ARKANSAS

K-12 SCIENCE STANDARDS

EDUCATION FOR A NEW GENERATION

Physical Science - Integrated

2016

Table of Contents

Notes:

1. Student Performance Expectations (PEs) may be taught in any sequence or grouping within a grade level. Several PEs are described as being "partially addressed in this course" because the same PE is revisited in a subsequent course during which that PE is fully addressed.
2. An asterisk (*) indicates an engineering connection to a practice, core idea, or crosscutting concept.
3. The Clarification Statements are examples and additional guidance for the instructor. AR indicates Arkansas-specific Clarification Statements.
4. The Assessment Boundaries delineate content that may be taught but not assessed in large-scale assessments. AR indicates Arkansas-specific Assessment Boundaries.
5. The section entitled "foundation boxes" is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.
6. The examples given (e.g.,) are suggestions for the instructor.
7. Throughout this document, connections are provided to the nature of science as defined by *A Framework for K-12 Science Education* (NRC 2012).
8. Throughout this document, connections are provided to Engineering, Technology, and Applications of Science as defined by *A Framework for K-12 Science Education* (NRC 2012).
9. Each set of PEs lists connections to other disciplinary core ideas (DCIs) within the Arkansas K-12 Science Standards and to the Arkansas English Language Arts Standards, Arkansas Disciplinary Literacy Standards, and the Arkansas Mathematics Standards.

Arkansas K-12 Science Standards Overview

The Arkansas K-12 Science Standards are based on *A Framework for K-12 Science Education* (NRC 2012) and are meant to reflect a new vision for science education. The following conceptual shifts reflect what is new about these science standards. The Arkansas K-12 Science Standards

- reflect science as it is practiced and experienced in the real world,
- build logically from Kindergarten through Grade 12,
- focus on deeper understanding as well as application of content,
- integrate practices, crosscutting concepts, and core ideas, and
- make explicit connections to literacy and math.

As part of teaching the Arkansas K-12 Science Standards, it will be important to instruct and guide students in adopting appropriate safety precautions for their student-directed science investigations. Reducing risk and preventing accidents in science classrooms begin with planning. The following four steps are recommended in carrying out a hazard and risk assessment for any planned lab investigation:

1. Identify all hazards. Hazards may be physical, chemical, health, or environmental.
2. Evaluate the type of risk associated with each hazard.
3. Write the procedure and all necessary safety precautions in such a way as to eliminate or reduce the risk associated with each hazard.
4. Prepare for any emergency that might arise in spite of all of the required safety precautions.

According to Arkansas Code Annotated § 6-10-113 (2012) for eye protection, every student and teacher in public schools participating in any chemical or combined chemical-physical laboratories involving caustic or explosive chemicals or hot liquids or solids is required to wear industrial-quality eye protective devices (eye goggles) at all times while participating in science investigations.

The Arkansas K-12 Science Standards outline the knowledge and science and engineering practices that all students should learn by the end of high school. The standards are three-dimensional because each student performance expectation engages students at the nexus of the following three dimensions:

- Dimension 1 describes scientific and engineering practices.
- Dimension 2 describes crosscutting concepts, overarching science concepts that apply across science disciplines.
- Dimension 3 describes core ideas in the science disciplines.

Science and Engineering Practices

The eight practices describe what scientists use to investigate and build models and theories of the world around them or that engineers use as they build and design systems. The practices are essential for all students to learn and are as follows:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

The seven crosscutting concepts bridge disciplinary boundaries and unit core ideas throughout the fields of science and engineering. Their purpose is to help students deepen their understanding of the disciplinary core ideas, and develop a coherent, and scientifically based view of the world. The seven crosscutting concepts are as follows:

1. *Patterns*- Observed patterns of forms and events guide organization and classification, and prompt questions about relationships and the factors that influence them.
2. *Cause and effect- Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. *Scale, proportion, and quantity*- In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. *Systems and system models*- Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. *Energy and matter: Flows, cycles, and conservation*- Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. *Structure and function*- The way in which an object or living thing is shaped and its substructure determines many of its properties and functions.
7. *Stability and change*- For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Disciplinary Core Ideas

The disciplinary core ideas describe the content that occurs at each grade or course. The Arkansas K-12 Science Standards focus on a limited number of core ideas in science and engineering both within and across the disciplines and are built on the notion of learning as a developmental progression. The Disciplinary Core Ideas are grouped into the following domains:

- Physical Science (PS)
- Life Science (LS)
- Earth and Space Science (ESS)
- Engineering, Technology and Applications of Science (ETS)

Connections to the Arkansas English Language Arts Standards

Evidence-based reasoning is the foundation of good scientific practice. The Arkansas K-12 Science Standards incorporate reasoning skills used in language arts to help students improve mastery and understanding in all three disciplines. The Arkansas K-8 Science Committee made every effort to align grade-by-grade with the English language arts (ELA) standards so concepts support what students are learning in their entire curriculum. Connections to specific ELA standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons.

The intersections between Arkansas K-12 Science Standards and Arkansas ELA Standards teach students to analyze data, model concepts, and strategically use tools through productive talk and shared activity. Reading in science requires an appreciation of the norms and conventions of the discipline of science, including understanding the nature of evidence used, an attention to precision and detail, and the capacity to make and assess intricate arguments, synthesize complex information, and follow detailed procedures and accounts of events and concepts. These practice-based standards help teachers foster a classroom culture where students think and reason together, connecting around the subject matter and core ideas.

Connections to the Arkansas Disciplinary Literacy Standards

Reading is critical to building knowledge in science. College and career ready reading in science requires an appreciation of the norms and conventions of each discipline, such as the kinds of evidence used in science; an understanding of domain-specific words and phrases; an attention to precise details; and the capacity to evaluate intricate arguments, synthesize complex information, and follow detailed descriptions of events and concepts. When reading scientific and technical texts, students need to be able to gain knowledge from challenging texts that often make extensive use of elaborate diagrams and data to convey information and illustrate concepts. Students must be able to read complex informational texts in science with independence and confidence because the vast majority of reading in college and workforce training programs will be sophisticated nonfiction.

