices and crosscutting concepts will actively engage students in science, building on their natural curiosity and encouraging further study in science and engineering fields. As science also requires the ability to think and reason, students will therefore also develop the skills necessary to be successful in college, career, and society.

GRADE SIX

Theme: Structure and Function

Grade 6 students need concrete opportunities to engage with natural phenomena. The integration of Earth and space, life, and physical sciences gives students many opportunities to explore the relationship of structure and function in the world around them. By analyzing the macro- and microscopic world, the role of cells in life functions, the interdependence in ecosystems, the diversity of life on Earth, the relationship between force and motion, and the organization and interactions of objects in the universe, Grade 6 students can make claims and provide evidence about structure-function relationships in different scientific domains.

GRADE SIX: Life Science

6.1 Hierarchical Organization

Conceptual Understanding: Living things are distinguished from nonliving things by several characteristics. All living things are comprised of one (unicellular) or more (multicellular) cells, which are the smallest units of life. Cells carry out life functions and undergo cell division using specialized structures that allow them to acquire energy and water, grow, reproduce, dispose of waste, and survive. Multicellular organisms are organized in a hierarchy of increasing complexity with related, specialized structures and functions.

6.1 Students will demonstrate an understanding that living things range from simple to complex organisms, are organized hierarchically, and function as whole living systems.

6.1.1 *Use argument supported by evidence in order to distinguish between living and non-living things, including viruses and bacteria.*

6.1.2 *Obtain and communicate evidence to construct logical arguments in support of the cell theory.*

6.1.3 *Develop and use models to explain how specific cellular components (cell wall, cell membrane, nucleus, chloroplast, vacuole, and mitochondria) function together to support the life of plants, animals, fungi, protists, and bacteria.*

6.1.4 *Compare and contrast different cells in order to classify them as protist, fungus, plant, or animal.*

6.1.5 *Provide evidence that organisms are unicellular or multicellular.*

6.1.6 *Develop and use models to show relationships among the increasing complexity of multicellular organisms (cells, tissues, organs, organ systems, organisms) and how they serve the needs of the organism.*

GRADE SIX: Life Science

6.3 Ecology and Interdependence

Conceptual Understanding: All organisms depend on biotic and abiotic factors for survival. When any environmental factor changes, a corresponding change in diversity and population of organisms will also occur. The environment and the organism in which it lives are therefore interdependent.

6.3 Students will demonstrate an understanding of the relationships among survival, environmental changes, and diversity as they relate to the interactions of organisms, populations, and the environment.

- 6.3.1** *Use scientific reasoning to explain differences between biotic and abiotic factors that demonstrate what living organisms need to survive.*
- 6.3.2** *Develop and use models to describe the levels of organization within ecosystems (species, populations, communities, ecosystems, and biomes).*
- 6.3.3** *Analyze and interpret how an ecologist might determine cause and effect relationships to explore how changes in the physical environment (limiting factors, natural disasters) can lead to population changes within an ecosystem.*
- 6.3.4** *Investigate organism interactions in a competitive or mutually beneficial relationship (predation, competition, cooperation, or symbiotic relationships).*
- 6.3.5** *Develop and use simulation data (food chains, webs, and pyramids) to analyze how energy is conserved as it is transferred through an ecosystem from producers (autotrophs) to consumers (heterotrophs, including humans) to decomposers.*

GRADE SIX: Life Science

6.4 Adaptation and Diversity

Conceptual Understanding: Because living organisms are so diverse, scientists have created a system by which living things are organized into groups according to their characteristics (physical and/or genomic) for identification and research purposes. The kingdoms are very diverse but also have quite a bit in common. Organisms exhibit structural and behavioral characteristics such as adaptations, patterns of growth and development, and life cycles that increase their chances of reproduction and survival in a changing environment.

- 6.4** **Students will demonstrate an understanding of classification tools and models such as dichotomous keys to classify representative organisms based on the characteristics of the kingdoms: Archaeobacteria, Eubacteria, Protists, Fungi, Plants, and Animals.**
- 6.4.1** *Compare and contrast modern classification techniques to the historical practices used by scientists such as Aristotle and Carolus Linnaeus.*
- 6.4.2** *Use classification tools to explore the diversity of organisms in kingdoms (animals, plants, fungi, protists, bacteria). Support claims that organisms have shared structural and behavioral characteristics.*
- 6.4.3** *Analyze and interpret data from observations to describe how fungi obtain energy and respond to stimuli.*
- 6.4.4** *Conduct investigations to compare the characteristics of protists (euglena, paramecium, amoeba) and the methods they use to obtain energy and move through their environment.*
- 6.4.5** *Engage in scientific arguments to support claims that bacteria (Archaeobacteria and Eubacteria) and viruses can be both helpful and harmful to other organisms and the environment.*

GRADE SIX: Physical Science

6.6 Motions, Forces, and Energy

Conceptual Understanding: Newton's Laws describe forces and motion affecting substances in various environments and situations. Motion is determined by the amount of force applied. Focusing on magnetic, frictional, and gravitational forces will provide an understanding of the relationship between distance and contact forces.

- 6.6 Students will demonstrate an understanding of Newton’s laws of motion using real world models and examples.**
- 6.6.1** *Use an engineering design process to create or improve safety devices (e.g., seat belts, car seats, helmets) by applying Newton’s Laws of motion. Use an engineering design process to define the problem, design, construct, evaluate, and improve the safety device.**
- 6.6.2** *Use mathematical computation and diagrams to calculate the sum of forces acting on various objects.*
- 6.6.3** *Investigate and communicate ways to manipulate applied/frictional forces to improve movement of objects on various surfaces (e.g., athletic shoes, wheels on cars).*
- 6.6.4** *Compare and contrast magnetic (electromagnetic), electric, frictional, and gravitational forces.*
- 6.6.5** *Conduct investigations to predict and explain the motion of an object according to its position, direction, speed, and acceleration.*
- 6.6.6** *Investigate forces (gravity, friction, drag, lift, thrust) acting on objects (e.g., airplane, bicycle helmets). Use data to explain the differences between the forces in various environments.*
- 6.6.7** *Determine the relationships between the concepts of potential, kinetic, and thermal energy (e.g., William Rankine’s steam engine theory).*
- 6.6.8** *Develop a system to capture and distribute thermal energy that makes renewable energy more readily available and reduces human impact on the environment (e.g., building solar water heaters, conserving home energy). Use an engineering design process to define the problem, design, construct, evaluate, and improve the system.**

GRADE SIX: Earth and Space Science

6.8 Earth and the Universe

Conceptual Understanding: The hierarchical organization of the universe is the result of complex structure and function. Current theories suggest that time began with a period of extremely rapid expansion. Presently, Earth’s solar system consists of the Sun and other objects that are held in orbit by the Sun’s gravitational force. The interactions of the Earth, the Moon, and the Sun have effects that can be observed on Earth. Various technologies have aided in our understanding of Earth’s place in the universe.

- 6.8 Students will demonstrate an understanding of Earth’s place in the universe and the interactions of the solar system (sun, planets, their moons, comets, and asteroids) using evidence from multiple scientific resources to explain how these objects are held in orbit around the Sun because of its gravitational pull.**
- 6.8.1** *Obtain, evaluate, and summarize past and present theories and evidence to explain the formation and composition of the universe.*
- 6.8.2** *Use graphical displays or models to explain the hierarchical structure (stars, galaxies, galactic clusters) of the universe.*
- 6.8.3** *Evaluate modern techniques used to explore our solar system’s position in the universe.*
- 6.8.4** *Obtain and evaluate information to model and compare the characteristics and movements of objects in the solar system (including planets, moons, asteroids, comets, and meteors).*
- 6.8.5** *Use models to develop explanations that relate the seasons to Earth’s tilt as it orbits the Sun and how the angle of the Sun’s rays affect the amount of solar energy absorbed by Earth’s surface.*

- 6.8.6** *Construct explanations for how gravity affects the motion of objects in the solar system and tides on Earth.*
- 6.8.7** *Design models representing motions within the Sun-Earth-Moon system to explain phenomena observed from the Earth's surface (positions of celestial bodies, day and year, moon phases, solar and lunar eclipses, and tides).*
- 6.8.8** *Analyze and interpret data from the surface features of the Sun (e.g., photosphere, corona, sunspots, prominences, and solar flares) to predict how these features may affect Earth.*

GRADE SEVEN

Theme: Systems and Cycles

Students relate systems and cycles through analyzing various small scale and large scale phenomena. Using scientific methods, students can connect Earth's systems with the flow of energy in supporting living and nonliving organisms and specific interactions of matter. Students use multiple investigative methods to discover evidence, make claims, and generate explanations about systems and cycles that take place on Earth. A focus on organization and cycles of matter requires students to apply skills and make connections across genres of science since most complex cycles have multiple interactions.

GRADE SEVEN: Life Science

7.3 Ecology and Interdependence

Conceptual Understanding: Emphasis is on predicting consistent patterns of interactions among different cycling systems in terms of the relationships between organisms and abiotic components within ecosystems. Rearrangement of food molecules through chemical processes in cellular respiration and photosynthesis is an important part of energy cycling in all life systems. Preservation of biodiversity and consideration of human impacts are themes in maintaining ecosystem services.

7.3 Students will demonstrate an understanding of the importance that matter cycles between living and nonliving parts of the ecosystem to sustain life on Earth.

7.3.1 *Analyze diagrams to provide evidence of the importance of the cycling of water, oxygen, carbon, and nitrogen through organisms.*

7.3.2 *Analyze and interpret data to explain how the processes of photosynthesis, cellular respiration, and transpiration work together to meet the needs of plants and animals.*

7.3.3 *Develop and use models to describe how food molecules (carbohydrates, lipids, proteins) are processed through chemical reactions using oxygen (aerobic) to form new molecules.*

7.3.4 *Obtain and evaluate information to communicate that anaerobic bacteria do not require oxygen to achieve their energy needs.*

7.3.5 *Explain how disruptions in cycles affect biodiversity and ecosystem services such as water, food, and medications, which are needed to sustain human life on Earth.*

7.3.6 *Design solutions for sustaining the health of ecosystem services to maintain biodiversity and the resources needed by humans for survival (e.g., water purification, nutrient recycling, prevention of soil erosion, and prevention or management of invasive species).*

GRADE SEVEN: Physical Science

7.5 Organization of Matter and Chemical Interactions

Conceptual Understanding: Matter and its interactions can be distinguished by investigating physical properties (e.g., mass, density, solubility) using chemical processes and experimentation. Atoms are the basic building blocks of ordinary matter. New substances formed through the combination of atoms make gases, liquids, and solids interact in different ways according to heat and pressure. As these chemical combinations take place, substances react in various ways, yet matter is always conserved in a reaction.

7.5A Students will demonstrate an understanding of the physical and chemical properties of matter.

- 7.5A.1** *Collect and evaluate qualitative data to describe substances using physical properties (state, boiling/melting point, density, heat/electrical conductivity, color, and magnetic properties).*
- 7.5A.2** *Analyze and interpret qualitative data to describe substances using chemical properties (the ability to burn or rust).*
- 7.5A.3** *Compare and contrast chemical and physical properties (e.g., combustion, oxidation, pH, solubility, reaction with water).*

Conceptual Understanding: Gases, liquids, and solids are made of atoms and/or molecules that are in constant motion. In a liquid, the molecules are constantly in contact with each other; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and vibrate in position but do not change relative locations. The movement of the atoms and molecules depends on the amount of energy in the system at the time. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

7.5B Students will demonstrate an understanding about the effects of temperature and pressure on physical state, molecular motion, and molecular interactions.

- 7.5B.1** *Make predictions about the effect of temperature and pressure on the relative motion of molecules (speed, expansion, and condensation) relative to recent breakthroughs in polymer and materials science (e.g. self-healing protective films, silicone computer processors, pervious/porous concrete).*
- 7.5B.2** *Use evidence from multiple scientific investigations to communicate the proportional relationships between pressure, volume, density, and temperature of a gas.*
- 7.5B.3** *Ask questions to explain how density of matter (observable in various objects) is affected by a change in heat and/or pressure.*

Conceptual Understanding: All substances are composed of one or more elements. Elements are pure substances which contain only one kind of atom. The periodic table organizes these elements based on similar properties. Compounds are substances composed of two or more elements. Chemical formulas can be used to describe compounds.

7.5C Students will demonstrate an understanding of the proper use of the periodic table to predict and identify elemental properties and how elements interact.

- 7.5C.1** *Develop and use models that explain the structure of an atom.*
- 7.5C.2** *Use informational text to sequence the major discoveries leading to the current atomic model.*
- 7.5C.3** *Collect, organize, and interpret data from investigations to identify and analyze the relationships between the physical and chemical properties of elements, atoms, molecules, compounds, solutions, and mixtures.*
- 7.5C.4** *Predict the properties and interactions of given elements using the periodic table (metals, non-metals, reactivity, and conductors).*
- 7.5C.5** *Describe concepts used to construct chemical formulas (e.g. CH_4 , H_2O) to determine the number of atoms in a chemical formula.*
- 7.5C.6** *Using the periodic table, write logical arguments explaining how bonds (ionic and covalent) form between groups of elements (e.g. oxygen gas, ozone, water, table salt, and methane).*

Conceptual Understanding: Substances (such as metals or acids) are identified according to their physical or chemical properties. Changes to substances can either be physical or chemical. Many substances react chemically with other substances to form new substances with different properties. Some chemical reactions release energy and others store energy.

7.5D Students will demonstrate an understanding of chemical formulas and common chemical substances to predict the types of reactions and possible outcomes of the reactions.

7.5D.1 *Analyze evidence from a scientific investigation to predict likely outcomes of chemical reactions.*

7.5D.2 *Design and conduct scientific investigations to support evidence that chemical reactions (e.g., cooking, combustion, rusting, decomposition, photosynthesis, and cellular respiration) have occurred.*

7.5D.3 *Collect, organize, and interpret data using various tools regarding neutralization of acids and bases using common substances.*

7.5D.4 *Build a model to explain that chemical reactions can store (formation of bonds) or release energy (breaking of bonds).*

Conceptual Understanding: In a chemical process, the atoms that make up original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and the mass does not change.

7.5E Students will demonstrate an understanding of the law of conservation of mass.

7.5E.1 *Conduct simple scientific investigations to show that total mass is not altered during a chemical reaction in a closed system. Compare results of investigations to Antoine-Laurent Lavoisier's discovery of the law of conservation of mass.*

7.5E.2 *Analyze data from investigations to explain why the total mass of the product in an open system appears to be less than the mass of reactants.*

7.5E.3 *Compare and contrast balanced and unbalanced chemical equations to demonstrate the number of atoms does not change in the reaction.*

GRADE SEVEN: Earth and Space Science

7.9 Earth's Systems and Cycles

Conceptual Understanding: Complex patterns in the movement of air and water in the atmosphere are major determinants of local weather. Global movements of water and its changes in form are propelled by sunlight and gravity. Variations in temperature drive a global pattern of interconnected currents. Interactions between sunlight, oceans, atmosphere, ice, landforms, and living things vary with latitude, altitude, and local and regional geography. Weather is difficult to predict; however, large scale patterns and trends in global climate, such as the gradual increase in average temperature, are more easily observed and predicted.

7.9A Students will demonstrate an understanding of how complex changes in the movement and patterns of air and water molecules caused by the sun, winds, landforms, ocean temperatures, and currents in the atmosphere are major determinants of local and global weather patterns.

- 7.9A.1 *Analyze and interpret weather patterns from various regions to differentiate between weather and climate.*
- 7.9A.2 *Analyze evidence to explain the weather conditions that result from the relationship between the movement of water and air masses.*
- 7.9A.3 *Using methods utilized by climate scientists, interpret atmospheric data from satellites, radar, and weather maps to predict weather patterns and conditions.*
- 7.9A.4 *Construct an explanation for how climate is determined in an area using global and surface features (e.g. latitude, elevation, shape of the land, distance from water, global winds and ocean currents).*
- 7.9A.5 *Develop models to explain the cause and effect relationship between solar energy and convection and the resulting weather patterns and climate conditions.*
- 7.9A.6 *Research and use models to explain what type of weather (thunderstorms, hurricanes, and tornadoes) results from the movement and interactions of air masses, high and low pressure systems, and frontal boundaries.*
- 7.9A.7 *Interpret topographic maps to predict how local and regional geography affect weather patterns and make them difficult to predict.*

Conceptual Understanding: Climate changes are defined as significant and persistent changes in an area's average or extreme weather conditions. Changes can occur if any of Earth's systems change (e.g., composition of the atmosphere, reflectivity of Earth's surface). The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. Greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping it habitable. Excess greenhouse gases could cause a detrimental impact on climate over time.

7.9B Students will demonstrate an understanding of the relationship between natural phenomena, human activity, and global climate change.

- 7.9B.1 *Read and evaluate scientific or technical information assessing the evidence and bias of each source to explain the causes and effects of climate change.*
- 7.9B.2 *Interpret data about the relationship between the release of carbon dioxide from burning fossil fuels into the atmosphere and the presence of greenhouse gases.*
- 7.9B.3 *Engage in scientific argument based on current evidence to determine whether climate change happens naturally or is being accelerated through the influence of man.*

Conceptual Understanding: The tilt of Earth's spin axis with respect to the plane of its orbit around the sun is important for a habitable Earth. The Earth's spin axis is tilted 23.5 degrees. Earth's axis points in the same direction in space no matter where Earth is in relation to the sun. The seasons are a result of this tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

7.9C Students will demonstrate an understanding that the seasons are the direct result of the Earth's tilt and the intensity of sunlight on the Earth's hemispheres.

- 7.9C.1 *Construct models and diagrams to illustrate how the tilt of Earth's axis results in differences in intensity of sunlight on the Earth's hemispheres throughout the course of one full revolution around the Sun.*
- 7.9C.2 *Investigate how variations of sunlight intensity experienced by each hemisphere (to include the equator and poles) create the four seasons.*

GRADE EIGHT

Theme: Cause and Effect

Since causes of complex phenomena and systems are not always immediately or physically visible to students, the need to develop abstract thinking skills is a significant outcome for Grade 8. Explaining patterns and making predictions based on an understanding of cause and effect allows students to conceptualize and describe the relationships among natural phenomena. In Grade 8, some examples of the relationships include the role of genetics in reproduction and heredity, the biology that explains unity and diversity, the transfer of energy, the result of dynamic changes to the Earth's surface, and human impact on the biosphere.

GRADE EIGHT: Life Science

8.2 Reproduction and Heredity

Conceptual Understanding: The process of passing genetic information to offspring is inheritance. During sexual reproduction, genetic information is passed to offspring resulting in similarities and differences between parental organisms and their offspring. Individuals within a population are more similar than individuals from different populations.

8.2A Students will demonstrate an understanding of how sexual reproduction results in offspring with genetic variation while asexual reproduction results in offspring with identical genetic information.

8.2A.1 Obtain and communicate information about the relationship of genes, chromosomes, and DNA, and construct explanations comparing their relationship to inherited characteristics.

8.2A.2 Create a diagram of mitosis and explain its role in asexual reproduction, which results in offspring with identical genetic information.

8.2A.3 Construct explanations of how genetic information is transferred during meiosis.

8.2A.4 Engage in discussion using models and evidence to explain that sexual reproduction produces offspring that have a new combination of genetic information different from either parent.

Conceptual Understanding: Inheritance is the key process causing similarities between parental organisms and their offspring. Organisms that reproduce sexually transfer genetic information (DNA) to their offspring. This transfer of genetic information through inheritance leads to greater similarity among individuals within a population than between populations. Genetic changes can accumulate through natural selection or mutation that can lead to the evolution of species. Humans can manipulate genetic information using technology.

8.2B Students will demonstrate an understanding of the differences in inherited and acquired characteristics and how environmental factors (natural selection) and the use of technologies (selective breeding, genetic engineering) influence the transfer of genetic information.

8.2B.1 Construct an argument based on evidence for how environmental and genetic factors influence the growth of organisms.

8.2B.2 Use various scientific resources to research and support the historical findings of Gregor Mendel to explain the basic principles of heredity.

- 8.2B.3** *Use mathematical and computational thinking to analyze data and make predictions about the outcome of specific genetic crosses (monohybrid Punnett Squares) involving simple dominant/recessive traits.*
- 8.2B.4** *Debate the ethics of artificial selection (selective breeding, genetic engineering) and the societal impacts of humans changing the inheritance of desired traits in organisms.*

Conceptual Understanding: Genes are located on the chromosomes of cells, with each chromosome pair containing two variations of each distinct gene. Each distinct gene chiefly controls the production of a specific protein, which in turn affects the traits of the individual. Changes (mutations) in genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

8.2C **Students will demonstrate an understanding that chromosomes contain many distinct genes and that each gene holds the instructions for the production of a specific protein, which in turn affects the traits of an individual.**

- 8.2C.1** *Communicate through diagrams that chromosomes contain many distinct genes and that each gene holds the instructions for the production of specific proteins, which in turn affects the traits of the individual.*
- 8.2C.2** *Construct scientific arguments from evidence to support claims about the potentially harmful, beneficial, or neutral effects of genetic mutations on organisms.*

GRADE EIGHT: Life Science

8.4 Adaptation and Diversity

Conceptual Understanding: The scientific theory of evolution underlies the study of biology and provides an explanation for both the diversity of life on Earth and similarities of all organisms at the chemical, cellular, and molecular level. Multiple forms of scientific evidence support evolution. Adaptations are physical or behavioral changes that are inherited and enhance the ability of an organism to survive and reproduce in a particular environment:

- 8.4A** **Students will demonstrate an understanding of the process of natural selection, in which variations in a population increase some individuals' likelihood of surviving and reproducing in a changing environment.**
- 8.4A.1** *Use various scientific resources to analyze the historical findings of Charles Darwin to explain basic principles of natural selection.*
- 8.4A.2** *Investigate to construct explanations about natural selection that connect growth, survival, and reproduction to genetic factors, environmental factors, food intake, and interactions with other organisms.*

Conceptual Understanding: Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. The traits of organisms that survive a change in the environment are inherited by offspring and become more common in the population. The traits of organisms that cannot survive a change in the environment are not passed to offspring and become less common. In separated populations, the changes can be large enough that the populations evolve to become separate species. Extinction occurs when the environment changes and the adaptive characteristics of a species, including its behaviors, are insufficient to allow its survival.

