



# ARKANSAS

## K-12 SCIENCE STANDARDS

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EDUCATION FOR A NEW GENERATION

### Earth Science

2016

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### 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 → **GRADE TWO**

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

Interdependent Relationships in Ecosystems		
Students who demonstrate understanding can:		
<b>2-LS2-1</b> ← <b>Plan and conduct an investigation to determine if plants need sunlight and water to grow.</b> [Assessment]	<div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Student Performance Expectations (PEs)</b> </div>	[Assessment] *
← <b>Boundary:</b> Assessment is limited to testing one variable.		
<b>2-LS2-2</b> ← <b>Develop a simple model that mimics the function of plants or animals, such as a seed or pollinating plant.</b>		
<b>2-LS4-1</b> ← <b>Make observations of plants and animals to compare growth and behavior of different habitats.</b> [Clarification]		
← <b>Statement:</b> Emphasis is on the diversity of living things in a variety of habitats. [Assessment]		
← <b>Boundary:</b> Assessment does not include specific animal and plant names in specific habitats.		
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> :		
<div style="background-color: #0056b3; color: white; padding: 2px; text-align: center; font-weight: bold;">Science and Engineering Practices</div> <p><b>Developing and Using Models</b> 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.</p> <ul style="list-style-type: none"> <li>Develop a simple model based on evidence to represent a proposed object or tool. (2-LS2-2)</li> </ul> <p><b>Planning and Carrying Out Investigations</b> 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.</p> <ul style="list-style-type: none"> <li>Plan and conduct an investigation collaboratively to produce data as the basis for evidence to answer a question. (2-LS2-1)</li> <li>Make observations (firsthand or from media) to collect data that can be used to make comparisons. (2-LS4-1)</li> </ul> <hr/> <p style="text-align: center;"><b>Connections to Nature of Science</b></p> <p><b>Scientific Knowledge is Based on Empirical Evidence</b></p> <ul style="list-style-type: none"> <li>Scientists look for patterns and order when making observations about the world. (2-LS4-1)</li> </ul>	<div style="background-color: #e67e22; color: white; padding: 2px; text-align: center; font-weight: bold;">Disciplinary Core Ideas</div> <p><b>LS2.A: Interdependent Relationships in Ecosystems</b></p> <ul style="list-style-type: none"> <li>Plants depend on water and light to grow. (2-LS2-1)</li> <li>Plants depend on animals for pollination or to move their seeds around. (2-LS2-2)</li> </ul> <p><b>LS4.D: Biodiversity and Humans</b></p> <ul style="list-style-type: none"> <li>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)</li> </ul> <p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"> <li>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)</li> </ul>	<div style="background-color: #008000; color: white; padding: 2px; text-align: center; font-weight: bold;">Crosscutting Concepts</div> <p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Events have causes that generate observable patterns. (2-LS2-1)</li> </ul> <p><b>Structure and Function</b></p> <ul style="list-style-type: none"> <li>The shape and stability of structures of natural and designed objects are related to their function(s). (2-LS2-2)</li> </ul>
<div style="border: 1px solid black; padding: 2px; width: fit-content;">Designates which PE uses this practice</div>	<div style="border: 1px solid black; padding: 2px; width: fit-content;">Designates which PE incorporates this disciplinary core idea (DCI)</div>	<div style="border: 1px solid black; padding: 2px; width: fit-content;">Designates which PE incorporates this crosscutting concept (CC)</div>
<div style="border: 1px solid black; padding: 2px; width: fit-content;">Connections to the Nature of Science</div>	<div style="border: 1px solid black; padding: 2px; width: fit-content;">DCI codes from <i>A Framework for K-12 Science Education</i> in boldface type.</div>	
Connections to other DCIs in second grade: N/A		
Connections to other DCIs across grade levels: <b>K.LS1.C</b> (2-LS2-1); <b>K.ESS3.A</b> (2-LS2-1); <b>K-2.ETS1.A</b> (2-LS2-2); <b>3.LS4.C</b> (2-LS4-1); <b>3.LS4.D</b> (2-LS4-1); <b>5.LS1.C</b> (2-LS2-1); <b>5.LS2.A</b> (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