For students, writing is a key means of asserting and defending claims, showing what they know about science, and conveying what they have experienced, imagined, thought, and felt. To be college and career ready writers, students must take task, purpose, and audience into careful consideration, choosing words, information, structures, and formats deliberately. They need to be able to use technology strategically when creating, refining, and collaborating on writing. They have to become adept at gathering information, evaluating sources, and citing material accurately, reporting finds from their research and analysis of sources in a clear and cogent manner. They must have the flexibility, concentration, and fluency to produce high-quality first-draft text under a tight deadline and the capacity to revisit and make improvements to a piece of writing over multiple drafts when circumstances encourage or require it.

Connections to the Arkansas Mathematics Standards

Science is a quantitative discipline, so it is important for educators to ensure that students' science learning coheres well with their understanding of mathematics. To achieve this alignment, the Arkansas K-12 Science Committee made every effort to ensure that the mathematics standards do not outpace or misalign to the grade-by-grade science standards. Connections to specific math standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons.

How to Read
Arkansas K-12 Science

Topic

An asterisk indicates an engineering connection to a practice or disciplinary core idea.

GRADE TWO

Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

2-LS2-1 Plan and conduct an investigation to determine if plants need sunlight and water to grow. [Assessment Boundary: Assessment is limited to testing one variab

2-LS2-2 Develop a simple model that mimics the function o ...**eeds or pollinating plants.** *

2-LS4-1 Make observations of plants and animals to compa ...**fferent habitats.** [Clarification Statement: Emphasis is on the diversity of living things ... [Assessment Boundary: Assessment does not include specific animal and plant names in specific habitats.]

Student Performance Expectations (PEs)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions. ▪ Develop a simple model based on evidence to represent a proposed object or tool. (2-LS2-2) **Planning and Carrying Out Investigations** Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. ▪ Plan and conduct an investig... collaboratively to produce da... as the basis for evidence to a... question. (2-LS2-1) ▪ Make observations (firsthand or from media) to collect data that can be used to make comparisons. (2-LS4-1) --- **Connections to Nature of Science** **Scientific Knowledge is Based on Empirical Evidence** ▪ Scientists look for patterns and order when making observations about the world. (2-LS4-1)	**LS2.A: Interdependent Relationships in Ecosystems** ▪ Plants depend on water and light to grow. (2-LS2-1) ▪ Plants depend on animals for pollination or to move their seeds around. (2-LS2-2) **LS4.D: Biodiversity and Humans** ▪ There are many different kinds of living things in any area, and they exist in different places on land and in water. (2-LS4-1) **ETS1.B: Developing Possible Solutions** ▪ Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (2-LS2-2) ▪	**Cause and Effect** ▪ Events have causes that generate observable patterns. (2-LS2-1) **Structure and Function** ▪ The shape and stability of structures of natural and designed objects are related to their function(s). (2-LS2-2)

Designates which PE uses this practice

Designates which PE incorporates this disciplinary core idea (DCI)

Designates which PE incorporates this crosscutting concept (CC)

Connections to the Nature of Science

DCI codes from *A Framework for K-12 Science Education* in boldface type.

Connections to other DCIs in second grade: N/A

Connections to other DCIs across grade levels: **K.LS1.C** (2-LS2-1); **K-ESS3.A** (2-LS2-1); **K-2.ETS1.A** (2-LS2-2); **3.LS4.C** (2-LS4-1); **3.LS4.D** (2-LS4-1); **5.LS1.C** (2-LS2-1); **5.LS2.A** (2-LS2-2, 2-LS4-1)

Connections to the Arkansas English Language Arts and Mathematics Standards are often found by scrolling to the next page

Physical Science - Integrated Course Learning Progression Chart

Topic 1: Elements, Matter, and Interactions	Topic 2: Matter in Organisms	Topic 3: Forces and Motion	Topic 4: Energy	Topic 5: Waves	Topic 6: Interactions of Humans and the Environment
AR PSI-PS1-1	PSI-LS1-5	AR PSII-PS2-1	AR PSI-PS3-1	AR PSI-PS4-1	AR PSI-LS2-7
AR PSI-PS1-2	AR PSI-LS1-7	PSI-PS2-3	AR PSI-PS3-2	PSI-PS4-2	AR PSI-LS4-5
AR PSI-PS1-3	AR PSI-LS2-4	PSI-PS2-5	PSI-PS3-3	AR PSI5-ETS1-2	AR PSI-ESS2-1
PSI-PS1-4	AR PSI2-ETS1-2	PSI-PS2-6	PSI-PS3-4		AR PSI-ESS3-1
AR PSI-PS1-7		AR PSI-ESS1-5	AR PSI4-ETS1-3		AR PSI-ESS3-2
AR PSI-ESS2-7		AR PSI3-ETS1-1			AR PSI6-ETS1-1
					AR PSI6-ETS1-2
					AR PSI6-ETS1-3
					AR PSI6-ETS1-4

Arkansas Clarification Statement/Assessment Boundary (AR)

Physical Science - Integrated Course Overview

(Course code 423000)

The Arkansas K-12 Science Standards for physical science - integrated is an integrated science course that focuses on conceptual understanding of foundational core ideas, science and engineering practices, and crosscutting concepts, and is composed of physical science, Earth and space science, life science, and engineering design standards. Students will earn 1 unit of Smart Core/physical science credit for graduation. It is recommended that students be enrolled in Algebra I concurrently with this course. Teachers with chemistry, physics, physical science, physical/Earth, and physics/math licenses are qualified to teach this course.

Students in physical science - integrated continue to develop their understanding of the core ideas in the physical, life, and earth and space sciences learned in middle school. These ideas include the most fundamental concepts from chemistry, physics, biology, and Earth and space science but are intended to leave room for expanded study in upper-level high school courses. The performance expectations in physical science - integrated build on the middle school ideas and skills and allow high school students to explain more in-depth phenomena central not only to the physical sciences, but to life and earth and space sciences as well. There are six topics in physical science - integrated: (1) Elements, Matter, and Interactions, (2) Matter in Organisms, (3) Forces and Motion, (4) Energy, (5) Waves, and (6) Interactions of Humans and the Environment.