- 8.4B** Students will demonstrate an understanding of how similarities and differences among living and extinct species provide evidence that changes have occurred in organisms over time and that similarity of characteristics provides evidence of common ancestry.
- 8.4B.1** Analyze and interpret data (e.g. pictures, graphs) to explain that evolution occurs when there is a change in gene frequency in a population over time.
- 8.4B.2** Construct written and verbal explanations for how limitations in genetic variation prevent the mechanisms of evolutionary change to take place.
- 8.4B.3** Obtain and evaluate scientific information to explain that an accumulation of genetic mutations over time can lead to the evolution of species (speciation).
- 8.4B.4** Analyze displays of pictorial data to compare and contrast embryological and gross anatomical similarities and differences across multiple species to infer evolutionary relationships.

GRADE EIGHT: Physical Science

8.6 Motions, Forces, and Energy

Conceptual Understanding: Waves have energy that is transferred when they interact with various types of matter. A repeating pattern of motion allows the transfer of energy from place to place without overall displacement of matter. All types of waves have some features in common. When waves interact, they affect each other resulting in changes to the resonance. Many modern technologies are based on waves and their interactions with matter.

- 8.6** Students will demonstrate an understanding of the properties, behaviors, and application of waves.
- 8.6.1** Collect, organize, and interpret data about the characteristics of sound and light waves to construct explanations about the relationship between matter and energy.
- 8.6.2** Propose and defend research based mechanisms for capturing and converting wave energy (frequency, amplitude, wavelength, and speed) into electrical energy.
- 8.6.3** Conduct simple investigations about the performance of waves to describe their behavior (e.g., refraction, reflection, transmission, and absorption) as they interact with various materials (e.g., lenses, mirrors, and prisms).
- 8.6.4** Use scientific processes to plan and conduct controlled investigations to conclude sound is a wave phenomenon that is characterized by amplitude and frequency.
- 8.6.5** Conduct scientific investigations that describe the behavior of sound when resonance changes (e.g., waves in a stretched string and design of musical instruments).
- 8.6.6** Obtain and evaluate scientific information to explain the relationship between seeing color and the transmission, absorption, or reflection of light waves by various materials.
- 8.6.7** Research the historical significance of wave technology to explain how digitized tools have evolved to encode and transmit information (e.g., telegraph, cell phones, and wireless computer networks).
- 8.6.8** Compare and contrast the behavior of sound and light waves to determine which types of waves need a medium for transmission.

GRADE EIGHT: Earth and Space Science

8.7 Earth's Structure and History

Conceptual Understanding: Fossils are preserved remains or traces of organisms that lived in the past. Thousands of layers of sedimentary rock not only provide evidence of the history of Earth itself but also of changes in organisms whose fossil remains have been found in those layers. The collection of fossils and their placement in chronological order (e.g., through the location of rock layers or through radioactive dating) is collectively known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.

8.7 Students will demonstrate an understanding of geological evidence to analyze patterns in Earth's major events, processes, and evolution in history.

- 8.7.1** *Use scientific evidence to create a timeline of Earth's history that depicts relative dates from index fossil records and layers of rock (strata).*
- 8.7.2** *Create a model of the processes involved in the rock cycle and relate it to the fossil record.*
- 8.7.3** *Construct and analyze scientific arguments to support claims that most fossil evidence is an indication of the diversity of life that was present on Earth and that relationships exist between past and current life forms.*
- 8.7.4** *Use research and evidence to document how evolution has been shaped both gradually and through mass extinction by Earth's varying geological conditions (e.g., climate change, meteor impacts, and volcanic eruptions).*

GRADE EIGHT: Earth and Space Science

8.9 Earth's Systems and Cycles

Conceptual Understanding: Earth systems and cycles are characterized by cause and effect relationships. All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. Landforms and water distribution result from constructive and destructive processes. Cycles operating in Earth's systems take place on spatial scales varying from fractions of millimeters to thousands of kilometers, and on a time scale that ranges from milliseconds to billions of years. Plate tectonics is the unifying theory that explains the past and current crustal movements at the surface. This theory provides a framework for understanding geological history. Mapping land and water patterns based on investigations of rocks and fossils can help forecast the proximity and probability of future events.

8.9A Students will demonstrate an understanding that physical processes and major geological events (e.g., plate movement, volcanic activity, mountain building, weathering, erosion) are powered by the Sun and the Earth's internal heat and have occurred over millions of years.

- 8.9A.1** *Investigate and explain how the flow of Earth's internal energy drives the cycling of matter through convection currents between Earth's surface and the deep interior causing plate movements.*
- 8.9A.2** *Explore and debate theories of plate tectonics to form conclusions about past and current movements of rocks at Earth's surface throughout history.*
- 8.9A.3** *Map land and water patterns from various time periods and use rocks and fossils to report evidence of how Earth's plates have moved great distances, collided, and spread apart.*

- 8.9A.4** *Research and assess the credibility of scientific ideas to debate and discuss how Earth's constructive and destructive processes have changed Earth's surface at varying time and spatial scales.*
- 8.9A.5** *Use models that demonstrate convergent and divergent plate movements that are responsible for most landforms and the distribution of most rocks and minerals within Earth's crust.*
- 8.9A.6** *Design and conduct investigations to evaluate the chemical and physical processes involved in the formation of soils.*
- 8.9A.7** *Explain the interconnected relationship between surface water and groundwater.*

Conceptual Understanding: Natural processes can cause sudden or gradual changes to Earth's systems. Some may adversely affect humans such as volcanic eruptions or earthquakes. Mapping the history of natural hazards in a region, combined with an understanding of related geological forces can help forecast the locations and likelihoods of future events.

8.9B **Students will demonstrate an understanding of natural hazards (volcanic eruptions, severe weather, earthquakes) and construct explanations for why some hazards are predictable and others are not.**

- 8.9B.1** *Research and map various types of natural hazards to determine their impact on society.*
- 8.9B.2** *Compare and contrast technologies that predict natural hazards to identify which types of technologies are most effective.*
- 8.9B.3** *Using an engineering design process, create mechanisms to improve community resilience, which safeguard against natural hazards (e.g. building restrictions in flood or tidal zones, regional watershed management, Firewise construction). Use an engineering design process to define the problem, design, construct, evaluate, and improve the mechanism.**

GRADE EIGHT: Earth and Space Science

8.10 Earth's Resources

Conceptual Understanding: Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources, both renewable and nonrenewable. Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats that could cause extinction or the threat of extinction of many species. Past and present geological events have distributed resources unevenly around the planet; therefore, there has been an increase in, and continued need for, technology to harness available resources and develop alternatives.

- 8.10** **Students will demonstrate an understanding that a decrease in natural resources is directly related to the increase in human population on Earth and must be conserved.**
- 8.10.1** *Read and evaluate scientific information about advancements in renewable and nonrenewable resources. Propose and defend ways to decrease national and global dependency on nonrenewable resources.*
- 8.10.2** *Create and defend a proposal for reducing the environmental effects humans have on Earth (e.g., population increases, consumer demands, chemical pollution, deforestation, and change in average annual temperature).*
- 8.10.3** *Using scientific data, debate the societal advantages and disadvantages of technological advancements in renewable energy sources.*

GRADES 9-12 OVERVIEW

The high school curriculum provides essential preparation for all students in Grades 9-12. This experience should promote the development of adequate scientific knowledge to allow students to make informed, critical choices and to succeed in both the workplace and in postsecondary courses.

Content standards are integrated with scientific and engineering practices (SEPs), cross-cutting concepts, and the use of technology to connect information gathered through scientific investigations with real-world applications and engineering solutions to human problems. The nature of science and historical perspectives are critical to understanding the foundation and processes of science, regardless of the scientific discipline.

The eight SEPs should not be considered a stand-alone set of practices, as previously presented, but rather incorporated throughout the set of content objectives. The SEPs are designed so that students may develop skills and apply knowledge to solve real-life problems. While presented as distinct skill sets, the eight practices intentionally overlap and interconnect as students explore the science concepts.

The core science content utilizes hands-on classroom instruction to reinforce the seven crosscutting concepts (i.e., patterns; cause and effect; scale, portion, and quantity; systems and system models; energy and matter; structure and function; and stability and change).

The National Academies' (2012) research-based findings state that "the actual doing of science or engineering can pique students' curiosity, capture their interest and motivate their continued study..." (p. 42). Science curricula should actively engage students in learning through scientific investigations. At least 30% of the course should be dedicated to laboratory experiences, including, but not limited to:

- field studies and field trips
- manipulatives and model
- guided experimentation
- student independent research and/or science fair
- computer-based simulations
- case studies

Technology plays multiple roles in content mastery. It encompasses students' awareness of current technology applications, the use of technology in data collection, and its use by teachers and students in content delivery.

Students need to be supplied with the appropriate materials and equipment necessary to conduct scientific investigations. Student safety and safe practices are primary concerns. For this reason, teachers should adhere to the National Science Teachers Association (NSTA) safety recommendations, which can be accessed at <http://www.nsta.org/docs/SafetyInTheScienceClassroom.pdf>.

The Engineering Design Process (EDP) is a step-by-step method of devising a system, component, or process to meet desired needs. This is similar to the "scientific method" which is taught to young scientists. However, the EDP is a flexible process. Students can begin at any step, focus on just one step, move back and forth between steps, or repeat the cycle. Engineering standards are represented in some performance objectives with specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.**

Professional development and teacher resources will be developed for teachers as EDP is incorporated into Mississippi standards.

Each high school course contains the “Overarching SEPs for Inquiry Extension of Labs” that provides guidance for scientific investigations in all courses.

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

BIOLOGY

Biology, **a one-credit course**, is a laboratory-based course that is designed to build a life science foundation emphasizing patterns, processes, and interactions among organisms. Students are expected to master conceptual understandings based on both individual investigations and the investigations conducted by others. Individual learning experiences are used to support claims and engage in evidence-based arguments. In this way, students explore the organization of life; the interdependence between organisms and their environment; the chemical composition of life; the role of DNA, RNA, and protein in cellular structure and function; inheritance; and evolution. Local resources coupled with external resources, including evidence-based literature, will be used to extend and increase the complexity of these core ideas.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to utilize science and engineering practices to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. The recommendation is that students should be actively engaged in inquiry activities, lab experiences, and scientific research (projects) for a minimum of 30% of class time.

The standards and performance objectives do not have to be taught in the order presented in this document. The performance objectives are intentionally broad to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students.

Objectives identified by “**Enrichment:**” are considered enrichment material that may be expanded upon as time permits. Engineering standards are represented in some performance objectives with specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.**

Biology

BIO.1 Cells as a System

Conceptual Understanding: Biologists have determined that organisms share unique characteristics that differentiate them from non-living things. Organisms range from very simple to extremely complex.

BIO.1A Students will demonstrate an understanding of the characteristics of life and biological organization.

BIO.1A.1 *Ask questions to differentiate between living and non-living things.*

BIO.1A.2 *Describe the tenets of cell theory and the contributions of Schwann, Hooke, Schleiden, and Virchow.*

BIO.1A.3 *Using specific examples, explain how cells can be organized into complex tissues, organs, and organ systems in multicellular organisms.*

BIO.1A.4 *Use evidence from current scientific literature to support whether a virus is living or non-living.*

Conceptual Understanding: Organisms are composed of four primary macromolecules: carbohydrates, lipids, proteins, and nucleic acids. Metabolism is the sum of all chemical reactions between molecules within cells. Cells continuously utilize materials obtained from the environment and the breakdown of other macromolecules to synthesize their own large macromolecules for cellular structures and functions. These metabolic reactions require enzymes for catalysis.

BIO.1B Students will analyze the structure and function of the macromolecules that make up cells.

BIO.1B.1 *Develop and use models to compare and contrast the structure and function of carbohydrates, lipids, proteins, and nucleic acids (DNA and RNA) in organisms.*

BIO.1B.2 *Design and conduct an experiment to determine how enzymes react given various environmental conditions (i.e., pH, temperature, and concentration). Analyze, interpret, graph, and present data to explain how those changing conditions affect the enzyme activity and the rate of the reactions that take place in biological organisms.*

Conceptual Understanding: Cells are the basic units of all organisms, both prokaryotes and eukaryotes. Prokaryotic and eukaryotic cells differ in key structural features, but both can perform all functions necessary for life.

BIO.1C Students will relate the diversity of organelles to a variety of specialized cellular functions.

BIO.1C.1 *Develop and use models to explore how specialized structures within cells (e.g., nucleus, cytoskeleton, endoplasmic reticulum, ribosomes, Golgi apparatus, lysosomes, mitochondria, chloroplast, centrosomes, and vacuoles) interact to carry out the functions necessary for organism survival.*

BIO.1C.2 *Investigate to compare and contrast prokaryotic cells and eukaryotic cells, and plant, animal, and fungal cells.*

BIO.1C.3 *Contrast the structure of viruses with that of cells, and explain why viruses must use living cells to reproduce.*

Conceptual Understanding: The structure of the cell membrane allows it to be a selectively permeable barrier and maintain homeostasis. Substances that enter or exit the cell must do so via the cell membrane. This transport across the membrane may occur through a variety of mechanisms, including simple diffusion, facilitated diffusion, osmosis, and active transport.

BIO.1D Students will describe the structure of the cell membrane and analyze how the structure is related to its primary function of regulating transport in and out of cells to maintain homeostasis.

BIO.1D.1 *Plan and conduct investigations to prove that the cell membrane is a semi-permeable, allowing it to maintain homeostasis with its environment through active and passive transport processes.*

BIO.1D.2 *Develop and use models to explain how the cell deals with imbalances of solute concentration across the cell membrane (i.e., hypertonic, hypotonic, and isotonic conditions, sodium/potassium pump).*

Conceptual Understanding: Cells grow and reproduce through a regulated cell cycle. Within multicellular organisms, cells repeatedly divide for repair, replacement, and growth. Likewise, an embryo begins as a single cell that reproduces to form a complex, multicellular organism through the processes of cell division and differentiation.

BIO.1E Students will develop and use models to explain the role of the cell cycle during growth, development, and maintenance in multicellular organisms.

BIO.1E.1 *Construct models to explain how the processes of cell division and cell differentiation produce and maintain complex multicellular organisms.*

BIO.1E.2 *Ask questions to describe the changes that occur in a cell during replication. Define problems that might occur if the cell does not progress through the cycle correctly (cancer).*

BIO.1E.3 *Relate the processes of cellular reproduction to asexual reproduction in simple organisms (i.e., budding, vegetative propagation, regeneration, binary fission). Explain why the DNA of the daughter cells is the same as the parent cell.*

BIO.1E.4 ***Enrichment:** Use an engineering design process to investigate the role of stem cells in regeneration and asexual reproduction, then develop applications of stem cell research to solve human medical conditions.**

Biology

BIO.2 Energy Transfer

Conceptual Understanding: Organisms require energy in order to perform life functions. Cells are transformers of energy, continuously utilizing a complex sequence of reactions in which energy is transferred from one form to another, for example, from light energy to chemical energy to kinetic energy. Emphasis is on illustrating the inputs and outputs of matter and the transfer and transformation of energy in photosynthesis and cellular respiration. Assessment is limited to identification of the phases (i.e., glycolysis, citric acid cycle, and electron transport chain) in cellular respiration as well as light and light-independent reactions of photosynthesis and does not include specific biochemical reactions within the phases.

BIO.2 Students will explain that cells transform energy through the processes of photosynthesis and cellular respiration to drive cellular functions.

BIO.2.1 *Use models to demonstrate that ATP and ADP are cycled within a cell as a means to transfer energy.*

BIO.2.2 *Develop models of the major reactants and products of photosynthesis to demonstrate the transformation of light energy into stored chemical energy in cells. Emphasize the chemical processes in which bonds are broken and energy is released, and new bonds are formed and energy is stored.*

BIO.2.3 *Develop models of the major reactants and products of cellular respiration (aerobic and anaerobic) to demonstrate the transformation of the chemical energy stored in food to the available energy of ATP. Emphasize the chemical processes in which bonds are broken and energy is released, and new bonds are formed and energy is stored.*

BIO.2.4 *Conduct scientific investigations or computer simulations to compare aerobic and anaerobic cellular respiration in plants and animals, using real world examples.*

- BIO.2.5** *Enrichment: Investigate variables (e.g., nutrient availability, temperature) that affect anaerobic respiration and current real-world applications of fermentation.*
- BIO.2.6** *Enrichment: Use an engineering design process to manipulate factors involved in fermentation to optimize energy production.**

Biology

BIO.3 Reproduction and Heredity

Conceptual Understanding: Somatic cells contain homologous pairs of chromosomes, one member of each pair obtained from each parent, that form a diploid set of chromosomes in each cell. These chromosomes are similar in genetic information but may contain different alleles of these genes. For sexual reproduction, an offspring must inherit a haploid set from each parent. Haploid gametes are formed by meiosis, a specialized cell division in which the chromosome number is reduced by half. During meiosis, members of a homologous pair may exchange information and then are randomly sorted into gametes resulting in genetic variation in sex cells.

BIO.3A **Students will develop and use models to explain the role of meiosis in the production of haploid gametes required for sexual reproduction.**

- BIO.3A.1** *Model sex cell formation (meiosis) and combination (fertilization) to demonstrate the maintenance of chromosome number through each generation in sexually reproducing populations. Explain why the DNA of the daughter cells is different from the DNA of the parent cell.*
- BIO.3A.2** *Compare and contrast mitosis and meiosis in terms of reproduction.*
- BIO.3A.3** *Investigate chromosomal abnormalities (e.g., Down syndrome, Turner's syndrome, and Klinefelter syndrome) that might arise from errors in meiosis (nondisjunction) and how these abnormalities are identified (karyotypes).*

Conceptual Understanding: Offspring inherit DNA from their parents. The genes contained in the DNA (genotype) determine the traits expressed in the offspring's phenotype. Alleles of a gene may demonstrate various patterns of inheritance. These patterns of inheritance may be followed through multiple generations within families.

BIO.3B **Students will analyze and interpret data collected from probability calculations to explain the variation of expressed traits within a population.**

- BIO.3B.1** *Demonstrate Mendel's law of dominance and segregation using mathematics to predict phenotypic and genotypic ratios by constructing Punnett squares with both homozygous and heterozygous allele pairs.*
- BIO.3B.2** *Illustrate Mendel's law of independent assortment using Punnett squares and/or the product rule of probability to analyze monohybrid crosses.*
- BIO.3B.3** *Investigate traits that follow non-Mendelian inheritance patterns (e.g., incomplete dominance, codominance, multiple alleles in human blood types, and sex-linkage).*
- BIO.3B.4** *Analyze and interpret data (e.g., pedigrees, family, and population studies) regarding Mendelian and complex genetic traits (e.g., sickle-cell anemia, cystic fibrosis, muscular dystrophy, color-blindness, and hemophilia) to determine patterns of inheritance and disease risk.*

Conceptual Understanding: Gene expression results in the production of proteins and thus determines the phenotypes of the organism. Changes in the DNA occur throughout an organism's life. Mutations are a source of genetic variation that may have a positive, negative, or no effect on the organism.

BIO.3C Students will construct an explanation based on evidence to describe how the structure and nucleotide base sequence of DNA determines the structure of proteins or RNA that carry out essential functions of life.

BIO.3C.1 *Develop and use models to explain the relationship between DNA, genes, and chromosomes in coding the instructions for the traits transferred from parent to offspring.*

BIO.3C.2 *Evaluate the mechanisms of transcription and translation in protein synthesis.*

BIO.3C.3 *Use models to predict how various changes in the nucleotide sequence (e.g., point mutations, deletions, and additions) will affect the resulting protein product and the subsequent inherited trait.*

BIO.3C.4 *Ask questions to determine how DNA technology benefits society. Engage in scientific argument from evidence the ethical issues surrounding the use of DNA technology (e.g., cloning, transgenic organisms, stem cell research, and the Human Genome Project, gel electrophoresis).*

BIO.3C.5 **Enrichment:** *Investigate current biotechnological applications in the study of the genome (e.g., transcriptome, proteome, individualized sequencing, and individualized gene therapy).*

Biology

BIO.4 Adaptations and Evolution

Conceptual Understanding: Evolution is a key unifying principle in biology. Differentiating between organic and chemical evolution, and the analysis of the gradual changes in populations over time helps students understand common features and differences between species and thus the relatedness between species. There are several factors that affect how natural selection acts on populations within their environments leading to speciation, extinction, and the current diversity of life on earth.

BIO.4 Students will analyze and interpret evidence to explain the unity and diversity of life.

BIO.4.1 *Use models to differentiate between organic and chemical evolution, illustrating the steps leading to aerobic heterotrophs and photosynthetic autotrophs.*

BIO.4.2 *Evaluate empirical evidence of common ancestry and biological evolution, including comparative anatomy (e.g., homologous structures and embryological similarities), fossil record, molecular/biochemical similarities (e.g., gene and protein homology), and biogeographic distribution.*

BIO.4.3 *Construct cladograms/phylogenetic trees to illustrate relatedness between species.*

BIO.4.4 *Design models and use simulations to investigate the interaction between changing environments and genetic variation in natural selection leading to adaptations in populations and differential success of populations.*

BIO.4.5 *Ask questions to explain Darwin's theory that genetic variation, competition, overproduction, and unequal reproductive success act as driving forces of natural selection and evolution.*

BIO.4.6 *Construct explanations for the mechanisms of speciation (e.g., geographic and reproductive isolation).*

- BIO.4.7** *Enrichment: Construct explanations for how various disease agents (bacteria, viruses, chemicals) can influence natural selection.*

Biology

BIO.5 Interdependence of Organisms and Their Environments

Conceptual Understanding: Complex interactions within an ecosystem affect the numbers and types of organisms that survive. Fluctuations in conditions can affect the ecosystem's function, resources, and habitat availability. Ecosystems are subject to carrying capacities and can only support a limited number of organisms and populations. Factors that can affect the carrying capacities of populations are both biotic and abiotic.