The performance expectations (standards) for physical science - integrated blend physical science, life science, and Earth and space science core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge to explain ideas across the science disciplines. Students are also expected to demonstrate understanding of several engineering practices, including design and evaluation. Connections with other science disciplines help high school students develop these capabilities in various contexts. For example, in the life sciences students are expected to design, evaluate, and refine a solution for reducing human impact on the environment (PSI-LS2-7). In the physical sciences students solve problems by applying their engineering capabilities along with their knowledge of conditions for forces during collisions (PS-PS2-3) and conversion of energy from one form to another (PSI-PS3-3). In the Earth and space sciences students apply their engineering capabilities to reduce human impacts on Earth systems, and improve social and environmental cost-benefit ratios (PSI-ESS3-2).

Additionally, it should be noted the physical science - integrated standards are not intended to be used as curriculum. Instead, the standards are the minimum that students should know and be able to do. Therefore, teachers should continue to differentiate for the needs of their students by adding depth and additional rigor.

Students in physical science - Integrated also continue their ability to develop possible solutions for major global problems with engineering design challenges. At the high school level, students are expected to engage with major global issues at the interface of science, technology, society and the environment, and to bring to light the kinds of analytical and strategic thinking that prior training and increased maturity make possible. As in prior levels, these capabilities can be thought of in three stages:

- **Defining the problem** at the high school level requires both qualitative and quantitative analysis. For example, the need to provide food and fresh water for future generations comes into sharp focus when considering the speed at which the world population is growing and conditions in countries that have experienced famine. While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering.
- **Developing possible solutions** for major global problems begins by breaking them down into smaller problems that can be tackled with engineering methods. To evaluate potential solutions, students are expected to not only consider a wide range of criteria but to also recognize that criteria

needs to be prioritized. For example, public safety or environmental protection may be more important than cost or even functionality. Decisions on priorities can then guide tradeoff choices.

- **Improving designs** at the high school level may involve sophisticated methods, such as using computer simulations to model proposed solutions. Students are expected to use such methods to take into account a range of criteria and constraints, anticipate possible societal and environmental impacts, and test the validity of their simulations by comparison to the real world.

Physical Science - Integrated Topics Overview

(Course code 423000)

The performance expectations in **Topic 1: Elements, Matter, and Interactions** help students formulate an answer to these questions:

- How can one explain the structure and properties of matter?
- How do substances combine or change (react) to make new substances?
- How does one characterize and explain these reactions and make predictions about them?

Students develop an understanding of the substructure of atoms and provide more mechanistic explanations of the properties of substances. Students use the periodic table as a tool to explain and predict the properties of elements. Phenomena involving nuclei are also important to understand, as they explain the formation and abundance of the elements. The crosscutting concepts of patterns, and energy and matter are called out as organizing concepts for these disciplinary core ideas. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Using this expanded knowledge of chemical reactions, students explain important biological and geophysical phenomena. In these performance expectations, students demonstrate proficiency in developing and using models, planning and conducting investigations, and communicating scientific and technical information, and to use these practices to demonstrate understanding of the core ideas.

The performance expectations in **Topic 2: Matter in Organisms** help students answer these questions:

- How do organisms obtain and use energy they need to live and grow?
- How do matter and energy move through ecosystems?

High school students can construct explanations for the role of energy in the cycling of matter in organisms and ecosystems. Students apply mathematical concepts to develop evidence to support explanations of the interactions of photosynthesis and cellular respiration and develop models to communicate these explanations. Students relate the nature of science to how explanations may change in light of new evidence and the implications for our understanding of the tentative nature of science. Students understand organisms' interactions with each other and their physical environment, how organisms obtain resources, change the environment, and how these changes affect both organisms and ecosystems. In addition, students utilize the crosscutting concepts of matter and energy to make sense of ecosystem dynamics.

The performance expectations in **Topic 3: Forces and Motion** help students answer the question:

- How can one explain and predict interactions between objects and within systems of objects?

The topic is organized into two ideas: forces and motion and types of interactions. Students build an understanding of forces and interactions and Newton's Second Law. Students also develop understanding that the total momentum of a system of objects is conserved when there is no net force on the system. Students are able to use Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. Students are able to apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. Students demonstrate proficiency in planning and conducting investigations, analyzing data and using math to support claims, and applying scientific ideas to solve design problems, and to use these practices to demonstrate understanding of the core ideas. The crosscutting concepts of cause and effect and structure and function are called out as organizing concepts for these disciplinary core ideas.

The performance expectations in **Topic 4: Energy** help students answer the question:

- How do forces and energy affect matter?

Students develop a computational model to calculate the change in energy within components of a system. Students are able to use models to illustrate energy at a macroscopic scale. In the PS3 performance expectations, students demonstrate proficiency in developing and using models, planning and conducting investigations, using math to support claims, applying scientific ideas to solve design problems, and to use these practices to demonstrate understanding of the core ideas. The crosscutting concepts of systems and system models and energy and matter are called out as organizing concepts for these disciplinary core ideas.

The performance expectations in **Topic 5: Waves** help students understand how many new technologies work and answer the question:
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- How are waves used to transfer energy and send and store information?

Students apply understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances, store information, and investigate nature on many scales. Students understand that combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Students also demonstrate their understanding of engineering ideas by presenting information about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. Students demonstrate proficiency in asking questions and using mathematical thinking to demonstrate understanding of the core ideas. The crosscutting concepts of cause and effect and stability and change are highlighted as organizing concepts for these disciplinary core ideas.

The performance expectations in **Topic 6: Interactions of Humans and the Environment** help students answer these questions:

- How do humans depend on Earth's resources?
- How do people model and predict the effects of human activities on Earth's climate?

There are strong connections to mathematical practices of analyzing and interpreting data. The performance expectations strongly reflect the many societally relevant aspects of Earth and space science (resources, hazards, and environmental impacts) with an emphasis on using engineering and technology concepts to design solutions to challenges facing human society. Students understand the complex and significant interdependencies between humans and the rest of Earth's systems through the impacts of natural hazards, our dependencies on natural resources, and the environmental impacts of human activities. In the life science performance expectations, students are expected to demonstrate proficiency in the use of computer simulation models and engaging in argument from evidence; and to use these practices to demonstrate understanding of the core ideas. The crosscutting concepts of stability and change; cause and effect; and systems and system models are called out as organizing concepts for these disciplinary core ideas. While the performance expectations couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices that lead to the performance expectations.

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Physical Science - Integrated

Topic 1: Elements, Matter, and Interactions

Students who demonstrate understanding can:

PSI-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. [AR Clarification Statement: This PE is partially addressed in this course. Examples of properties that could be predicted from patterns could include types of bonds (ionic and covalent) formed, numbers of bonds formed, and hydrogen bonds in water.] [Assessment Boundary: Assessment is limited to main group elements.]

PSI-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. [AR Clarification Statement: This PE is partially addressed in this course. Examples could include recognizing patterns to identify types of chemical reactions, such as, combustion, single replacement, double replacement, decomposition and synthesis.] [Assessment Boundary: Assessment does not include predicting chemical products.]

PSI-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. [AR Clarification Statement: This PE is partially addressed in this course. Emphasis is on understanding of the strengths of forces between particles including hydrogen bonding in water. Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [AR Assessment Boundary: Assessment limited to materials of same states of matter.]

PSI-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. [Clarification Statement: This PE is partially addressed in this course. Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]

PSI-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. [AR Clarification Statement: This PE is partially addressed in this course. Emphasis is on demonstrating conservation of atoms through balancing chemical equations and assessing students' use of mathematical thinking, not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include the mole concept or complex chemical reactions.]

PSI-ESS2-7 Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth. [AR Clarification Statement: This PE is partially addressed in this course. Emphasis in this course is on identifying and describing the evidence for simultaneous co-evolution and the causes, effects, and feedbacks between the biosphere and Earth's other systems. Geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples could include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of life forms.] [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. ▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (PSI-PS1-4) ▪ Use a model to predict the relationships between systems or between components of a system. (PSI-PS1-1) **Planning and Carrying Out Investigations** Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. ▪ Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (PSI-PS1-3) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ▪ Use mathematical representations of phenomena to support claims. (PSI-PS1-7)	**PS1.A: Structure and Properties of Matter** ▪ Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (PSI-PS1-1) ▪ The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (PSI-PS1-1,PS-PS1-2) ▪ The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (PSI-PS1-3,PSI-PS2-6) ▪ A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (PSI-PS1-4) **PS1.B: Chemical Reactions** ▪ Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (PSI-PS1-4) ▪ The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (PSI-PS1-2, PSI-PS1-7) **PS2.B: Types of Interactions** ▪ Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (PSI-PS1-1, PSI-PS1-3)	**Patterns** ▪ Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (PSI-PS1-1,PSI-PS1-2, PSI -PS1-3) **Energy and Matter** ▪ The total amount of energy and matter in closed systems is conserved. (PSI-PS1-7) ▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (PSI-PS1-4) -- ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ▪ Science assumes the universe is a vast single system in which basic laws are consistent. (PSI-PS1-7)

Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. ▪ Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (PSI-PS1-2)	**ESS2.D: Weather and Climate** ▪ Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (PSI-ESS2-7) **ESS2.E: Biogeology** ▪ The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (PSI-ESS2-7)	

Connections to other DCIs in this course: **PSI.PS3.A** (PSI-PS1-4,PSI-PS1-8); **PSI.PS3.B** (PSI-PS1-4,PSI-PS1-7); **PSI.PS3.D** (PSI-PS1-4); **PSI.LS1.C** (PSI-PS1-1,PSI-PS1-2,PSI-PS1-4,PSI-PS1-7); **PSI.LS2.B** (PSI-PS1-7)

Connections to DCIs across grade-bands: **7.PS1.A** (PSI-PS1-1,PSI-PS1-2,PSI-PS1-3,PSI-PS1-4,PSI-PS1-7); **7.PS1.B** (PSI-PS1-1,PSI-PS1-2,PSI-PS1-4,PSI-PS1-7); **8.PS2.B** (PSI-PS1-3,PSI-PS1-4); **8.PS3.C** (PSI-PS1-4); **7.LS1.C** (PSI-PS1-4,PSI-PS1-7); **7.LS2.B** (PSI-PS1-7); **7.ESS2.A** (PSI-PS1-7)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (PSI-PS1-1)

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (PSI-PS1-3)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (PSI-PS1-2)

WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (PSI-PS1-2)

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (PSI-PS1-3)

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (PSI-PS1-3)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (PSI-PS1-3)

Connections to the Arkansas English Language Arts Standards:

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, auditory, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (PSI-PS1-4)

Connections to the Arkansas Mathematics Standards:	
MP.2	Reason abstractly and quantitatively. (PSI-PS1-7)
MP.4	Model with mathematics. (PSI-PS1-4)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (PSI-PS1-2,PSI-PS1-3,PSI-PS1-4,PSI-PS1-7)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (PSI-PS1-4,PSI-PS1-7)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (PSI-PS1-2,PSI-PS1-3,PSI-PS1-4,PSI-PS1-7)

Topic 2: Matter in Organisms

Students who demonstrate understanding can:

PSI-LS1-5 **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** [AR Clarification Statement: This PE is partially addressed in this course. Emphasis is on using photosynthesis as an example of a chemical reaction including energy transfer. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]

PSI-LS1-7 **Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.** [AR Clarification Statement: This PE is partially addressed in this course. Emphasis is on using physical systems as examples of chemical reactions such as cellular respiration and photosynthesis. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment should not include specific biochemical steps.]

PSI-LS2-4 **Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.** [AR Clarification Statement: This PE is partially addressed in this course. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.]