BIO.5 **Students will Investigate and evaluate the interdependence of living organisms and their environment.**

- BIO.5.1** *Illustrate levels of ecological hierarchy, including organism, population, community, ecosystem, biome, and biosphere.*
- BIO.5.2** *Analyze models of the cycling of matter (e.g., carbon, nitrogen, phosphorus, and water) between abiotic and biotic factors in an ecosystem and evaluate the ability of these cycles to maintain the health and sustainability of the ecosystem.*
- BIO.5.3** *Analyze and interpret quantitative data to construct an explanation for the effects of greenhouse gases on the carbon dioxide cycle and global climate.*
- BIO.5.4** *Develop and use models to describe the flow of energy and amount of biomass through food chains, food webs, and food pyramids.*
- BIO.5.5** *Ask questions to evaluate symbiotic relationships (e.g., mutualism, parasitism, and commensalism) and other co-evolutionary (e.g., predator-prey, cooperation, competition, and mimicry) relationships within specific environments.*
- BIO.5.6** *Analyze and interpret population data, both density-dependent and density-independent, to define limiting factors. Use graphical representations (growth curves) to illustrate the carrying capacity within ecosystems.*
- BIO.5.7** *Ask questions to define factors involved in primary and secondary ecological succession using local, real world examples.*
- BIO.5.8** ***Enrichment:** Use an engineering design process to create a solution that addresses changing ecological conditions (e.g., climate change, invasive species, loss of biodiversity, human population growth, habitat destruction, biomagnification, or natural phenomena).**
- BIO.5.9** ***Enrichment:** Use an engineering design process to investigate and model current technological uses of biomimicry to address solutions to real-world problems.**

Overarching (start to finish) SEPs for Inquiry Extension of Labs

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Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

BOTANY

Botany, a **one-half credit course**, is a laboratory-based course applying basic biological principles to the study of plants. Topics include morphological characteristics of each division and variation in their reproduction, physiology, taxonomy, evolution, and the interactions of human society and plants. Laboratory activities, research, the use of technology, and the effective communication of results through various methods are integral components of this course. It is recommended that Botany is taken after the successful completion of Biology.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to utilize the science and engineering practices to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. The recommendation is that students should actively engage in inquiry activities, laboratory experiences, and scientific research (projects) for a minimum of 30% of class time.

The standards and performance objectives do not have to be taught in the order presented in this document. The performance objectives are intentionally broad to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students.

Objectives identified by “**Enrichment:**” are considered enrichment material that may be expanded upon as time permits. Engineering standards are represented in some performance objectives with specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.**

Botany

BOT.1 Plant Morphology, Cell Structure, and Function

Conceptual Understanding: Plants are a diverse and important part of the biosphere, providing oxygen, food, and shelter required for other organisms. The diversity of the plant kingdom is characterized by unique traits that are observed to identify the various plant divisions.

BOT.1 Students will investigate the morphology, anatomy, and physiology of plants.

- BOT.1.1** *Analyze models (3-D, paper, and/or computer-based) to distinguish the basic morphology of the plant kingdom, with attention to structures and their related functions. Use cladograms or phylogenetic trees to identify evolutionary features that distinguish the plant kingdom from other kingdoms.*
- BOT.1.2** *Using microscopes, observe, identify, record, and analyze (e.g., see and draw) cells and cell structures unique to plants. Use data measurements obtained from microscopy to compare the plant cells and organelle sizes between various examples (e.g., elodea, onion, or algae).*
- BOT.1.3** *Describe the relationship between the structure and purpose of plant organs (e.g., roots, stems, and leaves).*
- BOT.1.4** *Evaluate and explain how bacteria and fungi work symbiotically to enhance plant root function.*
- BOT.1.5** *Calculate surface area of leaves/roots, and compare surface areas of various plant specimens to explain adaptations of the various plant types.*

- BOT.1.6** *Demonstrate through model development and manipulation an understanding of plant biochemistry.*
- BOT.1.7** *Conduct investigations, collect and analyze data, and communicate results that explain the processes of photosynthesis and cellular respiration (e.g., light intensity, light color, light distance, temperature, altering pH, oxygen availability, and carbon dioxide concentration).*
- BOT.1.8** **Enrichment:** *Use an engineering design process to manipulate a variable of choice to refine a protocol to optimize output of photosynthesis or cellular respiration.**
- BOT.1.9** *Communicate the importance of carbon, hydrogen, oxygen, phosphorus, and nitrogen cycles to plant physiology through graphics such as poster or computer presentations.*
- BOT.1.10** *Identify and compare various live plant examples to explore plant morphological diversity, including leaf number, structure, and arrangement; root modifications; and flower structure and arrangement. Produce a visual product (e.g., an electronic presentation) to identify and communicate patterns of similarity and differences between the lab specimens.*
- BOT.1.11** *Compare and contrast functions of the various characteristics found in plant divisions and utilize dichotomous keys to identify plant species.*

Botany

BOT.2 Plant Evolution

Conceptual Understanding: Plants have been naturally selected to survive in a variety of habitats, from aquatic to arboreal. The development of these characteristics is used to construct cladograms that illustrate the evolution of plants.

- BOT.2** **Students will identify evolutionary modifications necessary for the terrestrial survival of plants.**
- BOT.2.1** *Summarize and justify the characteristics of nonvascular algae (blue-green and green algae) and bryophytes that provide evidence of evolution within the plant kingdom.*
- BOT.2.2** *Referencing the USDA plants database, identify, compare, and contrast seedless, naked seed, and enclosed-seed modifications for reproduction. Calculate the occurrence of seed types in given habitats.*
- BOT.2.3** *Summarize and justify the characteristics of angiosperms and gymnosperms that lead to their success as terrestrial plants.*
- BOT.2.4** *Research information to develop, produce, and communicate a scientifically justifiable argument for the rapid amplification and success of angiosperm compared to other plant divisions.*
- BOT.2.5** **Enrichment:** *Referencing the National Center for Biotechnology Information's gene/protein databases, propose and design a scientifically supportable cladogram or phylogenetic tree that illustrates the evolutionary modifications of the plant kingdom using genetic (DNA) or protein sequence comparisons/alignments.*

Botany

BOT.3 Plant Reproduction

Conceptual Understanding: Reproduction in plants occurs through different methods. Understanding the reproductive methods of plants allows humans to use these methods in agriculture and food development.

- BOT.3** **Students will characterize the reproductive strategies of plants.**

- BOT.3.1** Describe the various processes of asexual reproduction and vegetative propagation used by plants. Communicate the importance of these reproductive methods in regard to human food production.
- BOT.3.2** **Enrichment:** Research and present an agronomically important crop (e.g., potato, sweet potato, pineapple, or strawberry) that is produced via vegetative propagation (non-GMOs) for human consumption. Include evidence-based arguments that identify the potential benefits and negative effects of this method of crop production.
- BOT.3.3** Compare and contrast the consequences of the following reproductive methods: asexual reproduction, vegetative propagation, and sexual reproduction.
- BOT.3.4** Plan and conduct comparative flower dissection to identify reproductive structures within the flower.
- BOT.3.5** Compare the similarities between corresponding plant reproductive structures from a variety of species. Record via drawings of observed dissection specimens, and explain the similarities and differences observed.
- BOT.3.6** Identify differences in flower structure and shape. Provide a rationale that explains the value of these differences in flower structure to reproductive success (e.g., pollinators, flower shape, smell, color, size, orientation).
- BOT.3.7** Plan, conduct, and communicate the results of a comparative laboratory investigation of differing fruit types.
- BOT.3.8** Using laboratory data, correctly categorize the items as fruits, vegetables, nuts, modified stems, or other plant parts.
- BOT.3.9** Compare the scientific definitions to those used by the general public/society and the USDA to categorize food.

Botany

BOT.4 Society's Reliance on Plants

Conceptual Understanding: Human reliance on plants and plant products began with food and building materials. This use has expanded to include medicine, industrial clean up (phytoremediation) of human-generated byproducts and toxic waste, and plant examples used in biomimicry for solving human problems.

BOT.4 Students will explore the global value of plants and the interaction between humans and plants.

- BOT.4.1** Identify plants used in the bioremediation of an area due to natural processes (e.g., fire), industrial pollution, or wars, and develop and communicate a plan to remediate a habitat impacted by human interactions (e.g., carbon sinks, phytoremediation, or heavy metal detoxification).
- BOT.4.2** **Enrichment:** Use an engineering design process to define a problem, design, construct, evaluate, and improve a habitat impacted by human interactions.*
- BOT.4.3** Identify historical and modern medicinal uses of plants.
- BOT.4.4** Investigate the industrial use of plants.
- BOT.4.5** Explore the impacts (both positive and negative) of plant biotechnology/GMOs on human society. Present findings using digital media or technology, and include evidence using graphs or charts.
- BOT.4.6** **Enrichment:** Use an engineering design process to design and conduct an investigation that uses biomimicry to provide a plant-based solution to an environmental challenge.*

Botany

BOT.5 Plant Adaptations to Varying Habitats

Conceptual Understanding: Before animal life forms can survive within a habitat, there must be an existing plant population. Plants have specific adaptations that allow them to survive in habitats.

BOT.5 Students will explore adaptations that allow plants to survive in various habitats.

BOT.5.1 *Research plants found in various habitats. Analyze how plants use adaptations for survival in these habitats.*

BOT.5.2 *Relate atmospheric factors to biodiversity (e.g., climate as determined by temperature and precipitation).*

BOT.5.3 *Construct a model using technology that illustrates the levels of succession within a habitat (e.g., graveyard exploration, forest fire area, or reclamation sites).*

BOT.5.4 *Characterize and justify adaptations that allow plant survival in extreme environments (e.g., deserts, bogs, or salt flats).*

BOT.5.5 **Enrichment:** *Use an engineering design process to design and build a plant model based on extreme environment criteria to overcome the difficulties presented by this environment. Identify revisions to the proposed model over time.**

Botany

BOT.6 Local Plant Investigations

Conceptual Understanding: The plant diversity within the local environment impacts the health of the ecosystem. The ability to identify the plants within an ecosystem is a skill that will benefit students throughout life.

BOT.6 Students will ask questions, plan, and conduct field investigations on local plant communities.

BOT.6.1 *Conduct transects/plot studies to determine species, biodiversity, or health of a plant community. (Plots may be linear or a quadrat (square or circular) depending on the habitat. (Typically, relative density, relative dominance, and relative frequency of each species are calculated to infer an importance value of the species in the plot.)*

BOT.6.2 *Compare and contrast genomes using plant genetic databases (e.g., BLAST or plant GDB).*

BOT.6.3 **Enrichment:** *Use an engineering design process to define a problem, design, construct, evaluate, and improve a societal concern with the aid of plants (e.g., irrigation, water conservation, urban shading, green-space development, food deserts, or other local needs or issues).**

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CHEMISTRY

Chemistry, **a one-credit course**, is an elective and should be a rigorous course to prepare students for careers in science, technology, engineering, integrated STEM activities, and mathematics. Chemistry explores empirical concepts central to all areas of science. These concepts should be explored in-depth using both quantitative and qualitative analysis, computational and experimental rigor, and the use of inquiry-based methods of teaching. To accomplish a level of sophistication and depth, chemistry teachers should extend concepts mastered by students in earlier grades. Cornerstone objectives of chemistry that must be addressed and readdressed throughout the course are dimensional analysis, naming compounds, balancing equations, and stoichiometry. To be successful in Chemistry, it is recommended that students have completed Algebra I (Integrated Math I), and be enrolled in an upper level math course.

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Chemistry

CHE.1 Mathematical and Computational Analysis

Conceptual Understanding: Mathematical and computational analysis is a key component of scientific investigation and prediction of outcomes. These components create a more student-centered classroom.

CHE.1 Students will use mathematical and computational analysis to evaluate problems.

CHE.1.1 *Use dimensional analysis (factor/label) and significant figures to convert units and solve stoichiometric problems.*

CHE.1.2 *Use graphical analysis and develop data through spreadsheet programs (e.g., Excel, Google Sheet) or other software.*

CHE.1.3 *Express relationships between variables to develop models using formulas and graphs to generate formulas.*

- CHE.1.4** *Analyze hypotheses and develop conclusions using graphical analysis, cyber evaluations, and/or professional journal research.*
- CHE.1.5** **Enrichment:** *Research information from multiple appropriate sources and assess the credibility, accuracy, possible bias, and conclusions of each publication.*

Chemistry

CHE.2 Atomic Theory

Conceptual Understanding: Atomic theory is the foundation of modern chemistry concepts. Students must be presented with a solid foundation of the atom and its components. These concepts lead to an understanding of the interactions of these components to explain macro-observations of the world.

CHE.2 **Students will demonstrate an understanding of the atomic structure and the historical developments leading to modern atomic theory.**

- CHE.2.1** *Investigate the historical progression leading to the modern atomic theory, including, but not limited to, work done by Dalton, Rutherford's gold foil experiment, Thomson's cathode ray experiment, Millikan's oil drop experiment, and Bohr's interpretation of bright line spectra.*
- CHE.2.2** *Construct models (e.g., ball and stick, online simulations, mathematical computations) of atomic nuclei to explain the abundance weighted average (relative mass) of elements and isotopes on the published mass of elements.*
- CHE.2.3** *Investigate absorption and emission spectra to interpret explanations of electrons at discrete energy levels using tools such as online simulations, spectrometers, prisms, flame tests, and discharge tubes. Explore both laboratory experiments and real-world examples.*
- CHE.2.4** *Research appropriate sources to evaluate the way absorption and emission spectra are used to study astronomy and the formation of the universe.*

Chemistry

CHE.3 Periodic Table

Conceptual Understanding: Modern chemistry is based on the predictability of atomic behavior. Periodic patterns in elements led to the development of the periodic table. Electron configuration is a direct result of this periodic behavior. The predictable behavior of electrons has led to the discovery of new compounds, elements, and atomic interactions. Predictability of atom behavior is a key to understanding ionic and covalent bonding and production of compounds or molecules.

CHE.3 **Students will demonstrate an understanding of the periodic table as a systematic representation to predict properties of elements.**

- CHE.3.1** *Explore and communicate the organization of the periodic table, including history, groups, families, family names, metals, nonmetals, metalloids, and transition metals.*
- CHE.3.2** *Analyze properties of atoms and ions (e.g., metal/nonmetal/metalloid behavior, electrical/heat conductivity, electronegativity and electron affinity, ionization energy, and atomic/ionic radii) using periodic trends of elements based on the periodic table.*
- CHE.3.3** *Analyze the periodic table to identify quantum numbers (e.g., valence shell electrons, energy level, orbitals, sublevels, and oxidation numbers).*

Chemistry

CHE.4 Bonding

Conceptual Understanding: A firm understanding of bonding is necessary to further development of the basic chemical concepts of compounds and chemical interactions.

CHE.4 Students will demonstrate an understanding of the types of bonds and resulting atomic structures for the classification of chemical compounds.

CHE.4.1 *Develop and use models (e.g., Lewis dot, 3-D ball-stick, 3-D printing, or simulation programs such as PhET) to predict the type of bonding between atoms and the shape of simple compounds.*

CHE.4.2 *Use models such as Lewis structures and ball and stick models to depict the valence electrons and their role in the formation of ionic and covalent bonds.*

CHE.4.3 *Predict the ionic or covalent nature of different atoms based on electronegativity trends and/or position on the periodic table.*

CHE.4.4 *Use models and oxidation numbers to predict the type of bond, shape of the compound, and the polarity of the compound.*

CHE.4.5 *Use models of simple hydrocarbons to exemplify structural isomerism.*

CHE.4.6 *Use mathematical and computational analysis to determine the empirical formula and the percent composition of compounds.*

CHE.4.7 *Use scientific investigation to determine the percentage of composition for a substance (e.g., sugar in gum, water and/or unpopped kernels in popcorn, percent water in a hydrate). Compare results to justify conclusions based on experimental evidence.*

CHE.4.8 *Plan and conduct controlled scientific investigations to produce mathematical evidence of the empirical composition of a compound and its uses in the real world.*

Chemistry

CHE.5 Naming Compounds

Conceptual Understanding: Polyatomic ions (radicals) and oxidation numbers are used to predict how metallic ions, nonmetals, and transition metals are used in naming compounds.

CHE.5 Students will investigate and understand the accepted nomenclature used to identify the name and chemical formulas of compounds.

CHE.5.1 *Use the periodic table and a list of common polyatomic ions as a model to derive chemical compound formulas from compound names and compound names from chemical formulas.*

CHE.5.2 *Generate formulas of ionic and covalent compounds from compound names. Discuss compounds in everyday life and compile lists and uses of these chemicals.*

CHE.5.3 *Generate names of ionic and covalent compounds from their formulas. Name binary compounds, binary acids, stock compounds, ternary compounds, and ternary acids.*

Chemistry

CHE.6 Chemical Reactions

Conceptual Understanding: Understanding chemical reactions and predicting products of these reactions is essential to student success.

CHE.6 Students will demonstrate an understanding of the types, causes, and effects of chemical reactions.

CHE.6.1 *Develop and use models to predict the products of chemical reactions (e.g., synthesis reactions; single replacement; double displacement; and decomposition, including exceptions such as decomposition of hydroxides, chlorates, carbonates, and acids). Discuss and/or compile lists of reactions used in everyday life.*

CHE.6.2 *Plan, conduct, and communicate the results of investigations to demonstrate different types of simple chemical reactions.*

CHE.6.3 *Use mathematics and computational analysis to represent the ratio of reactants and products in terms of masses, molecules, and moles (stoichiometry).*

CHE.6.4 *Use mathematics and computational analysis to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Give real-world examples (e.g., burning wood).*

CHE.6.5 *Plan and conduct a controlled scientific investigation to produce mathematical evidence that mass is conserved. Use percent error to analyze the accuracy of results.*

CHE.6.6 *Use mathematics and computational analysis to support the concept of percent yield and limiting reagent.*

CHE.6.7 *Plan and conduct a controlled scientific investigation to produce mathematical evidence to predict and confirm the limiting reagent and percent yield in the reaction. Analyze quantitative data, draw conclusions, and communicate findings. Compare and analyze class data for validity.*

Chemistry

CHE.7 Gas Laws

Conceptual Understanding: The comparison and development of the molecular states of matter are an integral part of understanding matter. Pressure, volume, and temperature are imperative to understanding the states of matter.

CHE.7 Students will demonstrate an understanding of the structure and behavior of gases.

CHE.7.1 *Analyze the behavior of ideal and real gases in terms of pressure, volume, temperature, and number of particles.*

CHE.7.2 **Enrichment:** *Use an engineering design process to develop models (e.g., online simulations or student interactive activities) to explain and predict the behavior of each state of matter using the movement of particles and intermolecular forces to explain the behavior of matter.**

CHE.7.3 *Analyze and interpret heating curve graphs to explain the energy relationship between states of matter (e.g., thermochemistry-water heating from -20°C to 120°C).*

- CHE.7.4** Use mathematical computations to describe the relationships comparing pressure, temperature, volume, and number of particles, including Boyle's law, Charles's law, Dalton's law, combined gas laws, and ideal gas laws.
- CHE.7.5** **Enrichment:** Use an engineering design process and online simulations or lab investigations to design and model the results of controlled scientific investigations to produce mathematical evidence that confirms the gas-laws relationships.*
- CHE.7.6** Use the ideal gas law to support the prediction of volume, mass, and number of particles produced in chemical reactions (i.e., gas stoichiometry).
- CHE.7.7** Plan and conduct controlled scientific investigations to produce mathematical evidence that confirms that reactions involving gases conform to the law of conservation of mass.
- CHE.7.8** **Enrichment:** Using gas stoichiometry, calculate the volume of carbon dioxide needed to inflate a balloon to occupy a specific volume. Use an engineering design process to design, construct, evaluate, and improve a simulated air bag.*

Chemistry

CHE.8 Solutions

Conceptual Understanding: Solutions exist as solids, liquids, or gases. Solution concentration is expressed by specifying relative amounts of solute to solvent.

- CHE.8** Students will demonstrate an understanding of the nature of properties of various types of chemical solutions.
- CHE.8.1** Use mathematical and computational analysis to quantitatively express the concentration of solutions using the concepts such as molarity, percent by mass, and dilution.
- CHE.8.2** Develop and use models (e.g., online simulations, games, or video representations) to explain the dissolving process in solvents on the molecular level.
- CHE.8.3** Analyze and interpret data to predict the effect of temperature and pressure on solids and gases dissolved in water.
- CHE.8.4** Design, conduct, and communicate the results of experiments to test the conductivity of common ionic and covalent compounds in solution.
- CHE.8.5** Use mathematical and computational analysis to analyze molarity, molality, dilution, and percentage dilution problems.
- CHE.8.6** Design, conduct, and communicate the results of experiments to produce a specified volume of a solution of a specific molarity, and dilute a solution of a known molarity.
- CHE.8.7** Use mathematical and computational analysis to predict the results of reactions using the concentration of solutions (i.e., solution stoichiometry).
- CHE.8.8** **Enrichment:** Investigate parts per million and/or parts per billion as it applies to environmental concerns in your geographic region, and reference laws that govern these factors.

Chemistry (Enrichment)

CHE.9 Acids and Bases (Enrichment)

- CHE.9** **Enrichment:** Students will understand the nature and properties of acids, bases, and salt solutions.
- CHE.9.1** *Enrichment:* Analyze and interpret data to describe the properties of acids, bases, and salts.
- CHE.9.2** *Enrichment:* Analyze and interpret data to identify differences between strong and weak acids and bases (i.e., dissociation).
- CHE.9.3** *Enrichment:* Plan and conduct investigations using the pH scale to classify acid and base solutions.
- CHE.9.4** *Enrichment:* Analyze and evaluate the Arrhenius, Bronsted-Lowry, and Lewis acid-base definitions.
- CHE.9.5** *Enrichment:* Use mathematical and computational thinking to calculate pH from the hydrogen-ion concentration.
- CHE.9.6** *Enrichment:* Obtain, evaluate, and communicate information about how buffers stabilize pH in acid-base reactions.

Chemistry (Enrichment)

CHE.10 Thermochemistry (Enrichment)

- CHE.10** **Enrichment:** Students will understand that energy is exchanged or transformed in all chemical reactions.
- CHE.10.1** *Enrichment:* Construct explanations to explain how temperature and heat flow in terms of the motion of molecules (or atoms).
- CHE.10.2** *Enrichment:* Classify chemical reactions and phase changes as exothermic or endothermic based on enthalpy values. Use a graphical representation to illustrate the energy changes involved.
- CHE.10.3** *Enrichment:* Analyze and interpret data from energy diagrams and investigations to support claims that the amount of energy released or absorbed during a chemical reaction depends on changes in total bond energy.
- CHE.10.4** *Enrichment:* Use mathematical and computational thinking to solve problems involving heat flow and temperature changes, using known values of specific heat and latent heat of phase change.

Chemistry (Enrichment)

CHE.11 Equilibrium (Enrichment)

- CHE.11** **Enrichment:** Students will understand that chemical equilibrium is a dynamic process at the molecular level.
- CHE.11.1** *Enrichment:* Construct explanations to explain how to use Le Chatelier's principle to predict the effect of changes in concentration, temperature, and pressure.
- CHE.11.2** *Enrichment:* Predict when equilibrium is established in a chemical reaction.