PSI2-ETS1-2 **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** [AR Clarification Statement: Examples could focus on researching then designing one aspect at a time (e.g., health advantages and disadvantages of using polystyrene vs. polyethylene for constructing a water bottle.)]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Use a model based on evidence to illustrate the relationships between systems or between components of a system. (PSI-LS1-5,PSI-LS1-7)

Using Mathematics and Computational Thinking
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (PSI-LS1-5)
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (PSI-LS1-7)
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body

Crosscutting Concepts

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (PSI-LS1-5)
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (PSI-LS1-7)

Energy and Matter

- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (PSI-LS2-4)

on mathematical models of basic assumptions. ▪ Use mathematical representations of phenomena or design solutions to support claims. (PSI-LS2-4) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. ▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (PSI2-ETS1-2)	temperature despite ongoing energy transfer to the surrounding environment. (PSI-LS1-7) **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** ▪ Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. (PSI-LS2-4) **ETS1.C: Optimizing the Design Solution** ▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (PSI2-ETS1-2)	

Connections to other DCIs in this course: **PSI.PS1.B** (PSI-LS1-5,PSI-LS1-7); **PSI.PS2.B** (PSI-LS1-7); **PSI.PS3.B** (PSI-LS1-5,PSI-LS1-7,PSI-LS2-4)

Connections to DCIs across grade-bands: **7.PS1.B** (PSI-LS1-5,PSI-LS1-7); **6.PS3.C** (PSI-LS1-5,PSI-LS1-7, PSI-LS2-4)**; 7.LS1.C** (PSI-LS1-5,PSI-LS1-7,PSI-LS2-4); **7.LS2.B** (PSI-LS1-5,PSI-LS1-7,PSI-LS2-4); **6-8.ETS1.A** (PSI2-ETS1-2); **6-8.ETS1.B** (PSI2-ETS1-2); **6-8.ETS1.C** (PSI2-ETS1-2)

Connections to the Arkansas English Language Arts Standards:

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, auditory, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (PSI-LS1-5,PSI-LS1-7)

Connections to the Arkansas Mathematics Standards:

MP.2 Reason abstractly and quantitatively. (PSI-LS2-4)
MP.4 Model with mathematics. (PSI-LS2-4, PS2-ETS1-2)
HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (PSI-LS2-4)
HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (PSI-LS2-4)
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (PSI-LS2-4)

Physical Science - Integrated

Topic 3: Forces and Motion

Students who demonstrate understanding can:

PSI-PS2-1 **Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.** [AR Clarification Statement: This PE is partially addressed in this course. Emphasis on qualitative analysis of data. Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [AR Assessment Boundary: Assessment is limited to qualitative analysis of one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

PSI-PS2-3 **Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*** [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device in protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]

PSI-PS2-5 **Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.** [Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.]

PSI-PS2-6 **Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

PSI-ESS1-5 **Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.** [AR Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal (continental and oceanic) rocks. Examples could include evidence of the ages of oceanic crust (lithosphere that includes crust and upper mantle and the asthenosphere) increasing with distance from mid-ocean ridges (a result of divergent boundaries/plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).]

PSI3-ETS1-1 **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** [AR Clarification Statement: Examples of global challenges could include energy distribution, protective sports equipment, and transportation safety designs (automobile safety and shipping/packing materials).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models.	**PS1.A: Structure and Properties of Matter** ▪ The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (PSI-PS2-6) **PS2.A: Forces and Motion** ▪ Newton's second law accurately predicts changes in the motion of macroscopic objects. (PSI-PS2-1)	**Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (PSI-PS2-1, PSI-PS2-5)

▪ Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (PSI-PS2-5) **Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. ▪ Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (PSI-PS2-1) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. ▪ Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (PSI-PS2-3) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. ▪ Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (PSI-PS2-6) **Engaging in Argument from Evidence** Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and	▪ If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (PSI-PS2-3) **PS2.B: Types of Interactions** ▪ Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (PSI-PS2-5) ▪ Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (PSI-PS2-6) **PS3.A: Definitions of Energy** ▪ "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (PSI-PS2-5) **ESS1.C: The History of Planet Earth** Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (PSI-ESS1-5) **ESS2.B: Plate Tectonics and Large-Scale System Interactions** ▪ Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (PSI-ESS1-5) **ETS1.A: Defining and Delimiting Engineering Problems** ▪ Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (PSI-PS2-3) **ETS1.C: Optimizing the Design Solution** ▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (PSI-PS2-3)	▪ Systems can be designed to cause a desired effect. (PSI-PS2-3) **Structure and Function** ▪ Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (PSI-PS2-6) **Patterns** ▪ Empirical evidence is needed to identify patterns. (PSI-ESS1-5) --------------------------------- ***-Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (PSI3-ETS1-1)

sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. ▪ Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (PSI-ESS1-5) **Asking Questions and Defining Problems** Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. ▪ Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (PSI3-ETS1-1) **--** **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ▪ Theories and laws provide explanations in science. (PSI-PS2-1) ▪ Laws are statements or descriptions of the relationships among observable phenomena. (PSI-PS2-1)	**ETS1.A: Defining and Delimiting Engineering Problems** ▪ Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (PSI3-ETS1-1) ▪ Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (PSI3-ETS1-1)	

Connections to other DCIs in this course: **PSI.PS3.A** (PSI-PS2-5); **PSI.ESS2.A** (PSI-PS2-5); **PSI.ESS3.A** (PSI-PS2-5); **PSI.ESS2.A** (PSI-ESS1-5); **PSI.PS3.B** (PSI-ESS1-5)

Connections to DCIs across grade-bands: **7.PS1.A** (PSI-PS2-6); **8.PS2.A** (PSI-PS2-1,PS-PS2-3); **8.PS2.B** (PSI-PS2-5,PSI-PS2-6); **8.PS3.C** (PSI-PS2-1,PSI-PS2-3); **8.ESS1.B** (PSI-PS2-5); **6-8.ETS1.A** (PSI3-ETS1-1); **7.ESS2.A** (PSI-ESS1-5); **8.ESS1.C** (PSI-ESS1-5)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (PSI-PS2-1,PSI-PS2-6)

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (PSI-PS2-1),(PSI3-ETS1-1)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (PSI-ESS1-5, PSI3-ETS1-1)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (PSI3-ETS1-1)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (PS-ESS1-5, PS-PS2-6)

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (PSI-PS2-3,PSI-PS2-5)

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (PSI-PS2-5)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (PSI-PS2-1,PSI-PS2-5)

Connections to the Arkansas Mathematics Standards:

MP.2 Reason abstractly and quantitatively. (PSI-PS2-1,PSI3-ETS1-1)

MP.4 Model with mathematics. (PSI-PS2-1,PSI3-ETS1-1)

HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (PSI-PS2-1,PSI-PS2-5,PSI-PS2-6)

HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (PSI-PS2-1,PSI-PS2-5,PSI-PS2-6)

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (PSI-PS2-1,PSI-PS2-5,PSI-PS2-6)

HSA.SSE.A.1 Interpret expressions that represent a quantity in terms of its context; interpret parts of an expression using appropriate vocabulary, such as terms, factors, and coefficients; interpret complicated expressions by viewing one or more of their parts as a single entity. (PSI-PS2-1)

HSA.SSE.B.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression: factor a quadratic expression to reveal the zeros of the function it defines; complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines; use the properties of exponents to transform for exponential functions. (PSI-PS2-1)

HSA.CED.A.1 Create equations and inequalities in one variable and use them to solve problems. (PSI-PS2-1)

HSA.CED.A.2 Create equations in two or more variables to represent relationships between quantities; graph equations, in two variables, on a coordinate plane. (PSI-PS2-1)

HSA.CED.A.4 Rearrange literal equations using the properties of equality. (PSI-PS2-1)

HSF.IF.C.7 Graph functions expressed symbolically and show key features of the graph, with and without technology; graph linear and quadratic functions and, when applicable, show intercepts, maxima and minima; graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions; graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior; graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior; graph exponential and logarithmic functions, showing intercepts and end behavior; graph trigonometric functions, showing period, midline, and amplitude. (PSI-PS2-1)

HSS.ID.A.1 Represent data with plots on the real number line (dot plots, histograms, and box plots). (PSI-PS2-1)

Topic 4: Energy

Students who demonstrate understanding can:

PSI-PS3-1 **Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [AR Clarification Statement: This PE is partially addressed in this course. Emphasis is on explaining the meaning of mathematical expressions used in the model. Models could include spreadsheet analysis or other computer interfaces] [AR Assessment Boundary: Assessment is limited to basic algebraic expressions or computations.

PSI-PS3-2 **Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).** [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.] [AR Assessment Boundary: Assessment is limited to mechanical energy.]

PSI-PS3-3 **Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]

PSI-PS3-4 **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]

PSI4-ETS1-3 **Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.** [AR Clarification Statement: Examples could include building and evaluating wind turbines, solar cells, solar ovens, and generators.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. ▪ Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (PS-PS3-2)	**PS3.A: Definitions of Energy** ▪ Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (PSI-PS3-1,PS-PS3-2)	**Systems and System Models** ▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (PSI-PS3-4) ▪ Models can be used to predict the behavior of a system, but these predictions have limited

Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. ▪ Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (PSI-PS3-4) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ▪ Create a computational model or simulation of a phenomenon, designed device, process, or system. (PSI-PS3-1) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. ▪ Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized	▪ At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (PSI-PS3-2, PSI-PS3-3) ▪ These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (PSI-PS3-2) **PS3.B: Conservation of Energy and Energy Transfer** ▪ Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (PSI-PS3-1) ▪ Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (PSI-PS3-1,PSI-PS3-4) ▪ Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (PSI-PS3-1) ▪ The availability of energy limits what can occur in any system. (PSI-PS3-1) ▪ Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (PSI-PS3-4)	precision and reliability due to the assumptions and approximations inherent in models. (PSI-PS3-1) **Energy and Matter** ▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (PSI-PS3-3) ▪ Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (PSI-PS3-2) -- ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (PSI-PS3-3) ▪ New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (PSI4-ETS1-3) -- ***Connections to Nature of Science***

criteria, and tradeoff considerations. (PSI-PS3-3) ▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (PSI4-ETS1-3)	**PS3.D: Energy in Chemical Processes** ▪ Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (PSI-PS3-3,PSI-PS3-4) **ETS1.A: Defining and Delimiting Engineering Problems** ▪ Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (PSI-PS3-3) **ETS1.B: Developing Possible Solutions** ▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (PSI4-ETS1-3)	**Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ▪ Science assumes the universe is a vast single system in which basic laws are consistent. (PSI-PS3-1)

Connections to other DCIs in this course: **PSI.PS1.A** (PSI-PS3-2); **PSI.PS1.B** (PSI-PS3-1,PSI-PS3-2); **PSI.PS2.B** (PSI-PS3-2); **PSI.LS2.B** (PSI-PS3-1); **PSI.ESS2.D** (PSI-PS3-4); **PSI.ESS3.A** (PSI-PS3-3)

Connections to DCIs across grade-bands: **7.PS1.A** (PSI-PS3-2); **8.PS2.B** (PSI-PS3-2); **8.PS3.A** (PSI-PS3-1,PSI-PS3-2,PSI-PS3-3); **6.PS3.B** (PSI-PS3-1,PSI-PS3-3,PSI-PS3-4); **6.PS3.C** (PSI-PS3-2); **7.ESS2.A** (PSI-PS3-1,PSI-PS3-3); **6-8.ETS1.A** (PSI4-ETS1-3); **6-8.ETS1.B** (PSI4-ETS1-3)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (PSI-PS3-4)

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (PSI4-ETS1-3)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (PSI4-ETS1-3)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (PSI-ETS1-3)

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (PSI-PS3-3, PSI-PS3-4)

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (PSI-PS3-4)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (PSI-PS3-4)

Connections to the Arkansas English Language Arts Standards:

SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, auditory, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (PSI-PS3-1,PSI-PS3-2)

Connections to the Arkansas Mathematics Standards:

MP.2	Reason abstractly and quantitatively. (PSI-PS3-1,PSI-PS3-2,PSI-PS3-3,PSI-PS3-4,PSI4-ETS1-3)
MP.4	Model with mathematics. (PSI-PS3-1,PSI-PS3-2,PSI-PS3-3,PSI-PS3-4,PSI4-ETS1-3)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (PSI-PS3-1,PSI-PS3-3)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (PSI-PS3-1,PSI-PS3-3)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (PSI-PS3-1,PSI-PS3-3)

Physical Science - Integrated

Topic 5: Waves
Students who demonstrate understanding can: **PSI-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** [AR Clarification Statement: This PE is partially addressed in this course. Examples of data could include seismic waves and sound waves traveling through air and water.] [AR Assessment Boundary: Assessment is limited to describing relationships qualitatively.] **PSI-PS4-2 Evaluate questions about the advantages of using a digital transmission and storage of information.** [Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.] **PSI-5-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** [AR Clarification Statement: Examples of possible problems could include cell phone reception, emergency radio transmission, and earthquake notification.]
The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. ▪ Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (PSI-PS4-2) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ▪ Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (PSI-PS4-1) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs	**PS4.A: Wave Properties** ▪ The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (PSI-PS4-1) ▪ Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (PSI-PS4-2) **ETS1.C: Optimizing the Design Solution** ▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (PSI5-ETS1-2)	**Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (PSI-PS4-1) **Stability and Change** ▪ Systems can be designed for greater or lesser stability. (PSI-PS4-2) ------------------------------------ ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Engineering, Technology, and Science on Society and the Natural World** ▪ Modern civilization depends on major technological systems. (PSI-PS4-2) ▪ Engineers continuously modify these technological systems by applying scientific knowledge and

that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. ▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (PSI5-ETS1-2)		engineering design practices to increase benefits while decreasing costs and risks.(PSI-PS4-2)
Connections to other DCIs in this course: N/A		
Connections to DCIs across grade-bands: **8.PS4.A** (PSI-PS4-1,PSII-PS4-2); **8.PS4.B** (PS-PS4-1,PSI-PS4-2); **8.PS4.C** (PSI-PS4-2); **6-8.ETS1.A** (PSI5-ETS1-2); **6-8.ETS1.B** (PSI5-ETS1-2); **6-8.ETS1.C** (PSI5-ETS1-2);		
Connections to the Arkansas Disciplinary Literacy Standards: **RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (PSI-PS4-2) **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (PSI-PS4-2) **RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (PS-PS4-1) **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (PSI-PS4-2) *Connections to the Arkansas Mathematics Standards:* **MP.2** Reason abstractly and quantitatively. (PSI-PS4-1) **MP.4** Model with mathematics. (PSI-PS4-1,PSI5-ETS1-2) **HSA.SSE.A.1** Interpret expressions that represent a quantity in terms of its context. (PSI-PS4-1) **HSA.SSE.B.3** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression; factor a quadratic expressions to reveal the zeros of the function it defines; complete the square in a quadratic expression to reveal the maximum and minimum value of the function it defines; use the properties of exponents to transform expressions for exponential functions. (PSI-PS4-1) **HSA.CED.A.4** Rearrange literal equations using properties of equality. (PSI-PS4-1)		

Topic 6: Interactions of Humans and the Environment

Students who demonstrate understanding can:

PSI-LS2-7 **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*** [AR Clarification Statement: This PE is partially addressed in this course. Examples of human activities could include urbanization, fracking, greenhouse gases and dams. [AR Assessment Boundary: Assessment is to include student choice from multiple scenarios.]

PSI-LS4-5 **Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** [AR Clarification Statement: This PE is partially addressed in this course. Emphasis is on physical changes to the environment (temperature change and acidification).]

PSI-ESS2-1 **Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** [AR Clarification Statement: Emphasis is on how the appearance of land features (mountains, valleys, and plateaus) and sea floor features (trenches, ridges, and seamounts) are a result of both constructive forces (volcanism, tectonic uplift, and orogeny) and destructive mechanisms (weathering, mass wasting, and coastal erosion).

PSI-ESS3-1 **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.** [AR Clarification Statement: This PE is partially addressed in this course. Emphasis in this course is on key natural resources. Examples could include access to fresh water (rivers, lakes, and groundwater), regions of fertile soils (river deltas) and high concentrations of minerals and fossil fuels. Examples of natural hazards could include from interior processes (volcanic eruptions), surface processes (tsunamis, mass wasting, and soil erosion), and severe weather (hurricanes, floods, and droughts). Examples of the results of changes in climate that could affect populations or drive mass migrations could include changes to sea level and regional patterns of temperature and precipitation.]

PSI-ESS3-2 **Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*** [AR Clarification Statement: This PE is partially addressed in this course. Emphasis is on identifying possible problems to be solved (conservation, recycling, and minimizing impacts).]

PSI6-ETS1-1 **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** [AR Clarification Statement: Examples could include research and analysis of the spread of zebra mussels, decline of chestnut trees, and the impact of fracking.]

PSI6-ETS1-2 **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** [AR Clarification Statement: Examples of design challenges could include solving man-made erosion problems, reducing thermal/light pollution, and safe disposal of fracking waste fluids.]

PSI6-ETS1-3 **Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.** [AR Clarification Statement: Examples could include the environmental effects of certain plastics (cost, safety, biodegradability, and recyclability) and evaluating the tradeoffs for each source of energy production.]