CHE.11.3 *Enrichment: Use mathematical and computational thinking to calculate an equilibrium constant expression for a reaction.*

Chemistry (Enrichment)

CHE.12 Organic Nomenclature (Enrichment)

CHE.12 **Enrichment: Students will understand that the bonding characteristics of carbon allow the formation of many different organic molecules with various sizes, shapes, and chemical properties.**

CHE.12.1 *Enrichment: Construct explanations to explain the bonding characteristics of carbon that result in the formation of basic organic molecules.*

CHE.12.2 *Enrichment: Obtain information to communicate the system used for naming the basic linear hydrocarbons and isomers that contain single bonds, simple hydrocarbons with double and triple bonds, and simple molecules that contain a benzene ring.*

CHE.12.3 *Enrichment: Develop and use models to identify the functional groups that form the basis of alcohols, ketones, ethers, amines, esters, aldehydes, and organic acids.*

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

EARTH AND SPACE SCIENCE

The Earth and space science course, **a one-credit course**, provides opportunities for students to continue to develop and communicate a basic understanding of the Earth and its place in the universe through lab-based activities, integrated STEM activities, inquiry, mathematical expressions, and concept exploration. The Earth and space science course will help students apply scientific concepts in natural settings and guide them to become responsible stewards of Earth's natural resources.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a lab-based course, students are expected to design and conduct investigations using appropriate equipment, measurement, and safety procedures. The recommendation is that students should be actively engaged in inquiry activities, lab experiences, and scientific research for a minimum of 30% of the class time.

Although the standards and performance objectives do not have to be taught in the order presented in this document, they are arranged from the universe as a whole, through the solar system, the interacting systems of planet Earth, and the interrelationships between our planet and humans throughout time. The performance objectives are intentionally broad to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students.

Objectives identified by “**Enrichment:**” are considered enrichment material that may be expanded upon as time permits. Engineering standards are represented in some performance objectives with specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.**

Earth and Space Science

ESS.1 Earth in the Universe

Conceptual Understanding: The planet Earth is a very small part of a very large universe that has developed over a huge expanse of time.

ESS.1.A Students will develop an understanding of the universe, its development, immense size, and composition.

ESS.1A.1 *Describe the Big Bang theory and summarize observations (e.g., cosmic microwave background radiation, Hubble's law, and redshift caused by the Doppler effect) as evidence to support the formation and expansion of the universe.*

ESS.1A.2 *Interpret information from the Hertzsprung -Russell diagram to differentiate types of stars, including our sun, according to size, magnitude, and classification.*

ESS.1A.3 *Organize and interpret data sets for patterns and trends to compare and contrast stellar evolution in order to explain and communicate how a star changes during its life.*

ESS.1A.4 *Research and explain how nuclear fusion in stars and supernova lead to the formation of all other elements.*

Conceptual Understanding: The sun, moon, and planets have predictable patterns that are explained by forces and laws. Patterns of motion in the solar system can be described and predicted based on observations and an understanding of gravity.

ESS.1.B Students will develop an understanding of Earth, the solar system, and the laws that predict the motion of celestial bodies.

ESS.1B.1 *Read and evaluate scientific information for mechanisms/results (e.g., the solar nebular theory) to explain how the solar system was formed. Cite evidence and develop a logical argument.*

ESS.1B.2 *Compare and contrast celestial bodies (e.g., planets, natural satellites, comets, asteroids, and the Oort cloud) and their motion in our solar system (e.g., revolution and rotation). Build an Analemma calendar.*

ESS.1B.3 *Design a model (e.g., a gravity simulation using PVC and a neoprene screen) to demonstrate Kepler's laws and the relationships of the orbits of objects in our solar system. Relate them to Newton's law of universal gravitation and laws of motion.*

Earth and Space Science

ESS.2 Earth Structure and History

Conceptual Understanding: Earth's interior is divided into a solid inner core, a liquid outer core, a pliable mantle, and a solid crust. Even though the crust is solid, it is always in motion and is recycled through time.

ESS.2.A Students will develop an understanding of the structure and composition of Earth and its materials.

ESS.2A.1 *Analyze and interpret data to explain and communicate the differentiation of Earth's internal chemical structure (e.g., core, mantle, and crust) using the production of internal heat from the radioactive decay of unstable isotopes and gravitational energy.*

ESS.2A.2 *Analyze and interpret data to explain and communicate the differentiation of Earth's physical divisions (e.g., lithosphere and asthenosphere) using data from seismic waves and Earth's magnetic field.*

ESS.2A.3 *Investigate the physical and/or chemical characteristics of mineral specimens to identify minerals and mineral deposits/groups (e.g., oxides, carbonates, halides, sulfides, sulfates, silicates, and phosphates). Include the relationship between chemical bonds, chemical formulas, mineral use, and mineral properties.*

ESS.2A.4 *Investigate the physical and/or chemical characteristics of rock specimens to identify and categorize igneous, sedimentary, and metamorphic rocks. Include the processes that generate the transformation of rocks.*

Conceptual Understanding: Radioactive decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geological time. Plate tectonics is the unifying theory that explains the movements of rocks on Earth's surface and provides a comprehensive account of its geological history. Physical and chemical weathering is a result of the interactions of Earth's geosphere, hydrosphere, atmosphere, and biosphere.

- ESS.2.B Students will develop an understanding of the history and evolution of the earth.**
- ESS.2B.1** *Research, analyze, and evaluate the contributions of William Smith, James Hutton, Nicolaus Steno, Charles Lyell, and others to physical geology.*
- ESS.2B.2** *Apply different techniques (e.g., superposition, original horizontality, cross-cutting relationships, lateral continuity, principle of inclusions, fossil succession, and unconformities) to analyze and interpret the relative age of actual sequences, models, or photographs.*
- ESS.2B.3** *Use mathematical concepts to calculate the absolute age of earth materials using actual or simulated isotope ratios.*
- ESS.2B.4** *Research, analyze, and explain the origin of geologic features and processes that result from plate tectonics, including sea floor spreading, earthquake activity, volcanic activity, mountain building, and location of natural resources.*
- ESS.2B.5** *Use mathematical representations to interpret seismic graphs to triangulate the location of an earthquake's epicenter and magnitude and to correlate the frequency and magnitude of an earthquake.*
- ESS.2B.6** *Plan and conduct a scientific investigation to determine how factors (e.g., wind velocity, water velocity, ice, and temperature) may affect the rate of weathering.*
- ESS.2B.7** **Enrichment:** *Use an engineering design process to design a model to simulate the formation of caves and karst topography by groundwater.**

Earth and Space Science

ESS.3 Earth's Systems and Cycles

Conceptual Understanding: Earth's surface is comprised of the geosphere, hydrosphere, atmosphere, and biosphere, all of which are interconnected. The complex and dynamic interactions between these systems have shaped Earth, influenced climate, and shaped the evolution of life.

- ESS.3 Students will develop an understanding of the universe, its development, immense size, and composition.**
- ESS.3.1** *Use mathematical representations (e.g., latitude, longitude, and maps) to calculate the angle of noon solar incidence and relate the value to day length, distribution of sunlight, and seasonal change.*
- ESS.3.2** **Enrichment:** *Use an engineering design process to explore the concepts of passive solar architecture to design a structure that best utilizes solar incidence.**
- ESS.3.3** *Explain how temperature and density of ocean water influence circulation.*
- ESS.3.4** *Research and communicate information to explain the importance of the transfer of thermal energy among the hydrosphere, geosphere, and atmosphere. Include the unique physical and chemical properties of water, the water cycle, and energy transfer within the rock cycle.*
- ESS.3.5** *Analyze and interpret weather data using maps and global weather systems to explain and communicate the relationships among air masses, pressure systems, and frontal boundaries.*
- ESS.3.6** *Construct an explanation from data sets to obtain and evaluate scientific information to construct scientific arguments on changes in climate caused by various natural factors (e.g., plate tectonics and continent location and Milankovitch cycles) versus anthropogenic factors (e.g., fossil fuel use and agricultural factors).*

- ESS.3.7** *Cite evidence and develop logical arguments to identify the cause and effect relationships of the evolutionary milestones (e.g., photosynthesis and the atmosphere, the evolution of multicellular animals, the development of shells, and the colonization of terrestrial environments by plants and animals) that most profoundly shaped Earth's systems.*
- ESS.3.8** *Analyze and interpret the record of shared ancestry, evolution, and extinction as related to natural selection using fossils.*

Earth and Space Science

ESS.4 Earth's Resources and Human Activity

Conceptual Understanding: The dynamic Earth impacts human society. Natural hazards and other geologic events have shaped the course of human history. In addition, humans also impact the Earth through resource extraction and land use.

- ESS.4** **Students will develop an understanding of Earth's resources and the impact of human activities.**
- ESS.4.1** *Research, evaluate, and communicate about how human life on Earth shapes Earth's systems and responds to the interaction of Earth's systems (e.g., geosphere, hydrosphere, atmosphere, and biosphere). Examine how geochemical and ecological processes interact through time to cycle matter and energy and how human activity alters the rates of these processes.*
- ESS.4.2** *Research, assess, and communicate how Earth's systems influence the distribution of life, including how various natural hazards and geologic events (e.g., volcanic eruptions, earthquakes, landslides, tornadoes, and hurricanes) have shaped the course of human history.*
- ESS.4.3** *Analyze earthquake and volcanic data to determine patterns that can lead to predicting such hazards and mitigating impact to humans.*
- ESS.4.4** **Enrichment:** *Use an engineering design process to research, develop, and test models to aid in the responsible management of natural resources (e.g., recycling, composting, and energy usage).**
- ESS.4.5** **Enrichment:** *Research and communicate regarding geoscience career options (e.g., geologist, petroleum engineer, meteorologist, paleontologist, astronomer, and oceanographer).*

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

ENVIRONMENTAL SCIENCE

Environmental science, **a one-half credit course**, is a laboratory- or field-based course that explores ways in which the environment shapes living communities. Human sustainability and environmental balance are emphasized. Laboratory activities, research, the use of technology, and the effective communication of results through various methods are integral components of this course, which also emphasizes a student-centered and collaborative classroom environment.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world that increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to utilize the science and engineering practices to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. The recommendation is that students should be actively engaged in inquiry activities, laboratory experiences, and scientific research (projects) for a minimum of 30% of class time.

The standards and performance objectives do not have to be taught in the order presented in this document. The performance objectives are intentionally broad to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students.

Objectives identified by “**Enrichment:**” are considered enrichment material that may be expanded upon as time permits. Engineering standards are represented in some performance objectives with specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.**

Environmental Science

ENV.1 Biosphere and Biodiversity

Conceptual Understanding: The biosphere is a system of biomes, each with unique characteristics. These characteristics are classified as biotic or abiotic. The environment in which humans live is dependent on a system of cycles. These biogeochemical cycles are the water, nitrogen, carbon, and phosphorus cycles. The flow of energy within the environment is critical for the success of life. The biodiversity within a biome is fragile and easily affected by human actions. Plant and animal populations are dynamic and are demonstrated through graphical analysis.

ENV.1 Students will investigate the interdependence of diverse living organisms and their interactions with the components of the biosphere.

ENV.1.1 *Identify, investigate, and evaluate the interactions of the abiotic and biotic factors that determine the types of organisms that live in major biomes.*

ENV.1.2 *Evaluate evidence in nonfiction text to explain how biological or physical changes within biomes affect populations and communities and how changing conditions may result in altered ecosystems.*

ENV.1.3 *Use models to explain why the flow of energy through an ecosystem can be illustrated by a pyramid with less energy available at the higher trophic levels compared to lower levels.*

- ENV.1.4** Describe symbiotic relationships (e.g., mutualism, parasitism, and commensalism) and other co-evolutionary (e.g., predator-prey, cooperation, competition, and mimicry) relationships within specific environments.
- ENV.1.5** Develop and use models to diagram the flow of nitrogen, carbon, and phosphorus through the environment.
- ENV.1.6** Use mathematics, graphics, and informational text to determine how population density-dependent and density-independent limiting factors affect populations and diversity within ecosystems. Use technology to illustrate and compare a variety of population-growth curves.
- ENV.1.7** Analyze and interpret quantitative data to construct explanations of how the carrying capacity of an ecosystem may change as the availability of resources changes.
- ENV.1.8** Utilize data to communicate changes within a given population and the environmental factors that may have impacted these changes (e.g., weather patterns, natural disasters)
- ENV.1.9** Evaluate and communicate data that explains how human activity may impact biodiversity (e.g., introduction, removal, and reintroduction of an organism within an ecosystem; land usage) and genetic variations of organisms, including endangered and threatened species.
- ENV.1.10** **Enrichment:** Engage in scientific argument from evidence the benefits versus harm of genetically modified organisms.

Environmental Science

ENV.2 Natural Resources Use and Conservation

Conceptual Understanding: The environment is affected by human demand for its resources. However, through conservation applications, a balance may be reached between human sustainability and the environment.

- ENV.2** Students will relate the impact of human activities on the environment, conservation activities, and efforts to maintain and restore ecosystems.
- ENV.2.1** Differentiate between renewable and nonrenewable resources, and compare and contrast the pros and cons of using these resources.
- ENV.2.2** Investigate and research the pros and cons of using traditional sources of energy (e.g., fossil fuels) and alternative sources of energy (e.g., water, wind, geothermal, biomass/biofuels, solar).
- ENV.2.3** Compare and contrast biodegradable and nonbiodegradable wastes and their significance in landfills.
- ENV.2.4** Examine solutions for developing, conserving, managing, recycling, and reusing energy and mineral resources to minimize impacts in natural systems (e.g., agricultural soil use, mining for coal, construction sites, and exploration of petroleum and natural gas sources).
- ENV.2.5** Research various resources related to water quality and pollution (e.g., nonfictional text, EPA's Surf Your Watershed, MDEQ publications) and communicate the possible effects on the environment and human health.
- ENV.2.6** **Enrichment:** Obtain water from a local source (e.g., stream on campus, rainwater, ditch water) to monitor water quality over time, using a spreadsheet program to graphically represent collected data.

Environmental Science

ENV.3 Human Activities and Climate Change

Conceptual Understanding: Humans are a part of their environment and may have a detrimental impact on the environment. Using evidence based on scientific research, efforts are underway to repair the environment. Historical and current regional and global models illustrate the changes in the environment.

ENV.3 Students will discuss the direct and indirect impacts of certain types of human activities on the Earth's climate.

ENV.3.1 Use a model to describe cycling of carbon through the ocean, atmosphere, soil, and biosphere and how increases in carbon dioxide concentrations have resulted in atmospheric and climate changes.

ENV.3.2 Interpret data and climate models to predict how global and regional climate change can affect Earth's systems (e.g., precipitation, temperature, impacts on sea level, global ice volumes, and atmosphere and ocean composition).

ENV.3.3 Use satellite imagery and other resources to analyze changes in biomes over time (e.g., glacial retreat, deforestation, desertification) and propose strategies to reduce the impact of human activities leading to these issues.

ENV.3.4 **Enrichment:** Determine mathematically an individual's impact on the environment (carbon footprint, water usage, landfill contribution) and develop a plan to reduce personal contribution.

Environmental Science

ENV.4 Human Sustainability

Conceptual Understanding: Human health is dependent on the environment. Changes within an environment, whether natural or man-made, may lead to the spread of disease. Sudden environmental changes (e.g., tsunami or volcanic activity) lead to human migration into other areas of the environment. Case studies illustrate the need to intervene in environmental change, when possible, to improve health issues (e.g., smog's effect on asthma patients).

ENV.4 Students will demonstrate an understanding of the interdependence of human sustainability and the environment.

ENV.4.1 Identify human impact to develop a solution for protection of the atmosphere, considering pollutants (e.g., acid rain, air pollution, smog, ozone layer, or increased levels of greenhouse gases) and impacts on human health (e.g., asthma, COPD, emphysema, and cancer).

ENV.4.2 Evaluate data and other information to explain how key natural resources (e.g., water sources, fertile soils, concentrations of minerals, and fossil fuels), natural hazards, and climate changes influence human activity (e.g., mass migrations, human health).

ENV.4.3 **Enrichment:** Research and analyze case studies to determine the impact of human-related and natural environmental changes on human health and communicate possible solutions to reduce/resolve the dilemma.

- ENV.4.4** *Enrichment:* Explore online resources related to air pollution to determine air quality in a geographic area and communicate the possible effects on the environment and human health.
- ENV.4.5** *Enrichment:* Use an engineering design process to define a problem, design, construct, evaluate, and improve a device or method to reduce or prevent human impact on a natural resource (e.g., build a water filter, design an air purifier, develop a method to prevent parking lot pollution from entering a watershed).*

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

FOUNDATIONS OF BIOLOGY

Foundations of Biology, **a one-credit course**, is a research and inquiry-based course designed to give students the basic knowledge needed prior to attempting the rigorous Biology course required for graduation. This course is NOT a required prerequisite for Biology. However, if selected as a science elective, Foundations of Biology should not be taken after the successful completion of Biology. Concepts covered in this course include the history of biology and its impacts on society, the chemistry of life, organization and energy in living systems, the molecular basis of heredity, biological evolution, and ecological principals.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to utilize science and engineering practices to design and conduct investigations using appropriate equipment, measurement (SI units), and appropriate safety measures and practices. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. It is recommended that students should be actively engaged in inquiry activities, laboratory experiences, and scientific research (projects) for a minimum of 30% of class time.

The standards and performance objectives do not have to be taught in the order presented in this document. The performance objectives are intentionally broad to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students.

Objectives identified by “**Enrichment:**” are considered enrichment material that may be expanded upon as time permits. Engineering standards are represented in some performance objectives with specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.**

Foundations of Biology

FB.1 History of Biology and Impacts on Society

Conceptual Understanding: The history of science is a compilation of the works of many people. To understand science and its applications, the history of scientific experiments and developments must be understood. The needs of society have been the driving force behind numerous advances in science and technology. Advances in science and technology have forever changed, and will continue to change, society.

FB.1 Students will relate the importance of significant historical biological experiments and their impact of these on research, development, and society.

FB.1.1 *Identify and communicate the contributions of famous scientists and their experiments that formed fundamental scientific principles (e.g., Robert Hooke, Schleiden/ Schwann/Virchow, Griffith, Avery/MacLeod/McCarty, Hershey/Chase, Rosalind Franklin, Gregor Mendel, Watson/Crick, Pasteur, and Charles Darwin).*

- FB.1.2** *Trace and model the historical development of scientific ideas and theories (e.g., creation of the microscope, discovery of cells/cell theory, discovery of DNA/RNA, double helical shape of DNA, evolution/natural selection, endosymbiosis) through the development of a timeline.*
- FB.1.3** *Research, analyze, explain, and communicate how scientific enterprise relates to society and classic inventions (e.g., microscope, blood typing, gel electrophoresis equipment, DNA sequencing technology).*
- FB.1.5** **Enrichment:** *Research, analyze, explain, and communicate the influence of society, including cultural components, on the direction and progress of science and technology (e.g., medical treatments, emerging viruses, antibiotic resistance, vaccinations and re-emergent diseases, alternative energy development, and/or biomimicry).*

Foundations of Biology

FB.2 The Chemistry of Life

Conceptual Understanding: Living and non-living things are composed of elements. Elements have the unique ability to form compounds and molecules based on their atomic structures. Water has unique properties that allow it to form solutions with a variety of compounds. Living organisms are composed of biological molecules that interact with water and through chemical reactions, help to maintain homeostasis.

FB.2 **Students will demonstrate an understanding of the structure and interactions of matter and how the organization of matter supports living organisms.**

- FB.2.1** *Develop and use simple atomic models to describe the components of elements (e.g., relative position, charges of protons, neutrons, and electrons).*
- FB.2.2** *Obtain and use information about elements (e.g., chemical symbol, atomic number, atomic mass, and group or family) to describe the organization of the periodic table.*
- FB.2.3** *Relate chemical reactivity to an element's position on the periodic table. Use this information to determine what type of bond will form between elements (ionic, covalent, hydrogen).*
- FB.2.4** *Analyze and interpret data to classify common solutions as acids, bases, or neutral. Communicate the importance of pH in living systems.*
- FB.2.5** *Investigate how the properties of water (e.g., cohesion, adhesion, heat capacity, solvent properties) contribute to the maintenance of living cells and organisms.*
- FB.2.6** *Explain the role of the major biomolecules (carbohydrates, proteins -including enzymes, lipids, and nucleic acids) to the survival of living organisms.*
- FB.2.7** **Enrichment:** *Explore the structure of biomolecules using molecular models. Relate the structure of biomolecules to their function in living things (discuss types bonding, importance of the strength and weakness of the bond in function, energy in bonds, enzyme function).*

Foundations of Biology

FB.3 Organization and Energy in Living Systems

Conceptual Understanding: Cells are the basic unit of any living organism. All organisms are composed of one (unicellular) or many cells (multicellular). Living things use their cells to acquire energy from their environment to grow and reproduce, and then they respond and adapt to that environment for survival.

- FB.3** Students will demonstrate an understanding of how the structure of living organisms supports the essential functions of life.
- FB.3.1** Compare and contrast prokaryotic/eukaryotic and plant/animal/bacteria cells.
- FB.3.2** Use models to investigate and explain structures within living cells that support life (e.g., cytoplasm, cell membrane, cell wall, nucleus, mitochondria, chloroplasts, lysosomes, Golgi, vacuoles, ER, ribosomes, chromosomes, centrioles, cytoskeleton, nucleolus, nuclear membrane).
- FB.3.3** Compare and contrast active and passive cellular transport. Analyze the movement of water across a cell membrane in hypotonic, isotonic, and hypertonic solutions.
- FB.3.5** Analyze the relationship between photosynthesis and cellular respiration and explain that relationship in terms of the need for all living things to acquire energy from their environment.
- FB.3.6** Use models to explain how ADP and ATP cycle to store and release chemical energy using inorganic phosphate.
- FB.3.7** Compare and contrast the processes and results of mitosis and meiosis.
- FB.3.8** **Enrichment:** Research and orally communicate the possible outcomes of a failure of mitosis (cancer) or meiosis (nondisjunction).

Foundations of Biology

FB.4 Molecular Basis of Heredity

Conceptual Understanding: One strand of DNA creates a chromosome. Chromosomes have genes, which are simply segments of DNA. The information stored in DNA (in genes on chromosomes) determines the unique characteristics of an individual. DNA is the blueprint for RNA through transcription, which in turn, allows for the creation of a protein through translation. Modern technologies allow humans to manipulate DNA, RNA, and proteins to solve human dilemmas. Using technology to manipulate genetic information is controversial.