PSI6-ETS1-4 **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.** [AR Clarification Statement: Examples of possible simulations could include spreadsheet analysis or other computer interfaces. Examples of possible computer simulation resources could include PhET, ArcGIS, and InTeGrate-SERC.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science. ▪ Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (PSI-LS4-5) ▪ Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (PSI-ESS3-2) **Asking Questions and Defining Problems** Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. ▪ Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (PSI6-ETS1-1) **Using Mathematics and Computational Thinking** Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** ▪ Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (PSI-LS2-7) **LS4.C: Adaptation** ▪ Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (PSI-LS4-5) ▪ Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (PSI-LS4-5) **LS4.D: Biodiversity and Humans** ▪ Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (PSI-LS2-7) ▪ Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (PSI-LS2-7) **ESS2.A: Earth Materials and Systems** ▪ Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (PSI-ESS2-1)	**Stability and Change** ▪ Much of science deals with constructing explanations of how things change and how they remain stable. (PSI-LS2-6) **Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (PSI-LS4-5, PSI-ESS3-1) **Systems and System Models** ▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (PSI6-ETS1-4) ----------------------------------- ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (PSI-ESS3-2) ▪ Analysis of costs and benefits is a critical

▪ Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (PSI6-ETS1-4) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. ▪ Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (PSI-ESS3-1) ▪ Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (PSI-LS2-7) ▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (PSI6-ETS1-2) ▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (PSI6-ETS1-3)	**ESS3.A: Natural Resources** ▪ Resource availability has guided the development of human society. (PSI-ESS3-1) ▪ All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (PSI-ESS3-2) **ESS3.B: Natural Hazards** ▪ Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (PSI-ESS3-1) **ETS1.A: Defining and Delimiting Engineering Problems** ▪ Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (PSI6-ETS1-1) ▪ Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (PSI6-ETS1-1) **ETS1.B: Developing Possible Solutions** ▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (PSI-LS2-7, PSI-ESS3-2, PSI6-ETS1-3) ▪ Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (PSI6-ETS1-4)	aspect of decisions about technology. (PSI-ESS3-2) ▪ New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (PSI6-ETS1-1, PSI6-ETS1-3) ---------------------------------- ***Connections to Nature of Science*** **Science Addresses Questions About the Natural and Material World** ▪ Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (PSI-ESS3-2) ▪ Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (PSI-ESS3-2) Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (PSI-ESS3-2)

	ETS1.C: Optimizing the Design Solution ▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (PSI6-ETS1-2)	
Connections to other DCIs in this course: **PSI.PS3.B** (PSI-ESS3-2); **PSI.PS3.D** (PSI-ESS3-2); **PSI.LS2.B** (PS-ESS3-2); **PSI.LS3.B** (PSI-LS4-5); **PSI.ESS2.D** (PSI-LS2-7); **PSI.ESS2.E** (PSI-LS2-7, PSI-LS4-5); **PSI.ESS3.A** (PSI-LS2-7, PSI-LS4-5)		
Connections to DCIs across grade-bands: **6.PS3.D** (PSI-ESS3-2); **7.LS2.A** (PSI-LS4-5, PSI-ESS3-1, PSII-ESS3-2); **7.LS2.B** (PS-ESS3-2); **7.LS2.C** (PSI-LS2-7, PSI-LS4-5); **8.LS4.C** (PSI-LS4-5); **7.LS4.D** (PSI-ESS3-1, PSI-ESS3-2); **7.ESS2.A** (PSI-ESS3-1); **7.ESS3.A** (PSI-ESS3-1, PSI-ESS3-2); **7.ESS3.B** (PSI-ESS3-1); **6.ESS3.C** (PS-LS2-7, PSI-LS4-5, PSI-ESS3-2); **6.ESS3.D** (PSI-LS2-7); **6-8.ETS1.A** (PSI-ETS1-1, PSI6-ETS1-2, PSI6-ETS1-3, PSI6-ETS1-4); **6-8.ETS1.B** (PSI6-ETS1-2, PSI6-ETS1-3, PSI6-ETS1-4); **6-8.ETS1.C** (PSI6-ETS1-2, PSI6-ETS1-4)		

Connections to the Arkansas Disciplinary Literacy Standards:

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (PSI-LS2-7)

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (PSI-ESS3-1,PSI-ESS3-2)

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (PSI-LS2-7, PSI6-ETS1-1, PSI6-ETS1-3)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (PSI-LS2-7, PSI-LS4-5, PSI-ESS3-2, PSI6-ETS1-1, PSI6-ETS1-3)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (PSI6-ETS1-1, PSI6-ETS1-3)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (PSI-ESS3-1)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (PSI-LS4-5)

Connections to the Arkansas Mathematics Standards:

MP.2 Reason abstractly and quantitatively. (PSI-LS2-7), PSI-LS4-5, PSI-ESS3-1, PSI-ESS3-2, PSI6-ETS1-1, PSI6-ETS1-3, PSI6-ETS1-4)

MP.4 Model with mathematics. (PSI6-ETS1-1, PSI6-ETS1-2, PSI6-ETS1-3, PSI6-ETS1-4)

HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (PSI-LS2-7, PSI-ESS3-1)

HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (PSI-LS2-7, PSI-ESS3-1)

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (PSI-LS2-7, PSI-ESS3-1)

Contributors

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Angela Bassham – Salem School District	Brandon Lucius – Osceola School District
Allison Belcher – Little Rock School District	Matt Martin – Centerpoint School District
Debbie Bilyeu – Arkansas AIMS	Patti Meeks – Hamburg School District
Tami Blair – Texarkana School District	Melissa Miller – Farmington School District
Stephen Brodie – University of Arkansas at Fort Smith STEM Center	Jim Musser – Arkansas Tech University
Stephanie Brown – Quitman School District	Nanette Nichols – Wilbur D. Mills AR Education Cooperative
Sarah Croswell – Virtual Arkansas	John Nilz – North Little Rock School District
Tami Eggensperger – Cabot School District	Dennis Pevey – eSTEM Public Charter School
Jenna Gill – Siloam Springs School District	Tami Philyaw – Smackover – Norphlet School District
Douglas Hammon – Little Rock School District	Kathy Prophet – Springdale School District
Keith Harris – University of Arkansas at Little Rock Partnership for STEM Education	Carrie Shell – Highland School District
Lynne Hehr – University of Arkansas at Fayetteville STEM Center for Math and Science Education –	Will Squires – Caddo Hills School District
Leonda Holthoff – Star City School District	Eddie Tucker – Hamburg School District
Courtney Jones – Lincoln Consolidated School District	Jon White – Harding University
Rebecca Koelling – Highland School District	Andrew Williams – University of Arkansas at Monticello
Karen Ladd – Nettleton School District	Wendi J.W. Williams – Northwest Arkansas Community College
John Levy – North Arkansas College	Cathy Wissehr – University of Arkansas at Fayetteville