- FB.4** Students will demonstrate an understanding of how genetic information is transferred from parent to offspring.
- FB.4.1** Compare and contrast the basic structure and function of nucleic acids (e.g., DNA, RNA).
- FB.4.2** Obtain and communicate information illustrating the relationships among DNA, genes, chromosomes, and proteins to the basis of life.
- FB.4.3** Use models (e.g., Punnett squares) and mathematical reasoning to describe and predict patterns of inheritance of single genetic traits from parents to offspring (e.g., dominant, and recessive traits, incomplete dominance, codominance, multiple alleles, sex-linkage).
- FB.4.4** Obtain and communicate information to describe how mutations may affect genetic expression and provide examples.
- FB.4.5** Research and report genetic technologies that may improve the quality of life (e.g., genetic engineering, cloning, gene splicing, DNA testing).
- FB.4.6** **Enrichment:** Debate the pros and cons of using biotechnology to manipulate genetic information for human purpose (society).

Foundations of Biology

FB.5 Biological Evolution

Conceptual Understanding: The geologic time scale interpreted from rock strata and fossil evidence provides a way to organize major historical events in Earth's history. Rock strata can document the existence, diversity, extinction, and changes in many life forms. Adaptation by natural selection acting over generations is one important process by which species gradually change to respond to environmental pressures.

FB.5 Students will demonstrate an understanding of Earth's fossil record and its indication of the diversity of life over time.

- FB.5.1** *Investigate through research the contributions of scientists to the theory of evolution and evolutionary processes (e.g., Needham, Spallanzani, Redi, Pasteur, Lyell, Lamarck, Malthus, Wallace, Darwin).*
- FB.5.2** *Analyze and interpret data to support claims that different types of fossils provide evidence of the diversity of life that has existed on Earth and of the relationships between past and existing life on Earth.*
- FB.5.3** *Obtain and communicate information to explain how DNA evidence and fossil records support Darwin's theory of evolution.*
- FB.5.4** *Investigate how biological adaptations and genetic variations of traits in a population enhance the probability of survival in an environment (natural selection).*
- FB.5.5** **Enrichment:** *Create and analyze models that illustrate the relatedness between all living things (cladograms/phylogenetic trees).*

Foundations of Biology

FB.6 Ecological Principles

Conceptual Understanding: Ecosystems are dynamic in nature, full of complex interactions that affect the numbers and types of organisms that can survive. Biotic and abiotic factors affect ecosystems, allowing for them to sustain only a limited number of organisms and populations, known as a carrying capacity. There is a delicate balance that exists between the living and non-living things in an ecosystem. Humans can interrupt this balance, causing both local and global environmental issues.

FB.6 Students will understand the interdependence of living organisms and their environment.

- FB 6.1** *Ask questions to compare and contrast biotic and abiotic factors.*
- FB 6.2** *Use models to analyze the cycling of matter in an ecosystem (e.g., water, carbon dioxide/oxygen, nitrogen).*
- FB.6.3** *Obtain, evaluate, and communicate information to explain relationships that exist between abiotic and biotic components of an ecosystem. Explain how changes in biotic and abiotic components affect the balance of an ecosystem over time.*
- FB 6.4** *Develop and use models to discuss the climate, flora, and fauna of the terrestrial and aquatic biomes of the world.*
- FB 6.5** *Use models to analyze the flow of energy through food chains, webs, and pyramids.*

- FB 6.6** Engage in scientific argument from evidence to distinguish organisms that exist in symbiotic (mutualism, parasitism, commensalism) or co-evolutionary (predator-prey, cooperation, competition, and mimicry) relationships within ecosystems.
- FB 6.7** **Enrichment:** Design solutions to reduce the impact of human activity on the ecosystem.

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

FOUNDATIONS OF SCIENCE LITERACY

Foundations of Science Literacy, **a one-half credit course**, is designed as an inquiry-based ACT science preparation course in which objectives from the *ACT College and Career Readiness Standards – Science* are included. The course also includes basic skills that include analyzing technical texts and graphics (charts, graphs) along with implementing engineering processes and designs to solve problems. It is recommended that Foundations of Science Literacy be taken after the successful completion of Biology.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to utilize science and engineering practices to design and conduct investigations using appropriate equipment, measurement (SI units), and appropriate safety measures and practices. Students should design data tables and draw conclusions using mathematical computations and/or graphical analysis. It is recommended that students should be actively engaged in inquiry activities, laboratory experiences, and scientific research (projects) for a minimum of 30% of class time.

The standards and performance objectives do not have to be taught in the order presented in this document. The performance objectives are intentionally broad to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students. Exemplary lessons and resources will be presented with this course to assist teachers in developing hands-on, project-based strategies for the classroom.

Objectives identified by “**Enrichment:**” are considered enrichment material that may be expanded upon as time permits. Engineering standards are represented in some performance objectives with specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.**

Foundations of Science Literacy

FSL.1 History of Science and Impacts on Society

Conceptual Understanding: The history of science is a compilation of the works of many people. To understand science and its applications, the history of scientific experiments and developments must be understood. The needs of society have been the driving force behind numerous advances in science and technology. Advances in science and technology have forever changed, and will continue to change, society.

FSL.1 Students will relate the importance of significant historical experiments and their impact on research and development.

FSL.1.1 *Trace and model the historical development of scientific ideas and theories (e.g., atomic theory, plate tectonics, evolution, genetics, discovery of cells) through the development of a timeline.*

FSL.1.2 *Research, analyze, explain, and communicate how scientific enterprise relates to society and classic inventions (e.g., microscope, telescope, computer, and telephone).*

- FSL.1.3** *Identify and communicate the impact of mathematics and technology in the development of scientific thought and the practice of science (e.g., space exploration, the human genome project, and ocean exploration).*
- FSL.1.4** **Enrichment:** *Research, analyze, explain, and communicate the influence of society, including cultural components, on the direction and progress of science and technology (e.g., medical treatments, antibiotic resistance, alternative energy development, and biomimicry).*

Foundations of Science Literacy

FSL.2 Nature of Technology and Engineering

Conceptual Understanding: Societal demands influence the need for engineering design and technology. The goal of engineering is to design and manufacture useful devices or materials (technologies) to meet societal demands. Global challenges such as climate change, medical treatments, space exploration, food supply, and clean water drive engineering design and technology development to solve societal needs and wants. Engineering practices are critical to undertaking the world's challenges. Exposure to engineering activities sparks interest in the study of science, technology, engineering, and mathematics careers.

FSL.2 **Students will identify, research, and communicate the development of technology and engineering practices.**

- FSL.2.1** *Research and present a technology that was developed through engineering design. Identify its purpose, how it has advanced through alterations in design (e.g., systems that provide homes and businesses with utilities, parking structures, park and recreational structures, and traffic flow), and careers related to its use).*
- FSL.2.2** *Use an engineering design process to identify a problem within the local community, and propose and develop a possible solution for that problem.**
- FSL.2.3** **Enrichment:** *Use a computer simulation to model the impact of proposed solutions on a complex, real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**

Foundations of Science Literacy

FSL.3 Nature of Science

Conceptual Understanding: Science is characterized by the systematic gathering of information through various forms of direct and indirect observations, and the testing of this information by methods including, but not limited to, experimentation. By formulating their own questions, planning, and conducting investigations, learners build new meaning, understanding, and knowledge of science. This helps develop their critical thinking, reasoning and decision-making skills that will serve a learner for a lifetime.

FSL.3A **Students will apply science and engineering practices and skills to scientific investigations.**

- FSL.3A.1** *Ask questions and conduct research to generate a hypothesis, determine independent/dependent variables, and appropriate controls for scientific investigations and experiments.*

- FSL.3A.2** *Analyze data from simple experiments and construct organized models (e.g., data tables, graphs) detailing results from the experiments.*
- FSL.3A.3** *Demonstrate the proper use of safety procedures and scientific laboratory equipment. Select and use appropriate tools and instruments to collect qualitative and quantitative data.*
- FSL.3A.4** *Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for investigations, and (3) compare or combine data from two or more simple data presentations (e.g., order or sum data from a table, categorize data from a table using a scale from another table).*
- FSL.3A.5** *Analyze data sets from experiments for patterns and trends and identify any weaknesses in the experimental designs.*

Conceptual Understanding: Scientists interpret tables, graphs, and diagrams to locate data, examine relationships in the data, and extend those relationships beyond the data. Students should analyze scientific investigations and data presented in passages like those found in the science section of the ACT (e.g., Data Representation, Research Summaries, and Conflicting Viewpoint passages).

FSL.3B **Students will apply scientific literacy and thinking skills to analyze and interpret data found in various graphics including, but not limited to, those found in sample ACT science passages.**

- FSL.3B.1** *Analyze select data from a simple and complex data presentation (e.g., charts, graphs, diagrams).*
- FSL.3B.2** *Compare or combine data from two or more simple data presentations (e.g., order or sum data from a table, categorize data from a table using a scale from another table, relationships between data sets).*
- FSL.3B.3** *Translate information into a table, graph, or diagram. Determine patterns, trends, and relationships as the values of variables change.*
- FSL.3B.4** *Perform a simple interpolation or simple extrapolation using data in a table or graph. Determine and/or use a simple (e.g., linear) mathematical relationship that exists between data.*
- FSL.3B.5** *Analyze presented information when given new information (e.g., given a new scenario, how would a given scenario be changed).*

Conceptual Understanding: Scientists understand experimental design and procedures, compare designs and procedures across experiments, and understand how changes in design and procedures affect experimental results. Students should analyze scientific investigations and data presented in passages like those found in the science section of the ACT (e.g., Data Representation, Research Summaries, and Conflicting Viewpoint passages) to understand experimental designs and procedures.

FSL.3C **Students will apply scientific literacy and thinking skills to analyze scientific investigations found in various experimental designs including, but not limited to, those found in sample ACT science passages.**

- FSL.3C.1** *Analyze the methods and choice of tools used in simple and complex experimental designs.*
- FSL.3C.2** *Determine the validity of scientific questions (e.g., hypothesis) and variables for complex experimental designs.*
- FSL.3C.3** *Select and describe an alternate method for testing a hypothesis.*

- FSL.3C.4** *Predict how modifying the experimental design or adding another measurement in an experimental design will affect results of the experiment.*
- FSL.3C.5** *Determine which additional trials could be performed in an investigation to enhance the results of an experimental design.*

Conceptual Understanding: Scientists evaluate multiple explanations for the same phenomena to determine their differences, similarities, strengths, and weaknesses, and evaluating the validity of conclusions based on experimental results. They evaluate the validity of conclusions based on experimental results. Students should analyze scientific investigations and data presented in passages like those found in the science section of the ACT (e.g., Data Representation, Research Summaries, and Conflicting Viewpoint passages) to evaluate scientific explanations.

FSL.3D **Students will apply scientific literacy and thinking skills to evaluate theoretical models, inferences, and experimental results found in various experimental designs including, but not limited to, those found in sample ACT science passages.**

- FSL.3D.1** *Select the hypothesis, prediction, or conclusion that is, or is not, supported by data presentation or pieces of informational text.*
- FSL.3D.2** *Determine whether given information supports or contradicts a hypothesis or conclusion, and provide support for the reasoning.*
- FSL.3D.3** *Analyze and interpret data from informational texts and data to (1) reveal patterns and construct meaning (2) support or refute hypotheses, explanations, claims or designs, or (3) evaluate the strength of conclusions.*
- FSL.3D.4** *Use new information to make a prediction based on a theoretical model.*
- FSL.3D.5** *Select and explain why a hypothesis, prediction, or conclusion is, or is not, supported by two or more data presentations or theoretical models.*

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

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- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

GENETICS

Genetics, **a one-half credit course**, is a laboratory-based course that explores the principles of classical and molecular genetics. The structure and function relationship of DNA forms the foundation for the study of DNA inheritance, RNA and protein production, and the resulting phenotypes in organisms. Classical Mendelian genetics is explored to analyze patterns of inheritance and genetic variability within populations. Multiple applications of biotechnology are investigated to address a variety of problems in modern society.

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Genetics

GEN.1 Structure and Function of DNA

Conceptual Understanding: Chromosomes, the carriers of genetic information, are composed of both DNA and proteins. A significant body of evidence generated through multiple experiments by many scientists led to the conclusion that DNA is the universal genetic material. Once this was established, efforts focused on deciphering the structure of DNA and the mechanism through which DNA is passed on to cells with little to no errors. These discoveries formed the foundation of modern molecular genetics.

GEN.1A Students will demonstrate that all cells contain genetic material in the form of DNA.

GEN.1A.1 *Model the biochemical structure, either 3-D or computer-based, of DNA based on the experimental evidence available to Watson and Crick (Chargaff, 1950; Franklin, 1951).*

GEN.1A.2 *Assess the importance of the historical experiments that determined that DNA is the heritable material (Griffith, 1928; Avery, McCarty & MacLeod, 1944; Hershey & Chase, 1952).*

GEN.1A.3 *Relate the structure of DNA to its specific functions within the cell.*

- GEN.1A.4** *Conduct a standard DNA extraction protocol using salt, detergent, and ethanol from various cell types (e.g., plant, animal, fungus). Compare and contrast the consistency and quantity of DNA extracted from various cell types.*
- GEN.1A.5** ***Enrichment:** Use an engineering design process to refine the methodology to optimize the DNA-extraction process for various cell types.**
- GEN.1A.6** *Investigate the structural differences between the genomes (i.e., circular/linear chromosomes and plasmids) found in prokaryotes and eukaryotes.*

Conceptual Understanding: Before a cell divides, the DNA sequence of its chromosomes is replicated, and each daughter cell receives a copy. In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow.

GEN.1B **Students will analyze how the DNA sequence is copied and transmitted to new cells.**

- GEN.1B.1** *Compare and contrast various proposed models of DNA replication (i.e., conservative, semi-conservative, and disruptive). Evaluate the evidence used to determine the mechanism of DNA replication.*
- GEN.1B.2** *Develop and use models to illustrate the mechanics of DNA replication.*
- GEN.1B.3** *Microscopically observe and analyze the stages of the cell cycle (G_1 - S - G_2 - M) to describe the phenomenon, and identify methods at different cell cycle checkpoints through which the integrity of the DNA code is maintained.*

Genetics

GEN.2 Transcription, Translation, and Mutations

Conceptual Understanding: The genetic information stored in the DNA molecule is expressed to produce a protein and result in the formation of an observable trait, or phenotype, in the organism. Gene expression leads to protein production through the processes of transcription in the nucleus and translation in the ribosome.

GEN.2A **Students will analyze and explain the processes of transcription and translation in protein production.**

- GEN.2A.1.** *Compare and contrast the structure of RNA to DNA and relate this structure to the different function of each molecule.*
- GEN.2A.2** *Describe and model how the process of transcription produces RNA from a DNA template in both prokaryotes and eukaryotes.*
- GEN.2A.3** *Develop a model to show the relationship between the components involved in the mechanics of translation at the ribosome.*
- GEN.2A.4** *Analyze the multiple roles of RNA in translation. Compare the structure and function of tRNA, rRNA, mRNA, and snRNA.*
- GEN.2A.5** ***Enrichment:** Evaluate Beadle and Tatum’s “One Gene-One Enzyme Hypothesis” (1941) in the development of the central dogma ($DNA \rightarrow RNA \rightarrow Protein$). Explain how new discoveries, such as alternate splicing of introns, have led to the revision of the central dogma.*

Conceptual Understanding: Mutations may result in the formation of new gene alleles, alter protein structure, and produce new phenotypes.

GEN.2B Students will determine the causes and effects of mutations in DNA.

- GEN.2B.1** *Identify factors that cause mutations (e.g., environmental, errors in replication, and viral infections).*
- GEN.2B.2** *Explain how these mutations may result in changes in protein structure and function.*
- GEN.2B.3** *Describe cellular mechanisms that can help to minimize mutations (e.g., cell cycle checkpoints, DNA polymerase proofreading, and DNA repair enzymes).*
- GEN.2B.4** *Investigate the role of mutations and the loss of cell cycle regulation in the development of cancers.*
- GEN.2B.5** **Enrichment:** *Use an engineering design process to research the current status of genetic technology and personalized medicine, then propose and test targeted medical or forensic applications.**

Genetics

GEN.3 Biotechnological Applications

Conceptual Understanding: The application of modern molecular genetics led to the development of recombinant DNA technology and the subsequent explosion of biotechnology applications. Biotechnology and the use of genetically modified organisms have altered many aspects of daily life, including forensics, agriculture, and medicine.

GEN.3 Students will investigate biotechnology applications and bioengineering practices.

- GEN.3.1** *Explain and demonstrate the use of various tools and techniques of DNA manipulation and their applications in forensics (e.g., paternity and victim/suspect identification), agriculture (e.g., pesticide or herbicide resistance, improved yields, and improved nutritional value), and personalized medicine (e.g., targeted therapies, cancer treatment, production of insulin and human growth hormone, and engineering insect vectors of human parasites).*
- GEN.3.2** *Experimentally demonstrate genetic transformation, protein purification, and/or gel electrophoresis.*
- GEN.3.3** **Enrichment:** *Use an engineering design process to refine methodology and optimize the process of genetic transformation, protein purification, and/or gel electrophoresis.**
- GEN.3.4** **Enrichment:** *Develop logical arguments based on scientific evidence for and against ethical concerns regarding biotechnology/bioengineering.*

Genetics

GEN.4 Classic Mendelian Genetics

Conceptual Understanding: Gregor Mendel is known as the “Father of Genetics” due to his work with pea plants, which established that traits are passed from parents to offspring in predictable ways. Mendel’s findings formed the foundation from which geneticists can determine the mode of inheritance of various traits (e.g., dominant, recessive, and codominant).

- GEN.4** Students will analyze and interpret data collected from probability calculations to explain the inheritance of traits within a population.
- GEN.4.1** *Demonstrate Mendel’s law of dominance and segregation using mathematics to predict phenotypic and genotypic ratios.*
- GEN.4.2** *Illustrate Mendel’s law of independent assortment by analyzing multi-trait cross data sets for patterns and trends.*
- GEN.4.3** *Investigate traits that follow non-Mendelian inheritance patterns (e.g., incomplete dominance, codominance, multiple alleles, autosomal linkage, sex-linkage, polygenic, and epistasis).*
- GEN.4.4** *Construct pedigrees from observed phenotypes. Analyze and interpret data to determine patterns of inheritance and disease risk.*
- GEN.4.5** **Enrichment:** *Construct maps of genes on a chromosome based on data obtained from 2- and/or 3- point crosses or from recombination frequencies.*

Genetics

GEN.5 Population Genetics

Conceptual Understanding: Most species display considerable amounts of genetic variation. The variation is represented as differences in allele frequencies within the gene pool of populations of a species. Variations in the structure of gene pools form the basis of evolutionary change.

- GEN.5** Students will apply population genetic concepts to explain variability of organisms within a population.
- GEN.5.1** *Model the inheritance of chromosomes through meiotic cell division and demonstrate how meiosis and sexual reproduction lead to genetic variation in populations.*
- GEN.5.2** *Explain how natural selection acts upon genetic variability within a population and may lead to changes in allelic frequencies over time and evolutionary changes in populations.*
- GEN.5.3** *Describe processes that cause changes in allelic frequencies (e.g., nonrandom mating, small population size, immigration and emigration, genetic drift, and mutation).*
- GEN.5.4** *Apply the Hardy-Weinberg formula to analyze changes in allelic frequencies due to natural selection in a population. Relate these changes to the environmental fitness of the phenotypes.*
- GEN.5.5** **Enrichment:** *Analyze computer simulations of the effects of natural selection on allelic frequencies in a population.*
- GEN.5.6** **Enrichment:** *Apply the concept of natural selection to analyze differences in human populations (e.g., skin color, lactose persistence, sickle cell anemia, and malaria).*
- GEN.5.7** **Enrichment:** *Use genomic databases for sequence analysis and apply the information to species comparisons, evolutionary relationships, and/or determine the molecular basis of inherited disorders.*

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

HUMAN ANATOMY AND PHYSIOLOGY

Human Anatomy and Physiology, **a one-credit course**, is a laboratory-based course that investigates the structures and functions of the human body. Core content emphasizes the structure and function of cells, tissues, and organs; organization of the human body and its biochemical composition; the skeletal, muscular, nervous, endocrine, digestive, respiratory, cardiovascular, integumentary, immune, urinary, and reproductive systems; and the impact of diseases on certain systems. Laboratory activities, research, the use of technology, and the effective communication of results through various methods are integral components of this course. It is recommended that Human Anatomy and Physiology be taken after successful completion of Biology.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. It is recommended that students should be actively engaged in inquiry activities, lab experiences, and scientific research (projects) for a minimum of 30% of the class time.

The standards and performance objectives do not have to be taught in the order presented in this document. The performance objectives are intentionally broad to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students.

Objectives identified by “**Enrichment:**” are considered enrichment material that may be expanded upon as time permits. Engineering standards are represented in some performance objectives with specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.**

Human Anatomy and Physiology

HAP.1 Physiological Functions/Anatomical Structure

Conceptual Understanding: Anatomists have developed a universal set of reference terms that aid in the identification of body structures with a high degree of specificity. Body organization from simple to complex levels and an introduction to the organ systems forming the body lead to a higher understanding of anatomical structures in the human body.

HAP.1 Students will demonstrate an understanding of how anatomical structures and physiological functions are organized and described using anatomical position.

HAP.1.1 *Apply appropriate anatomical terminology when explaining the orientation of regions, directions, and body planes or sections.*

HAP.1.2 *Locate organs and their applicable body cavities and systems.*

HAP.1.3 *Investigate the interdependence of the various body systems to each other and to the body as a whole.*

Human Anatomy and Physiology

HAP.2 Cells and Tissues

Conceptual Understanding: The smallest structural and functional unit of the human body is the cell. The cell is composed of organelles that perform varied but specific functions. Cells within the human body can metabolize, digest foods, dispose of waste, reproduce, grow, move, and respond to stimuli. Groups of cells that are similar in structure and function form the four types of tissues (epithelial, connective, nervous, and muscle) found in the human body.

HAP.2 Students will demonstrate an understanding of the relationship of cells and tissues that form complex structures of the body.

HAP.2.1 *Analyze the characteristics of the four main tissue types: epithelial, connective, muscle, and nervous. Examine tissues using microscopes and other various technologies.*

HAP.2.2 *Construct a model to demonstrate how the structural organization of cells in a tissue relates to the specialized function of that tissue.*

HAP.2.3 *Enrichment: Use an engineering design process to research and develop medications (i.e., targeted cancer therapy drugs) that target uncontrolled cancer cell reproduction.**

Human Anatomy and Physiology

HAP.3 Integumentary System

Conceptual Understanding: The integumentary system is composed of epithelial membranes (i.e., skin, epidermis, mucosae, and serosae). The connective-tissue synovial membranes cover, insulate, protect, and cushion body organs as well as the entire body. The integumentary system is critical to maintaining homeostasis using internal and external regulators.

HAP.3 Students will investigate the structures and functions of the integumentary system, including the cause and effect of diseases and disorders.

HAP.3.1 *Identify structures and explain the functions of the integumentary system, including layers of skin, accessory structures, and types of membranes.*

HAP.3.2 *Investigate specific mechanisms (e.g., feedback and temperature regulation) through which the skin maintains homeostasis.*

HAP.3.3 *Analyze the causes and effects of various pathological conditions (e.g., burns, skin cancer, bacterial/viral infections, and chemical dermatitis).*

HAP.3.4 *Enrichment: Use an engineering design process to design and model/simulate effective treatments for skin disorders (e.g., tissue grafts).**

Human Anatomy and Physiology

HAP.4 Skeletal System

Conceptual Understanding: The skeletal system is composed of cartilage and bone. Together these supportive tissues form the framework for the body. The skeletal system encloses organs, attaches skeletal muscles, and connects bone, forming joints to aid in movement.

HAP.4 Students will investigate the structures and functions of the skeletal system including the cause and effect of diseases and disorders.

- HAP.4.1** Use models to compare the structure and function of the skeletal system.
- HAP.4.2** Develop and use models to identify and classify major bones as part of the appendicular or axial skeleton.
- HAP.4.3** Identify and classify types of joints and their movement.
- HAP.4.4** Demonstrate an understanding of the growth and development of the skeletal system, differentiating between endochondral and intramembranous ossification.
- HAP.4.5** Construct explanations detailing how mechanisms (e.g., Ca^{2+} regulation) are used by the skeletal system to maintain homeostasis.
- HAP.4.6** Analyze the causes and effects of various pathological conditions (e.g., bone fractures, osteoporosis, bone cancers, various types of arthritis, and carpal tunnel syndrome).
- HAP.4.7** **Enrichment:** Use an engineering design process to develop, model, and test effective treatments for bone disorders (i.e., prosthetics).*

Human Anatomy and Physiology

HAP.5 Muscular System

Conceptual Understanding: The muscular system, with the aid of three types of muscle tissue (skeletal, cardiac, and smooth), provides movement, contour and shape, joint stability, heat generation, and the transportation of materials throughout the body.

HAP.5 Students will investigate the structures and functions of the muscular system, including the cause and effect of diseases and disorders.

- HAP.5.1** Develop and use models to illustrate muscle structure, muscle locations and groups, actions, origins, and insertions.
- HAP.5.2** Describe the structure and function of the skeletal muscle fiber and the motor unit.
- HAP.5.3** Explain the molecular mechanism of muscle contraction and relaxation.
- HAP.5.4** Use models to locate the major muscles and investigate the movements controlled by each muscle.
- HAP.5.5** Compare and contrast the anatomy and physiology of the three types of muscle tissue.
- HAP.5.6** Use technology to plan and conduct an investigation to demonstrate the physiology of muscle contraction, muscle fatigue, or muscle tone. Collect and analyze data to interpret results, then explain and communicate conclusions.
- HAP.5.7** Analyze the causes and effects of various pathological conditions, (e.g., fibromyalgia, muscular dystrophy, cerebral palsy, muscle cramps/strains, and tendonitis).
- HAP.5.8** **Enrichment:** Use an engineering design process to develop effective ergonomic devices to prevent muscle fatigue and strain (e.g., carpal tunnel, exoskeletons for paralysis, or training plans to prevent strains/sprains/cramps).*

Human Anatomy and Physiology

HAP.6 Nervous System

Conceptual Understanding: The nervous system is composed of the central nervous system and the peripheral nervous system. These divisions work together to create every thought, action, and sensation that occurs within the body. The exploration of the special senses will provide an understanding of sight, hearing, smell, and taste.

HAP. 6 Students will investigate the structures and functions of the nervous system, including the cause and effect of diseases and disorders.

- HAP.6.1** *Describe and evaluate how the nervous system functions and interconnects with all other body systems.*
- HAP.6.2** *Analyze the structure and function of neurons and their supporting neuroglia cells (e.g. astrocytes, oligodendrocytes, Schwann cells, microglial).*
- HAP.6.3** *Discuss the structure and function of the brain and spinal cord.*
- HAP.6.4** *Compare and contrast the structures and functions of the central and peripheral nervous systems. Investigate how the systems interact to maintain homeostasis (e.g., reflex responses, sensory responses).*
- HAP.6.5** **Enrichment:** *Plan and conduct an experiment to test reflex response rates under varying conditions. Using technology, construct graphs in order to analyze and interpret data to explain and communicate conclusions.*
- HAP.6.6** *Describe the major characteristics of the autonomic nervous system. Contrast the roles of the sympathetic and parasympathetic nervous systems in maintaining homeostasis.*
- HAP.6.7** *Describe the structure and function of the special senses (i.e., vision, hearing, taste, and olfaction).*
- HAP.6.8** *Analyze the causes and effects of various pathological conditions (e.g., addiction, depression, schizophrenia, Alzheimer's, sports-related chronic traumatic encephalopathy [CTE], dementia, chronic migraine, stroke, and epilepsy).*
- HAP.6.9** **Enrichment:** *Use an engineering design process to develop, model, and test preventative devices for neurological injuries and/or disorders (e.g., concussion-proof helmets or possible medications for addiction and depression).**

Human Anatomy and Physiology

HAP.7 Endocrine System

Conceptual Understanding: The endocrine system, using hormones, gives instructions that control growth and development, reproductive capabilities, and the physiological homeostasis of the body systems.

HAP.7 Students will demonstrate an understanding of the major organs of the endocrine system and the associated hormonal production and regulation.

- HAP.7.1** *Obtain, evaluate, and communicate information to illustrate that the endocrine glands secrete hormones that help the body maintain homeostasis through feedback mechanisms.*
- HAP.7.2** *Discuss the function of each endocrine gland and the various hormones secreted.*
- HAP.7.3** *Model specific mechanisms through which the endocrine system maintains homeostasis (e.g., insulin/glucagon and glucose regulation; T_3 / T_4 and metabolic rates; calcitonin/parathyroid and calcium regulation; antidiuretic hormone and water balance; growth hormone; and cortisol and stress).*
- HAP.7.4** *Analyze the causes and effects of various pathological conditions (e.g., diabetes mellitus, pituitary dwarfism, Graves' disease, Cushing's syndrome, hypothyroidism, and obesity).*
- HAP.7.5** **Enrichment:** *Use an engineering design process to develop effective treatments for endocrine disorders (e.g., methods to regulate hormonal imbalance).**

Human Anatomy and Physiology

HAP.8 Male and Female Reproductive Systems

Conceptual Understanding: The reproductive system's biological function is to generate offspring for the continuance of our species. Interactions of the egg and sperm, the biological clock, and fertility play critical roles in the production of an offspring. Proper embryonic development directly depends on the health of the reproductive system.

HAP. 8 Students will investigate the structures and functions of the male and female reproductive system, including the cause and effect of diseases and disorders.

HAP.8.1 Compare and contrast the structure and function of the male and female reproductive systems.

HAP.8.2 Describe the male reproductive anatomy and relate structure to sperm production and release.

HAP.8.3 Describe the female reproductive anatomy and relate structure to egg production and release.

HAP.8.4 Construct explanations detailing the role of hormones in the regulation of sperm and egg development. Analyze the role of negative feedback in regulation of the female menstrual cycle and pregnancy.

HAP.8.5 Evaluate and communicate information about various contraceptive methods to prevent fertilization and/or implantation.

HAP.8.6 Describe the changes that occur during embryonic/fetal development, birth, and the growth and development from infancy, childhood, and adolescence to adult.

HAP.8.7 Analyze the causes and effects of various pathological conditions (e.g., infertility, ovarian cysts, endometriosis, sexually transmitted diseases, and ectopic pregnancy). Research and design effective treatments for infertility.

Human Anatomy and Physiology

HAP.9 Blood

Conceptual Understanding: Blood is the necessary fluid that transports oxygen and other elements throughout the body and removes waste products. Blood's unique composition allows for grouping into four major blood type groups (A, B, AB, and O). Blood types are based on the presence or absence of inherited antigens on the surface of the red blood cells.

HAP.9 Students will analyze the structure and functions of blood and its role in maintaining homeostasis.

HAP.9.1 Describe the structure, function, and origin of the cellular components and plasma components of blood.

HAP.9.2 Distinguish the cellular difference between the ABO blood groups and investigate blood type differences utilizing antibodies to determine compatible donors and recipients.

HAP.9.3 Analyze the causes and effects of various pathological conditions (e.g., anemia, malaria, leukemia, hemophilia, and blood doping).

HAP.9.4 **Enrichment:** Use an engineering design process to develop effective treatments for blood disorders (e.g., methods to regulate blood cell counts or blood doping tests).*

Human Anatomy and Physiology

HAP.10 Cardiovascular System

Conceptual Understanding: The cardiovascular system is composed of the heart and blood vessels. The heart is the mechanism that cycles the blood throughout the body via the blood vessels. Using blood as a carrier, the system transports nutrients, gases, wastes, antibodies, electrolytes, and many other substances to and from the cells of the body. The location, size, and orientation of the heart, blood vessels, veins, arteries, and capillaries are essential in maintaining cardiovascular health. Maintenance of this system is vital.

HAP.10 Students will investigate the structures and functions of the cardiovascular system, including the cause and effect of diseases and disorders.

HAP.10.1 *Design and use models to investigate the functions of the organs of the cardiovascular system.*

HAP.10.2 *Describe the flow of blood through the pulmonary system and systemic circulation.*

HAP.10.3 *Investigate the structure and function of different types of blood vessels (e.g., arteries, capillaries, veins). Identify the role each plays in the transport and exchange of materials.*

HAP.10.4 *Demonstrate the role of valves in regulating blood flow.*

HAP.10.5 *Plan and conduct an investigation to test the effects of various stimuli on heart rate and/or blood pressure. Construct graphs in order to analyze data and communicate conclusions.*

HAP.10.6 *Analyze the causes and effects of various pathological conditions (e.g., hypertension, myocardial infarction, mitral valve prolapse, varicose veins, and arrhythmia).*

HAP.10.7 *Enrichment: Use an engineering design process to develop, model, and test effective treatments for cardiovascular diseases (e.g., methods to regulate heart rate, artificial replacement valves, open blood vessels, or strengthening leaky valves).**

Human Anatomy and Physiology

HAP.11 Lymphatic System

Conceptual Understanding: The lymphatic system is composed of lymphoid vessels and organs. These vessels assist the cardiovascular system by maintaining blood volume. The lymphoid organs defend the body from pathogens by providing sites for development and maturation of immune system cells. There are multiple disorders of the immune system affecting the human population.

HAP. 11 Students will investigate the structures and functions of the lymphatic system, including the cause and effect of diseases and disorders.

HAP.11.1 *Analyze the functions of leukocytes, lymph, and lymphatic organs in the immune system.*

HAP.11.2 *Compare the primary functions of the lymphatic system and its relationship to the cardiovascular system.*

HAP.11.3 *Compare and contrast the body's non-specific and specific lines of defense, including an analysis of the roles of various leukocytes: basophils, eosinophils, neutrophils, monocytes, and lymphocytes.*

HAP.11.4 *Correlate the functions of the spleen, thymus, lymph nodes, and lymphocytes to the development of immunity.*

- HAP.11.5** Differentiate the role of B-lymphocytes and T-lymphocytes in the development of humoral and cell-mediated immunity and primary and secondary immune responses.
- HAP.11.6** Investigate various forms of acquired and passive immunity (e.g., fetal immunity, breastfed babies, vaccinations, and plasma donations).
- HAP.11.7** Analyze the causes and effects of various pathological conditions (e.g., viral infections, autoimmune disorders, immunodeficiency disorders, and lymphomas).

Human Anatomy and Physiology

HAP.12 Respiratory System

Conceptual Understanding: The respiratory system provides the body with an abundant and continuous supply of oxygen and removes carbon dioxide from the body. The organs of this system include the nose, pharynx, larynx, trachea, bronchi and their smaller branches, and the lungs. The interaction of these organs with the cardiovascular system transports respiratory gases to the tissue cells throughout the body. Interruptions in the mechanics of this system will lead to respiratory distress.

HAP. 12 Students will investigate the structures and functions of the respiratory system, including the cause and effect of diseases and disorders.

- HAP.12.1** Design and use models to illustrate the functions of the organs of the respiratory system.
- HAP.12.2** Describe structural adaptations of the respiratory tract and relate these structural features to the function of preparing incoming air for gas exchange at the alveolus.
- HAP.12.3** Identify the five mechanics of gas exchange: pulmonary ventilation, external respiration, transport gases, internal respiration, and cellular respiration.
- HAP.12.4** **Enrichment:** Use an engineering design process to develop a model of the mechanisms that support breathing, and illustrate the inverse relationship between volume and pressure in the thoracic cavity.*
- HAP.12.5** Analyze the causes and effects of various pathological conditions (e.g., asthma, bronchitis, pneumonia, and COPD).
- HAP.12.6** Research and discuss new environmental causes of respiratory distress (e.g., e-cigarettes, environmental pollutants, and changes in inhaled gas composition).

Human Anatomy and Physiology

HAP.13 Digestive System

Conceptual Understanding: The digestive system processes food so that it can be absorbed and used by the body's cells. The organs of the system are responsible for food ingestion, digestion, absorption, and elimination of the undigested remains from the body.

HAP.13 Students will investigate the structures and functions of the digestive system, including the cause and effect of diseases and disorders.

- HAP.13.1** Analyze the structure-function relationship in organs of the digestive system.
- HAP.13.2** Use models to describe structural adaptations present in each organ of the tract and correlate the structures to specific processing of food at each stage (e.g., types of teeth; muscular, elastic wall and mucous lining of the stomach; villi and microvilli of the small intestine; and sphincters along the digestive tract).

- HAP.13.3** *Identify the accessory organs (i.e., salivary glands, liver, gallbladder, and pancreas) for digestion and describe their function.*
- HAP.13.4** *Plan and conduct an experiment to illustrate the necessity of mechanical digestion for efficient chemical digestion.*
- HAP.13.5** *Analyze the activity of digestive enzymes within different organs of the digestive tract, connecting enzyme function to environmental factors such as pH.*
- HAP.13.6** *Evaluate the role of hormones (i.e., gastrin, leptin, and insulin) in the regulation of hunger and satiety/fullness.*
- HAP.13.7** *Analyze the causes and effects of various pathological conditions (e.g., GERD/acid reflux, stomach ulcers, lactose intolerance, irritable bowel syndrome, gallstones, appendicitis, and hormonal imbalances and obesity).*
- HAP.13.8** **Enrichment:** *Use an engineering design process to develop effective treatments for gastrointestinal diseases (e.g., methods to regulate stomach acids or soothe ulcers, treat food intolerance, and dietary requirements/modifications).**

Human Anatomy and Physiology

HAP.14 Urinary System

Conceptual Understanding: The urinary system regulates the body's homeostasis by removing nitrogenous wastes while maintaining water balance, electrolytes, and the blood's acid/base balance within the body. The kidney is the primary filtration and reabsorption organ of the urinary system, controlling the composition of urine and, in turn, regulating blood composition. Improper function of the kidneys could lead to death if not corrected.

- HAP.14** **Students will investigate the structures and functions of the urinary system, including the cause and effect of diseases and disorders.**
- HAP.14.1** *Understand the structure and function of the urinary system in relation to maintenance of homeostasis.*
- HAP.14.2** *Describe the processes of filtration and selective reabsorption within the nephrons as it relates to the formation of urine and excretion of excess materials in the blood.*
- HAP.14.3** *Investigate relationship between urine composition and the maintenance of blood sugar, blood pressure, and blood volume.*
- HAP.14.4** **Enrichment:** *Conduct a urinalysis to compare the composition of urine from various "patients."*
- HAP.14.5** *Develop and use models to illustrate the path of urine through the urinary tract.*
- HAP.14.6** *Analyze the causes and effects of various pathological conditions and other kidney abnormalities (e.g., kidney stones, urinary tract infections, gout, dialysis, and incontinence).*

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

MARINE AND AQUATIC SCIENCE I

MARINE AND AQUATIC SCIENCE II

Marine and Aquatic Science I, a one-half credit course, and Marine and Aquatic Science II, a one-half credit course, are laboratory-based courses that investigate the biodiversity of salt water and fresh water organisms, including their interactions with the physical and chemical environment. Science and engineering practices, cross-cutting concepts, nature of science, and technology are incorporated into the standards. Special emphases relating to human impacts and career opportunities are integral components of this course. Marine and Aquatic Science I must be taken before Marine and Aquatic Science II. It is recommended that Marine and Aquatic Science I and II be taken after the successful completion of Biology.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a lab-based course, students are expected to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. It is recommended that students should be actively engaged in inquiry activities, lab experiences, and scientific research (projects) for a minimum of 30% of the class time.

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Marine and Aquatic Science I

MAQ.1 Water Properties and Quality

Conceptual Understanding: Water is essential to all life on earth. The chemical and physical properties of water allow for all essential processes with biota. Analysis of water quality indicates ecosystem health and balance. Recycling of water throughout the biosphere allows for replenishment of fresh water, but contamination by human activities are hindering the total amount of potable fresh water.

MAQ.1 Students will develop an understanding of the unique physical and chemical properties of water and how those properties shape life on earth.

MAQ.1.1 *Characterize the physical and chemical properties of water, including specific heat, surface temperature, universal solvent, and hydrogen bonding between water molecules (i.e., cohesion/adhesion/capillary action).*

- MAQ.1.2** *Describe the role of water within biological systems (e.g., provides the medium necessary to allow for life processes such as protein synthesis, enzymatic reactions, and passive transport).*
- MAQ.1.3** *Diagram, utilizing digital or physical models, the water cycle and how it relates to the total amount of fresh water available to living things at any given time.*
- MAQ.1.4** *Collect, analyze, and communicate quantitative data that includes dissolved oxygen, pH, temperature, salinity, mineral content, nitrogen compounds, and turbidity from an aquatic environment (i.e., hydrometer, refractometer, Secchi disk, and chemical test kits).*
- MAQ.1.5** *Research, analyze, and communicate current technology and career opportunities available to collect this data on a global scale using CTD, buoy data, or satellites.*
- MAQ.1.6** **Enrichment:** *Use an engineering design process to reduce the effects of pollution in aquatic ecosystems (e.g., microplastics, garbage patches, oil spills, and eutrophication). Students will design a proposed solution based on current research and/or observations, and develop a model in order to test their design. Data from experimentation will be analyzed, organized graphically, and communicated to classmates to determine the effectiveness of the proposed solution.**

Marine and Aquatic Science I

MAQ.2 Fluid Dynamics

Conceptual Understanding: Fluid dynamics include properties and features of waves, currents, and tides. Each of these is vital for uniformity of temperature and chemical balance within ecosystems. Physical changes can be attributed to the movement of water, including shoreline development, erosion, and island formation. Climate change is influencing changes in our present fluid dynamic models.

MAQ.2 **Students will develop an understanding of the principles of fluid dynamics as it relates to both salt and freshwater systems.**

- MAQ.2.1** *Characterize wave features and wave properties, including wavelength, period, wave speed, breakers, and constructive waves and their effects on shoreline communities (e.g., headlands, embayments, shoreline erosion, and deposition).*
- MAQ.2.2** *Survey predictable patterns of tides (i.e., tidal period and range, diurnal, semidiurnal, mixed, spring, and neap tides) to correlate with moon phases in graphical form.*
- MAQ.2.3** *Summarize principles related to currents (e.g., global wind patterns, Coriolis effect, Ekman spiral, surface, thermohaline, upwelling, downwelling, El Niño, La Niña, hurricanes, Barrier Island movement).*
- MAQ.2.4** *Research, analyze, and communicate scientific arguments to support climate models that predict how global and regional climate change can affect Earth's systems (e.g., precipitation and temperature and their associated impacts on sea level, global ice volumes, and atmosphere and ocean composition).*
- MAQ.2.5** *Distinguish among lentic and lotic water systems, including water flow, seasonal overturn, and watershed mapping.*

Marine and Aquatic Science I

MAQ.3 Geological Features

Conceptual Understanding: Plate tectonics explain present geological features that can be described in different aquatic ecosystems. Natural phenomena, such as sea floor spreading, are caused by plate tectonic action. The distance from shoreline and availability of light classifies different areas of the ocean.

MAQ.3 Students will understand the principles of plate tectonics, sea floor spreading, and physical features of oceanic zones.

MAQ.3.1 Use geospatial data to analyze, explain, and communicate differences among the major geological features of specific aquatic ecosystems (e.g., plate tectonics, continental rise, continental slope, abyssal plain, trenches, sea mounts, island formation, and watersheds).

MAQ.3.2 Develop an understanding of plate tectonics to predict certain geological features (e.g., sea floor spreading, paleomagnetic measurements, and orogenesis).

MAQ.3.3 Classify zones of the ocean based on distance from shorelines (i.e., intertidal, neritic, oceanic, and benthic zones), temperature, and light availability (i.e., epipelagic, mesopelagic, bathypelagic, abyssopelagic, and hadopelagic).

MAQ.3.4 Classify zones of freshwater sources based on the velocity of current, depth, and temperature.

Marine and Aquatic Science I

MAQ.4 Flora and Fauna

Conceptual Understanding: Unique flora and fauna can be found in different aquatic ecosystems. Their features and unique biochemistry may serve to further the human quality of life. However, human impacts and natural events have altered many of these ecosystems in different ways.

MAQ.4 Students will examine characteristics of specific aquatic ecosystems and the effects of human and natural phenomena on those ecosystems.

MAQ.4.1 Compare and contrast the unique biotic and abiotic characteristics of the following selected aquatic ecosystems: intertidal zone, wetlands/estuaries, coral reef, barrier islands, continental slope/shelf, abyss, rivers/streams/watersheds, and lakes/ponds.

MAQ.4.2 Recognize representative examples of plants and animals that would be specifically adapted to the aquatic ecosystems, and identify adaptations necessary to survive.

MAQ.4.3 Determine the niches within trophic levels in the aquatic ecosystems by creating food webs and researching the symbiotic relationships that exist.

MAQ.4.4 Research, analyze, and communicate the effects of urbanization and continued expansion by humans on the aquatic ecosystems' biodiversity (e.g., land use changes, erosion and sedimentation, over-fishing, invasive/exotic species, and pollution).

MAQ.4.5 Explore the importance of species diversity to the biological resources needed by human populations, including food (e.g., aquaculture and mariculture), medicine, and natural aesthetics.

MAQ.4.6 Research, analyze, and communicate the effects of natural phenomena (e.g., hurricanes, floods, drought, and sea-level rise) on the aquatic ecosystems.

- MAQ.4.7** *Research, analyze, and communicate which and in what capacity local, state, and federal regulatory agencies are involved in different aquatic ecosystems, including current environmental policies already in place (e.g., the Clean Water Act and the Endangered Species Act). Research should include, but is not limited to, how humans can preserve animal diversity through the use of habitat creation and conservation, research, legislation, medical and breeding programs, and management of genetic diversity at local and global levels.*
- MAQ.4.8** **Enrichment:** *Choose an environmental issue that currently exists in one of the aquatic ecosystems and use an engineering design process to propose and develop a possible solution using scientific knowledge and best management practices (BMPs). Create an environmental action plan to include moral, legal, societal, political, and economic decisions that impact animal diversity in both the short and long term. Results from developed plans will be communicated with classmates.**

Marine and Aquatic Science II

MAQ.5 Primary Producers

Conceptual Understanding: Primary producers are the basis of every food web in aquatic ecosystems. While many producers are photosynthetic autotrophs, chemosynthesis is also a common form of energy conversion. Surveying shared and derived characteristics of producers demonstrates evolutionary development. Various methods are currently utilized to measure primary productivity in various ecosystems.

MAQ.5 **Students will explore the biodiversity and interactions among aquatic life.**

- MAQ.5.1** *Survey common primary producers and their roles in primary production in relation to geographical distribution within various aquatic ecosystems.*
- MAQ.5.2** *List and describe common autotrophs that may be found in particular aquatic ecosystems, including prokaryotes (e.g., Cyanobacteria and Archaeobacteria), protists (e.g., diatoms, dinoflagellates, green algae, kelp, sargassum, and red algae), and plants (e.g., cord grasses, reeds, seagrasses, and mangroves).*
- MAQ.5.3** *Recognize characteristics that are shared and derived using graphical representations of primary-producer evolution and develop cladograms/phylogenetic trees.*
- MAQ.5.4** *Use dichotomous keys to identify sample producers within an aquatic ecosystem.*
- MAQ.5.5** *Paraphrase energy conversion processes (e.g., photosynthesis and chemosynthesis).*
- MAQ.5.6** **Enrichment:** *Research, analyze, and communicate historical and current methodologies for measuring primary productivity. Use an engineering design process to design and develop improvements to measure primary productivity (e.g., the light and dark bottle method and satellite data).**

Marine and Aquatic Science II

MAQ.6 Invertebrate Consumers

Conceptual Understanding: Many consumers found within aquatic ecosystems range from single-celled protozoa to multicellular invertebrates. While many of these consumers share basic morphological characteristics, derived characters demonstrate evolutionary relationships. Varied adaptations are found among these organisms for successful niches within selected ecosystems.

MAQ.6 Students will investigate characteristics of aquatic invertebrates.

- MAQ.6.1** *Characterize aquatic representatives of the following taxa: Protozoa (e.g., foraminiferians, radiolarians, amoeba, and paramecium), Porifera, Cnidaria, Platyhelminthes, Nematoda, Annelida, Rotifera, Mollusca, Arthropoda, Bryozoa, Brachiopoda, and Echinodermata.*
- MAQ.6.2** *Identify characteristics that are shared and derived using graphical representations of animal evolution (i.e., cladograms and phylogenetic trees) and develop cladograms and phylogenetic trees.*
- MAQ.6.3** *Develop a dichotomous classification key to be used in the identification of sample aquatic invertebrates.*
- MAQ.6.4** *Compare and contrast major body plans (e.g., asymmetry, radial, bilateral symmetry, acoelomate, pseudocoelomate, and eucoelomate).*
- MAQ.6.5** *Explain various life cycles found among animals (e.g., polyp and medusa in cnidarians, multiple hosts and stages in the platyhelminthic life cycle, and arthropod metamorphosis).*
- MAQ.6.6** *Dissect representative taxa (e.g., clam and squid), collect data, compare their internal and external anatomy, analyze, explain, and communicate results.*
- MAQ.6.7** *Using key morphological and physiological adaptations found within animal taxa, assess how animals interact with their environment to determine their ecological roles.*
- MAQ.6.8** **Enrichment:** *Given a niche in a specific environment, use an engineering design process to design an animal, listing characteristics based on your knowledge of shared and derived characters, internal and external anatomy, and how the animal would adapt morphologically and physiologically relative to its ecological role and specific environment.**

Marine and Aquatic Science II**MAQ.7 Vertebrate Consumers**

Conceptual Understanding: Other consumers that inhabit aquatic ecosystems are found within Phylum Chordata. While many of these consumers share basic morphological characteristics, derived characteristics demonstrate evolutionary relationships. Various adaptations are found among these organisms for successful niches within selected ecosystems.

MAQ.7 Students will investigate characteristics of aquatic invertebrates.

- MAQ.7.1** *Characterize aquatic representatives of the following taxa: Hemichordata, Urochordata, Cephalochordata, and Vertebrata (including Agnatha, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves, and Mammalia).*
- MAQ.7.2** *Identify characteristics that are shared and derived using graphical representation of animal evolution, and develop cladograms/phylogenetic trees.*
- MAQ.7.3** *Utilize a dichotomous key to identify select aquatic vertebrates.*
- MAQ.7.4** *Differentiate various life cycles found among animals (e.g., egg, tadpole, and adult stages of the amphibian life cycle; leathery eggs on land in reptiles; hard-shelled eggs in Aves; placental, marsupial, or monotremes in mammals; viviparous, ovoviviparous, and oviparous animals).*
- MAQ.7.5** *Dissect representative taxa (e.g., shark, fish); collect data; compare their internal and external anatomy; and analyze, explain, and communicate results.*
- MAQ.7.6** *Using key morphological and physiological adaptations found within aquatic vertebrate taxa, assess how animals interact with their environment to determine their ecological roles.*

MAQ.7.7 *Enrichment:* Given a niche in a specific environment, use an engineering design process to design an animal, listing characteristics based on your knowledge of shared and derived characteristics, internal and external anatomy, and how the animal would adapt morphologically and physiologically relative to its ecological role and specific environment.*

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

PHYSICAL SCIENCE

Physical Science, **a one-credit course**, provides opportunities for students to develop and communicate a basic understanding of physics and chemistry through lab-based activities, integrated STEM activities, inquiry, suitable mathematical expressions, and concept exploration. The Physical Science course will prepare students for the transition to other science courses and to become informed citizens of a modern world that is constantly changing. To be successful in Physical Science, it is recommended that students have completed Algebra I (Integrated Math I) or be enrolled in this math course.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to utilize the science and engineering practices to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. It is recommended that students should actively engage in inquiry activities, laboratory experiences, and scientific research (projects) for a minimum of 30% of class time.

The standards and performance objectives do not have to be taught in the order presented in this document. The performance objectives are intentionally broad to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students.

Objectives identified by “**Enrichment:**” are considered enrichment material that may be expanded upon as time permits. Engineering standards are represented in some performance objectives with specific wording that will prompt students to approach learning and exploration using the engineering process. **These performance objectives are marked with an * at the end of the statement.**

Physical Science

PHS.1 Nature of Matter

Conceptual Understanding: To actively develop scientific investigation, reasoning, and logic skills, this standard develops basic ideas about the characteristics and structure of matter. Matter is anything that has mass and occupies space. All matter is made up of small particles called atoms. Matter can exist as a solid, liquid, gas, or plasma.

PHS.1 Students will demonstrate an understanding of the nature of matter.

PHS.1.1 *Use contextual evidence to describe particle theory of matter. Examine the particle properties of solids, liquids, and gases.*

PHS.1.2 *Use scientific research to generate models to compare physical and chemical properties of elements, compounds, and mixtures.*

PHS.1.3 *Conduct an investigation to determine the identity of unknown substances by comparing properties to known substances.*

PHS.1.4 *Design and conduct investigations to explore techniques in measurements of mass, volume, length, and temperature.*

PHS.1.5 *Design and conduct an investigation using graphical analysis (e.g., line graph) to determine the density of liquids and/or solids.*

- PHS.1.6** *Use mathematical and computational analysis to solve density problems. Manipulate the density formula to determine density, volume, or mass or use dimensional analysis to solve problems.*

Physical Science

PHS.2 Atomic Theory

Conceptual Understanding: Many scientists have contributed to our understanding of atomic structure. The atom is the basic building block of matter and consists of subatomic particles (proton, neutron, electron, and quark) that differ in their location, charge, and relative mass.

- PHS.2** **Students will demonstrate an understanding of both modern and historical theories of atomic structure.**

- PHS.2.1** *Research and develop models (e.g., 3-D models, online simulations, or ball and stick) to investigate both modern and historical theories of atomic structure. Compare models and contributions of Dalton, Thomson, Rutherford, Bohr, and of modern atomic theory.*

Physical Science

PHS.3 Periodic Table

Conceptual Understanding: The organization of the periodic table allows scientists to obtain information and develop an understanding of concepts of atomic interactions. Developing scientific investigations increases logical reasoning and deduction skills to present the nature of science in the context of key scientific concepts.

- PHS.3** **Students will analyze the organization of the periodic table of elements to predict atomic interactions.**

- PHS.3.1** *Use contextual evidence to determine the organization of the periodic table, including metals, metalloids, and nonmetals; symbols; atomic number; atomic mass; chemical families/groups; and periods/series.*
- PHS.3.2** *Using the periodic table and scientific methods, investigate the formation of compounds through ionic and covalent bonding.*
- PHS.3.3** *Using naming conventions for binary compounds, write the compound name from the formula, and write balanced formulas from the name (e.g., carbon dioxide - CO_2 , sodium chloride - NaCl , iron III oxide- Fe_2O_3 , and calcium bromide - CaBr_2).*
- PHS.3.4** *Use naming conventions to name common acids and common compounds used in classroom labs (e.g., sodium bicarbonate (baking soda), NaHCO_3 ; hydrochloric acid, HCl ; sulfuric acid, H_2SO_4 ; acetic acid (vinegar), $\text{HC}_2\text{H}_3\text{O}_2$; and nitric acid, HNO_3).*
- PHS.3.5** *Use mathematical and computational analysis to determine the atomic mass of binary compounds.*

Physical Science

PHS.4 The Law of Conservation of Matter and Energy

Conceptual Understanding: The law of conservation of matter and energy states that matter and energy can be transformed in different ways, but the total amount of mass and energy will be conserved. These concepts should be investigated and further developed in the classroom.

PHS.4 Students will analyze changes in matter and the relationship of these changes to the law of conservation of matter and energy.

PHS.4.1 *Design and conduct experiments to investigate physical and chemical changes of various household products (e.g., rusting, sour milk, crushing, grinding, tearing, boiling, and freezing) and reactions of common chemicals that produce color changes or gases.*

PHS.4.2 *Design and conduct investigations to produce evidence that mass is conserved in chemical reactions (e.g., vinegar and baking soda in a Ziploc[®] bag).*

PHS.4.3 *Apply the concept of conservation of matter to balancing simple chemical equations.*

PHS.4.4 *Use mathematical and computational analysis to examine evidence that mass is conserved in chemical reactions using simple stoichiometry problems (1:1 mole ratio) or atomic masses to demonstrate the conservation of mass with a balanced equation.*

PHS.4.5 *Research nuclear reactions and their uses in the modern world, exploring concepts such as fusion, fission, stars as reactors, nuclear energy, and chain reactions.*

PHS.4.6 *Analyze and debate the advantages and disadvantages of nuclear reactions as energy sources.*

Physical Science

PHS.5 Newton's Laws of Motion

Conceptual Understanding: Kinematics (contact forces) describe the motion of objects using words, diagrams, numbers, graphs, and equations. The goal of any study of kinematics is to develop scientific models to describe and explain the motion of real-world objects. Newton's laws of motion are an example of a tool that can aid in the explanation of motion.

PHS.5 Students will analyze the scientific principles of motion, force, and work.

PHS.5.1 *Research the scientific contributions of Newton, and use models to communicate Newton's principles.*

PHS.5.2 *Design and conduct an investigation to study the motion of an object using properties such as displacement, time of motion, velocity, and acceleration.*

PHS.5.3 *Collect, organize, and interpret graphical data using correct metric units to determine the average speed of an object.*

PHS.5.4 *Use mathematical and computational analyses to show the relationships among force, mass, and acceleration (i.e., Newton's second law).*

PHS.5.5 *Design and construct an investigation using probe systems and/or online simulations to observe relationships between force, mass, and acceleration ($F=ma$).*

PHS.5.6 *Use an engineering design process and mathematical analysis to design and construct models to demonstrate the law of conservation of momentum (e.g., roller coasters, bicycle helmets, bumper systems).*

- PHS.5.7** Use mathematical and computational representations to create graphs and formulas that describe the relationships between force, work, and energy (i.e., $W=Fd$, $KE=\frac{1}{2}mv^2$, $PE=mgh$, $W=KE$).
- PHS.5.8** Research the efficiency of everyday machines, and debate ways to improve their economic impact on society (e.g., electrical appliances, transportation vehicles).

Physical Science

PHS.6 Waves

Conceptual Understanding: Waves are everywhere in nature. Understanding of the physical world is not complete until we understand the nature, properties, and behaviors of waves. Students have experienced transverse and horizontal waves in their everyday lives. The exploration of waves in greater depth will allow students to conceptualize these waves. The goal is to develop various models of waves and apply those models to understanding wave interactions.

PHS.6 Students will explore the characteristics of waves.

- PHS.6.1** Use models to analyze and describe examples of mechanical waves' properties (e.g., wavelength, frequency, speed, amplitude, rarefaction, and compression).
- PHS.6.2** Analyze examples and evidence of transverse and longitudinal waves found in nature (e.g., earthquakes, ocean waves, and sound waves).
- PHS.6.3** Generate wave models to explore energy transference.
- PHS.6.4** **Enrichment:** Use an engineering design process to design and build a musical instrument to demonstrate the influence of resonance on music.*
- PHS.6.5** Design and conduct experiments to investigate technological applications of sound (e.g., medical uses, music, acoustics, Doppler effects, and influences of mathematical theory on music).
- PHS.6.6** Research real-world applications to create models or visible representations of the electromagnetic spectrum, including visible light, infrared radiation, and ultraviolet radiation.
- PHS.6.7** **Enrichment:** Use an engineering design process to design and construct an apparatus that forms images or magnifies images using lenses and/or mirrors.*
- PHS.6.8** **Enrichment:** Debate the particle/wave behavior of light.

Physical Science

PHS.7 Energy

Conceptual Understanding: Concepts about different energy forms and energy transformations continue to be expanded and explored in greater depth, leading to the development of more mathematical applications. Focus should be on students actively developing scientific investigations, reasoning, and logic skills.

PHS.7 Students will examine different forms of energy and energy transformations.

- PHS.7.1** *Using digital resources, explore forms of energy (e.g., potential and kinetic energy, mechanical, chemical, electrical, thermal, radiant, and nuclear energy).*
- PHS.7.2** *Use scientific investigations to explore the transformation of energy from one type to another (e.g., potential to kinetic energy, and mechanical, chemical, electrical, thermal, radiant, and nuclear energy interactions).*
- PHS.7.3** *Using mathematical and computational analysis, calculate potential and kinetic energy based on given data. Use equations such as $PE=mgh$ and $KE=\frac{1}{2}mv^2$.*
- PHS.7.4** *Conduct investigations using online simulations, probe systems, video analysis software, and/or mechanical techniques to provide evidence of the conservation of energy as energy is converted from one form of energy to another (e.g., wind to electric, chemical to thermal, mechanical to thermal, and potential to kinetic).*

Physical Science

PHS.8 Thermal Energy

Conceptual Understanding: Thermal energy is transferred in the form of heat. Heat is always transferred from an area of high heat to low heat. More complex concepts and terminology related to phase changes are developed, including the distinction between heat and temperature.

PHS.8 Students will demonstrate an understanding of temperature scales, heat, and thermal energy transfer.

- PHS.8.1** *Compare and contrast temperature scales by converting between Celsius, Fahrenheit, and Kelvin.*
- PHS.8.2** *Apply particle theory to phase change and analyze freezing point, melting point, boiling point, vaporization, and condensation of different substances.*
- PHS.8.3** *Relate thermal energy transfer to real world applications of conduction (e.g., quenching metals), convection (e.g., movement of air masses/weather/plate tectonics), and radiation (e.g., electromagnetic).*
- PHS.8.4** **Enrichment:** *Use an engineering design process to construct a simulation of heat energy transfer between systems. Calculate the calories/joules of energy generated by burning food products. Communicate conclusions based on evidence from the simulation.**

Physical Science

PHS.9 Electricity

Conceptual Understanding: Electrical energy (both battery and circuit energy) is transformed into other forms of energy. Charged particles and magnetic fields are similar because they both store energy. Magnetic fields exert forces on moving charged particles. Students investigate practical uses of these concepts and develop a working understanding of the basic concepts of magnetism and electricity.

PHS.9 Students will explore basic principles of magnetism and electricity (e.g., static electricity, current electricity, and circuits).

PHS.9.1 Use digital resources and online simulations to investigate the basic principles of electricity, including static electricity, current electricity, and circuits. Use digital resources (e.g., online simulations) to build a model showing the relationship between magnetic fields and electric currents.

PHS.9.2 Distinguish between magnets, motors, and generators, and evaluate modern industrial uses of each.

PHS.9.3 **Enrichment:** Use an engineering design process to construct a working electric motor to perform a task. Communicate the design process and comparisons of task performance efficiencies.*

PHS.9.4 Use an engineering design process to construct and test conductors, semiconductors, and insulators using various materials to optimize efficiency.*

Overarching (start to finish) SEPs for Inquiry Extension of Labs

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Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

PHYSICS

Physics, a one-credit course, provides opportunities for students to develop and communicate an understanding of matter and energy through lab-based activities, integrated STEM activities, mathematical expressions, and concept exploration. Concepts covered in this course include kinematics, dynamics, energy, mechanical and electromagnetic waves, and electricity. Laboratory activities, uses of technology, effective communication of results, and research of contemporary scientific theories through various methods are integral components of this course. Science as inquiry is an integral part of the framework, placing emphasis on developing the ability to ask questions, observe, experiment, measure, problem solve, gather data, and communicate findings. Inquiry is not an isolated unit of instruction and must be embedded throughout the content strands. All Physics laboratories need to be well equipped with the materials and apparatuses necessary to allow students to have meaningful experiences in the laboratory. To be successful in Physics, it is recommended that students have completed Algebra I, Geometry, and Algebra II (Integrated Math I, II, II), and be enrolled in an upper level math course.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to utilize the science and engineering practices to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. It is recommended that students should actively engage in inquiry activities, laboratory experiences, and scientific research (projects) for a minimum of 30% of class time.

The standards and performance objectives do not have to be taught in the order presented in this document. The performance objectives are intentionally broad to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students.

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Physics

PHY.1 One-Dimensional Motion

Conceptual Understanding: Linear motion of objects is described by displacement, velocity, and acceleration. These concepts should be introduced as computational and investigative phenomena.

PHY.1 Students will investigate and understand how to analyze and interpret data.

PHY.1.1 *Investigate and analyze evidence gained through observation or experimental design regarding the one-dimensional (1-D) motion of objects. Design and conduct experiments to generate and interpret graphical evidence of distance, velocity, and acceleration through motion.*

- PHY.1.2** Interpret and predict 1-D motion based on displacement vs. time, velocity vs. time, or acceleration vs. time graphs (e.g., free-falling objects).
- PHY.1.3** Use mathematical and computational analysis to solve problems using kinematic equations.
- PHY.1.4** Use graphical analysis to derive kinematic equations.
- PHY.1.5** Differentiate and give examples of motion concepts such as distance-displacement, speed-velocity, and acceleration.
- PHY.1.6** Design and mathematically/graphically analyze quantitative data to explore displacement, velocity, and acceleration of various objects. Use probe systems, video analysis, graphical analysis software, digital spreadsheets, and/or online simulations.
- PHY.1.7** Design different scenarios, and predict graph shapes for distance/time, velocity/time, and acceleration/time graphs.
- PHY.1.8** Perform scenario to test the accuracy of predicted graph shapes.

Physics

PHY.2 Newton's Laws

Conceptual Understanding: Motion and acceleration can be explained by analyzing the contact interaction of objects. This motion and acceleration can be predicted by analyzing the forces (i.e., normal, tension, gravitational, applied, and frictional) acting on the object and applying Newton's laws of motion.

PHY.2 Students will develop an understanding of concepts related to Newtonian dynamics.

- PHY.2.1** Identify forces acting on a system by applying Newton's laws mathematically and graphically (e.g., vector and scalar quantities).
- PHY.2.2** Use models such as free-body diagrams to explain and predict the motion of an object from simple to complex motions, including circular motion.
- PHY.2.3** Use mathematical and graphical techniques to solve vector problems and find net forces acting on a body using free-body diagrams and/or online simulations.
- PHY.2.4** Use mathematical and computational analysis to derive simple equations of motion for various systems using Newton's second law (e.g., projectile motion).
- PHY.2.5** Use mathematical and computational analysis to explore forces (e.g., friction, force applied, normal, and tension).
- PHY.2.6** Analyze real-world applications to draw conclusions about Newton's three laws of motion using online simulations, probe systems, and/or laboratory experiences.
- PHY.2.7** Design an experiment to determine the forces acting on a stationary object on an inclined plane. Test your conclusions.
- PHY.2.8** Draw diagrams of forces applied to an object, and predict the angle of incline that will result in unbalanced forces acting on the object.
- PHY.2.9** Apply the effects of the universal gravitation law to generate a digital/physical graph, and interpret the forces between two masses, acceleration due to gravity, and planetary motion. (e.g., situations where g is constant, as in falling bodies).
- PHY.2.10** Explain centripetal acceleration while undergoing uniform circular motion to explore Kepler's third law using online simulations, models, and/or probe systems.

Physics

PHY.3 Work and Energy

Conceptual Understanding: Work and energy are synonymous. When investigating mechanical energy, energy is the ability to do work. The rate at which work is done is called power. Efficiency is the ratio of power input to the output of the system. In closed systems, energy is conserved.

PHY.3 Students will develop an understanding of concepts related to work and energy.

- PHY.3.1** *Use mathematical and computational analysis to qualitatively and quantitatively analyze the concept of work, energy, and power; explain and apply the conservation of energy and momentum.*
- PHY.3.2** *Through real-world applications, draw conclusions about mechanical potential energy and kinetic energy using online simulations and/or laboratory experiences.*
- PHY.3.3** *Design and conduct investigations into the principles of impulse, and compare conservation of momentum and conservation of kinetic energy in perfectly inelastic and elastic collisions using probe systems, online simulations, and/or laboratory experiences.*
- PHY.3.4** *Investigate, collect data, and summarize the principles of thermodynamics by exploring how heat energy is transferred from higher temperature to lower temperature until equilibrium is reached.*
- PHY.3.5** *Design, conduct, and communicate investigations that explore how temperature and thermal energy relate to molecular motion and states of matter.*
- PHY.3.6** *Use mathematical and computational analysis to analyze problems involving specific heat and heat capacity.*
- PHY.3.7** *Research to compare the first and second laws of thermodynamics as related to heat engines, refrigerators, and thermal efficiency.*
- PHY.3.8** *Explore the kinetic theory of ideal gases using digital resources.*
- PHY.3.9** *Research the efficiency of everyday machines (e.g., automobiles, hair dryers, refrigerators, and washing machines).*
- PHY.3.10** **Enrichment:** *Use an engineering design process to design and build a themed Rube Goldberg-type machine that has six or more steps and complete a desired task (e.g., pop a balloon, fill a bottle, shoot a projectile, or raise an object 35 cm) within an allotted time. Include a poster that demonstrates the calculations of the energy transformation or efficiency of the machine.**

Physics

PHY.4 Waves

Conceptual Understanding: Wave properties are the transfer of energy from one place to another. The investigation of these interactions must include simple harmonic motion, sound, and electromagnetic radiation.

PHY.4 Students will investigate and explore wave properties.

- PHY.4.1** *Analyze the characteristics and properties of simple harmonic motions, sound, and light.*
- PHY.4.2** *Describe and model through digital or physical means the characteristics and properties of mechanical waves by simulating and investigating properties of simple harmonic motion.*

- PHY.4.3** Use mathematical and computational analysis to explore wave characteristics (e.g., velocity, period, frequency, amplitude, phase, and wavelength).
- PHY.4.4** Investigate and communicate the relationship between the energy of a wave in terms of amplitude and frequency using probe systems, online simulations, and/or laboratory experiences.
- PHY.4.5** Design, investigate, and collect data for comparison of standing waves and waves in specific media (e.g., stretched string, water surface, and air) using online simulations, probe systems, and/or laboratory experiences.
- PHY.4.6** Explore and explain the Doppler effect as it relates to a moving source and to a moving observer using online simulations, probe systems, and/or real-world experiences.
- PHY.4.7** Explain the laws of reflection and refraction, and apply Snell's law to describe the relationship between the angles of incidence and refraction.
- PHY.4.8** Use ray diagrams and the thin lens equations to solve real-world problems involving object distance from lenses, using a lens bench, online simulations, and/or laboratory experiences.
- PHY.4.9** Research and defend conclusions among the different bands of electromagnetic radiation, including characteristics, properties, and similarities/differences, using examples of uses of each, including radio waves, microwaves, infrared, visible light, ultraviolet, and gamma rays.
- PHY.4.10** **Enrichment:** Research the ways absorption and emission spectra are used to study astronomy and the formation of the universe.
- PHY.4.11** **Enrichment:** Research digital nonfictional text to defend the wave-particle duality of light (i.e., wave model of light and particle model of light).
- PHY.4.12** **Enrichment:** Research uses of the electromagnetic spectrum or photoelectric effect.

Physics

PHY.5 Electricity and Magnetism

Conceptual Understanding: In electrical interactions, electrical energy (whether battery or circuit energy) is transformed into other forms of energy. Charged particles and magnetic fields are similar in that they store energy. Magnetic fields exert forces on moving charged particles. Changing magnetic fields cause electrons in wires to move and thus create a current.

PHY.5 Students will investigate the key components of electricity and magnetism.

- PHY.5.1** Analyze and explain electricity and the relationship between electricity and magnetism.
- PHY.5.2** Explore the characteristics of static charge and how a static charge is generated using simulations.
- PHY.5.3** Use mathematical and computational analysis to analyze problems dealing with electric field, electric potential, current, voltage, and resistance as related to Ohm's law.
- PHY.5.4** Develop and use models (e.g., circuit drawing and mathematical representation) to explain how electric circuits work by tracing the path of electrons, including concepts of energy transformation, transfer, conservation of energy, electric charge, and resistance using online simulations, probe systems, and/or laboratory experiences.
- PHY.5.5** Design and conduct an investigation of magnetic poles, magnetic flux and field, Ampère's law, Faraday's law, and Coulomb's law using online simulations, probe systems, and/or laboratory experiences.
- PHY.5.6** Use schematic diagrams to analyze the current flow in series and parallel electric circuits, given the component resistances and the imposed electric potential.

ZOOLOGY I

ZOOLOGY II

Zoology I, a one-half credit course, and Zoology II, a one-half credit course, are laboratory-based courses that survey the nine major phyla of the Kingdom Animalia. Morphology, taxonomy, anatomy, and physiology are investigated. Comparative studies are addressed during laboratory observations and dissections. Laboratory activities, research, the use of technology, and the effective communication of results through various methods are integral components of this course. It is recommended that Zoology I and/or Zoology II be taken after the successful completion of Biology.

NOTE: Students do not have to complete Zoology I before enrolling in Zoology II. The disciplinary core idea ZOO.1, Evolution, does not have to be repeated in Zoology II if students have successfully completed Zoology I and are continuing study with Zoology II.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world that increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a lab-based course, students are expected to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. It is recommended that students should be actively engaged in inquiry activities, lab experiences, and scientific research (projects) for a minimum of 30% of the class time.

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Zoology I

ZOO.1 Evolution

Conceptual Understanding: Evolution results from the interaction of four factors: (1) the potential for a species to increase in number, (2) genetic variation occurring within a species due to mutations and sexual reproduction, (3) limited supply of resources needed for survival resulting in competition, and (4) those organisms that are better adapted for an environment survive and reproduce. Genetic information provides evidence of evolution. DNA sequences vary among species, but some similarities remain. By comparing the DNA sequences of different organisms, multiple lines of descent may be inferred. The ongoing branching into multiple lines of descent may also be derived by comparing the amino acid sequences and by examining the anatomical and embryological evidence.

ZOO.1 Students will develop a model of evolutionary change over time.

ZOO.1.1 *Develop and use dichotomous keys to distinguish animals from protists, plants, and fungi.*

ZOO.1.2 *Describe how the fossil record documents the history of life on earth.*

- ZOO.1.3** *Recognize that the classification of living organisms is based on their evolutionary history and/or similarities in fossils and living organisms.*
- ZOO.1.4** *Construct cladograms or phylogenetic trees to show the evolutionary branches of an ancestral species and its descendants.*
- ZOO.1.5** *Design models to illustrate the interaction between changing environments and genetic variation in natural selection leading to adaptations in populations and differential success of populations.*
- ZOO.1.6** **Enrichment:** *Use an engineering design process to develop an artificial habitat to meet the requirements of a population that has been impacted by human activity.**

Zoology I

ZOO.2 Phyla Porifera and Cnidaria

Conceptual Understanding: Phyla Porifera and Cnidaria are two of the most primitive of animal phyla. They distinguish themselves from other metazoans by their lack of bilateral symmetry. Each phylum has its own anatomy, physiology, and unique role in aquatic ecosystems.

- ZOO.2** **Students will understand the structure and function of Phylum (P.) Porifera and P. Cnidaria and how each adapts to their environments.**
- ZOO.2.1** *Differentiate among asymmetry, radial symmetry, and bilateral symmetry in an animal's body plan.*
- ZOO.2.2** *Identify the anatomy and physiology of a sponge, including how specialized cells within sponges work cooperatively without forming tissues to capture and digest food.*
- ZOO.2.3** *Describe the importance of P. Porifera in aquatic habitats.*
- ZOO.2.4** *Create a model, either physical or digital, illustrating the anatomy of a sponge, tracing the flow of water.*
- ZOO.2.5** **Enrichment:** *Use an engineering design process to determine the quantity of water that may be absorbed per unit in a natural sponge versus a synthetic sponge.**
- ZOO.2.6** *Contrast the polyp lifestyle of most Cnidarians with the medusa lifestyle of jellyfish, including how both utilize a single body opening.*
- ZOO.2.7** *Describe how nematocysts (stinging cells) of Cnidarians are used for capturing food and for defense.*
- ZOO.2.8** **Enrichment:** *Utilize an engineering design process to create a simulated nematocyst, including possible biomimicry use.**
- ZOO.2.9** *Describe the ecological importance of and human impacts on coral reefs.*
- ZOO.2.10** *Create a digital or physical model illustrating the anatomy of a cnidarian, citing similarities and differences between polyps and medusas.*

Zoology I

ZOO.3 Phylum Mollusca

Conceptual Understanding: Phylum Mollusca is one of the most diverse phyla on earth, occupying almost every type of ecosystem. Despite its diversity, mollusks share a basic body plan and are well adapted to their niches within environments.

ZOO.3 Students will understand the structure and function of P. Mollusca, and how they adapt to their environments.

ZOO.3.1 *Despite the diversity of mollusks, explain how they all share a common body plan (i.e., mantle, visceral mass, and foot).*

ZOO.3.2 *Describe why mollusks are classified as eucoelomates.*

ZOO.3.3 *Explain how the mantle is used in forming the shell.*

ZOO.3.4 *Describe how the radula is used in feeding.*

ZOO.3.5 *Develop a dichotomous key to contrast characteristics of gastropods, bivalves, and cephalopods.*

ZOO.3.6 *Examine how the unique characteristics of cephalopods lead to survival.*

ZOO.3.7 *Create a model comparing the anatomy of gastropods, bivalves, and cephalopods.*

ZOO.3.8 **Enrichment:** *Use an engineering design process to model the jet propulsion utilized by cephalopods in mechanical design of fluid systems (e.g., improving hydraulic systems).**

Zoology I

ZOO.4 Phyla Platyhelminthes, Nematoda, and Annelida

Conceptual Understanding: Although the term “worms” may refer to an organism with a long, slender, soft body with bilateral symmetry, worms may be subdivided into phyla based on their unique body plan. These include phyla Platyhelminthes, Nematoda, and Annelida.

ZOO.4 Students will describe the evolution of structure and function of P. Platyhelminthes, P. Nematoda, and P. Annelida.

ZOO.4.1 *Define and describe the closed circulatory system of an annelid.*

ZOO.4.2 *Differentiate between parasitic and free living.*

ZOO.4.3 *Compare and contrast the characteristics and lifestyles of flatworms, roundworms, and segmented worms.*

ZOO.4.4 *Create a model comparing acoelomate, pseudocoelomate, and eucoelomate body plans of sponges.*

ZOO.4.5 *Describe the evolutionary importance of the segmented body plans of annelids.*

ZOO.4.6 *Dissect representative taxa, and compare their internal and external anatomy and complexity.*

ZOO.4.7 **Enrichment:** *Design, conduct, and communicate results of an experiment demonstrating the importance of flatworms, roundworms, and annelids for human use (e.g., the earthworm in agriculture and the leech in medicine).*

ZOO.4.8 **Enrichment:** *Use an engineering design process to design and construct a system to utilize flatworms, roundworms, or annelids to meet a human need.**

Zoology I

ZOO.5 Phylum Arthropoda

Conceptual Understanding: Arthropods are the most successful of animal phyla, inhabiting land, sea, and air. Despite their differences, all arthropods share some characteristics enabling them to be united as one phylum.

- ZOO.5** Students will understand the basic structure and function of P. Arthropoda, and how they demonstrate the characteristics of living things.
- ZOO.5.1** Describe the evolutionary advantages of segmented bodies, hard exoskeletons, and jointed appendages to arthropods and how they contribute to arthropods being the largest phyla in species diversity and the most geographically diverse.
- ZOO.5.2** Explain how the exoskeleton is used in locomotion, protection, and development.
- ZOO.5.3** **Enrichment:** Use an engineering design process to develop a biomimicry of an arthropod's exoskeleton to meet a human need.*
- ZOO.5.4** Identify organisms and characteristics of chelicerates, crustaceans, and insects.
- ZOO.5.5** Describe the importance of toxins for arachnids, such as spiders and scorpions.
- ZOO.5.6** Describe the importance of chela for decapods, such as lobsters and crabs.
- ZOO.5.7** Differentiate between complete and incomplete metamorphosis in insects' life cycles.
- ZOO.5.8** Explain the importance of eusociality in insects, such as ants, bees, and termites.
- ZOO.5.9** Dissect representative taxa, and compare their internal and external anatomy and complexity.

Zoology I

ZOO.6 Phylum Echinodermata

Conceptual Understanding: Phylum Echinodermata contains complex organisms exhibiting pentaradial symmetry and a sophisticated water vascular system.

- ZOO.6** Students will understand the structure and function of P. Echinodermata, and how they demonstrate the characteristics of living things.
- ZOO.6.1** Recognize that the echinoderms have spines on their skin that are extensions of plates that form from the endoskeleton.
- ZOO.6.2** Explain how the starfish inverts its stomach for external digestion of food.
- ZOO.6.2** Describe sea urchins' and sea cucumbers' defense structures and behaviors.
- ZOO.6.3** Describe the sexual and asexual reproduction of starfish.
- ZOO.6.4** Describe how the water vascular system is used for locomotion, feeding, and gas exchange.
- ZOO.6.5** Research, analyze, and communicate implications of applying the regeneration of starfish to human medicine.
- ZOO.6.6** Dissect representative taxa and compare their internal and external anatomy and complexity.
- ZOO.6.7** **Enrichment:** Use an engineering design process to model the water vascular system in hydraulic systems to meet a societal need.*

Zoology II

ZOO.1 Evolution *

* This standard does not have to be repeated if students have taken Zoology I during the first term.

Conceptual Understanding: Evolution results from the interaction of four factors: (1) the potential for a species to increase in number, (2) genetic variation occurring within a species due to mutations and sexual reproduction, (3) limited supply of resources needed for survival resulting in competition, and (4) those organisms that are better adapted for an environment survive and reproduce. Genetic information provides evidence of evolution. DNA sequences vary among species, but some similarities remain. By comparing the DNA sequences of different organisms, multiple lines of descent may be inferred. The ongoing branching into multiple lines of descent may also be derived by comparing the amino acid sequences and by examining the anatomical and embryological evidence.

ZOO.1 Students will develop a model of evolutionary change over time.

ZOO.1.1 *Develop and use dichotomous keys to distinguish animals from protists, plants, and fungi.*

ZOO.1.2 *Describe how the fossil record documents the history of life on earth.*

ZOO.1.3 *Recognize that the classification of living organisms is based on their evolutionary history and/or similarities in fossils and living organisms.*

ZOO.1.4 *Construct cladograms or phylogenetic trees to show the evolutionary branches of an ancestral species and its descendants.*

ZOO.1.5 *Design models to illustrate the interaction between changing environments and genetic variation in natural selection leading to adaptations in populations and differential success of populations.*

ZOO.1.6 **Enrichment:** *Use an engineering design process to develop an artificial habitat to meet the requirements of a population that has been impacted by human activity.**

Zoology II

ZOO.7 Phylum Chordata, Classes Chondrichthyes and Osteichthyes

Conceptual Understanding: Of the members of P. Chordata, fish species are most numerous. These aquatic vertebrates have gills throughout their lives and either have or are descended from ancestors with scales or armor.

ZOO.7 Students will understand the structure and function of P. Chordata, Classes Chondrichthyes and Osteichthyes, and how they demonstrate the characteristics of living things.

ZOO.7.1 *Students will understand why evolutionary changes lead to the diversity of fish and how they have adapted to the different aquatic environments.*

ZOO.7.2 *Compare and contrast the characteristics of Class (C.) Chondrichthyes and Osteichthyes.*

ZOO.7.3 *Identify specific fish species and characteristics that differentiate C. Chondrichthyes (e.g., sharks, skates, and rays).*

ZOO.7.4 *Describe how the body and jaw design of sharks make them adept predators.*

ZOO.7.5 *Label and describe functions of the anatomical features of the bony fish, including internal organs, lateral line system, operculum, swim bladder, and external fins.*

- ZOO.7.6** *Research, analyze, and communicate the effects of urbanization and continued expansion by humans on the biodiversity of fish species (e.g., overfishing and invasive species).*
- ZOO.7.7** *Dissect representative taxa and compare their internal and external anatomy and complexity.*
- ZOO.7.8** ***Enrichment:** Use an engineering design process to design a “balloon fish” that has neutral buoyancy (i.e., does not sink or float). Report which materials were used to create the “fish,” and predict which materials should be added to make the “fish” sink and which materials would make the “fish” float.**

Zoology II

ZOO.8 Phylum Chordata, Classes Amphibia and Reptilia

Conceptual understanding: The two groups of ectothermic tetrapods—amphibians and reptiles—are similar in appearance, but differ drastically in development and body structure.

- ZOO.8** **Students will understand the structure and function of P. Chordata, Classes Amphibia and Reptilia, and how they demonstrate the characteristics of living things.**
- ZOO.8.1** *Understand the evolution of tetrapods and the development of the structure and function of body systems and life cycles.*
- ZOO.8.2** *Describe the constraints that require amphibians to spend part of their lives in water and part on land, including the morphological and physiological changes as they pass from one stage of their life cycle to the next.*
- ZOO.8.3** *Describe adaptations that have led to reptiles living on land successfully.*
- ZOO.8.4** *Define what it means to be ectothermic, and identify ways in which reptiles regulate their body temperature.*
- ZOO.8.5** *Describe how snakes use chemosensory to locate and track prey.*
- ZOO.8.6** ***Enrichment:** Use an engineering design process to model biomimicry of ectothermic temperature regulation or chemosensory detection to meet a societal need.**
- ZOO.8.7** *Compare and contrast living and extinct reptiles.*
- ZOO.8.8** *Explain the importance of tetrapod evolution.*
- ZOO.8.9** *Identify the amniotic egg as the major derived characteristic of reptiles.*
- ZOO.8.10** *Dissect representative taxa and compare their internal and external anatomy and complexity.*

Zoology II

ZOO.9 Phylum Chordata, Class Aves

Conceptual understanding: Class Aves, including birds, are endothermic, egg-laying vertebrates with bodies covered in feathers. Although they are descendants of dinosaurs, they have evolved a unique physiology, making most capable of flight.

- ZOO.9** **Students will understand the structure and function of P. Chordata, Class Aves, and how they demonstrate the characteristics of living things.**
- ZOO. 9.1** *Trace the evolutionary history of modern birds beginning with the theropods. Relate how today’s birds have adapted to changing environments.*

- ZOO. 9.2** Describe the fossil evidence that indicates that birds evolved from two-legged dinosaurs called theropods.
- ZOO. 9.3** Define the term endothermic, and describe how birds regulate body temperature in extreme environments.
- ZOO. 9.4** **Enrichment:** Use an engineering design process to model biomimicry of endothermic temperature regulation to meet a societal need.*
- ZOO. 9.5** Explain how birds of prey use their keen sense of sight to locate and attack prey.
- ZOO. 9.6** Describe how corvids use their intellect for problem solving and locating food storage.
- ZOO. 9.7** Explain the importance of the evolution of flight and feathers, including the morphological and physiological adaptations needed to sustain flight.
- ZOO. 9.8** **Enrichment:** Use an engineering design process to utilize a bird's flight adaptations in the development of a flying aircraft (e.g., glider, plane).*
- ZOO. 9.9** Demonstrate how different adaptations of the bird beak and feet allow them to feed and survive in different environments.
- ZOO. 9.10** **Enrichment:** Use an engineering design process to develop a biomimicry of a bird's beak/feet to meet a societal need.*
- ZOO. 9.11** Describe the parenting behavior of different birds in order to incubate their eggs and care for hatchlings.
- ZOO. 9.12** **Enrichment:** Use an engineering design process to design and construct an incubator for hatching abandoned eggs.*
- ZOO. 9.13** Explain the reasons for bird migration and the innate behavior of migratory birds.
- ZOO. 9.14** Dissect representative taxa and compare their internal and external anatomy and complexity.

Zoology II

ZOO.10 Phylum Chordata, Class Mammalia

Conceptual Understanding: Class Mammalia consists of endothermic organisms with hair, a four-chambered heart, a diaphragm, and mammary glands. As inhabitants of every continent, they are successful in a great variety of ecosystems.

ZOO.10 Students will understand the structure and function of P. Chordata, Class Mammalia, and how they demonstrate the characteristics of living things.

- ZOO 10.1** Understand the characteristics and behaviors that distinguish mammals from other phyla, and use characteristics and behaviors to distinguish the major orders, including primates. Explain how human impact has changed the environments of other organisms.
- ZOO 10.2** Describe the characteristics of the first true mammal.
- ZOO 10.3** Distinguish among monotremes, marsupials, and eutherians, and describe the importance and differences in the placenta in marsupials and eutherians.
- ZOO 10.4** Describe characteristics that make primates unique, including investigating how the center of gravity relates to the evolution of bipedalism.
- ZOO 10.5** Dissect representative taxa and compare their internal and external anatomy and complexity.
- ZOO 10.6** Explain how human impacts have changed the environment of aquatic and terrestrial organisms (e.g., habitat destruction, urbanization, and climate change).
- ZOO 10.7** **Enrichment:** Use an engineering design process to develop a possible solution to an environmental issue that currently exists in an ecosystem.*

Overarching (start to finish) SEPs for Inquiry Extension of Labs

Ask questions to generate hypotheses for scientific investigations based on empirical evidence and observations and/or ask questions to **clarify or refine** models, explanations, or **designs**.

Plan and conduct controlled scientific investigations to produce data to answer questions, test hypotheses and predictions, and develop explanations or **evaluate design solutions**, which require the following:

- Identify dependent and independent variables and appropriate controls.
- Select and use appropriate tools or instruments to collect data, and represent data in an appropriate form.
- Analyze and interpret various types of data sets, using appropriate mathematics, in order to verify or refute the hypothesis or **determine an optimal design solution**.
- Construct an explanation of observed relationships between variables.
- Communicate scientific and/or **technical information** in various formats.