## Earth Science Learning Progression Chart

Topic 1: History of the Earth	Topic 2: Earth's Systems	Topic 3: Human Sustainability	Topic 4: Weather and Climate
AR ES-ESS1-5	ES-ESS2-2	AR ES-ESS3-1	AR ES-ESS2-4
AR ES-ESS1-6	ES-ESS2-3	AR ES-ESS3-2	AR ES-ESS3-5
AR ES-ESS2-1	AR ES-ESS2-5	AR ES-ESS3-3	AR ES4-ETS1-3
AR ES1-ETS1-1	AR ES-ESS2-6	AR ES-ESS3-4	
	AR ES-ESS2-7	AR ES-ESS3-6	
	AR ES2-ETS1-1	AR ES3-ETS1-1	
	AR ES2-ETS1-3	AR ES3-ETS1-2	
		AR ES3-ETS1-3	
		AR ES3-ETS1-4	

Arkansas Clarification Statements (AR)

## Earth Science Course Overview

(Course code 425020)

Earth science is a science course that continues to develop conceptual understanding of the interactions in Earth science, physical science, and life science systems by investigating Arkansas-specific phenomena. Students are building understanding of core ideas, science and engineering practices, and crosscutting concepts from previous science courses. The standards are built around the Earth science-systems approach which strongly reflects the many societally relevant aspects of Earth sciences (resources, hazards, environmental impacts) with an emphasis on using engineering and technology concepts to design solutions to challenges facing human society. Teachers with a physical/Earth, life/Earth license (including an Earth science endorsement) or others as approved by ADE are able to teach this course. Students will earn 1 Core requirement/career focus credit.

Students in Earth science develop understanding of key concepts that help them make sense of the interactions in Earth science, physical science, and life science. These concepts are building upon students' understanding of disciplinary ideas, science and engineering practices, and crosscutting concepts from earlier grades and high school science courses. There are four topics in Earth science: (1) History of the Earth, (2) Earth Systems, (3) Sustainability, and (4) Weather and Climate. The performance expectations engage students in core ideas of Earth science with an emphasis on using engineering and technology to design solutions to challenges facing human society. While the performance expectations indicate particular practices to address specific disciplinary core ideas, it is recommended that teachers include a variety of practices and strategies in their instruction.

Additionally, it should be noted that the Earth science 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 Earth science 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.

## Earth Science Topics Overview

The performance expectations in **Topic 1: History of the Earth** help students answer these questions:

- How do people reconstruct and date events in Earth's planetary history?
- Why do the continents move?

Students construct explanations for the scales of time over which Earth's processes operate. Earth science involves making inferences about events in Earth's history based on data records. A mathematical analysis of radiometric dating is used to comprehend how absolute ages are obtained for the geologic record. A key to Earth's history is the coevolution of the biosphere with Earth's other systems.

The performance expectations in **Topic 2: Earth's Systems** help students answer these questions:

- How do major Earth systems interact?
- How and why is Earth constantly changing?
- How do properties and movements of water shape Earth's surface and affect its systems?

Students develop models and explanations for how feedbacks between different Earth systems control the appearance of Earth's surface. Students investigate how water affects weather and chemical cycles.

The performance expectations in **Topic 3: Sustainability** help students answer these questions:

- How do humans depend on Earth's resources?
- How do humans change the planet?

Students investigate relationships between humans and Earth's systems through the impacts of natural hazards, natural resources, and environment. Students explore how humans can be agents for significant change in Earth's systems and that all of Earth's systems are interconnected. Changes in one system can produce unforeseen changes in others.

The performance expectations in **Topic 4: Weather and Climate** help students answer these questions:

- What regulates weather and climate?
- How do people model and predict the effects of human activities on Earth's climate?

Students use models to form explanations for the system interactions that control weather and climate, with a major emphasis on the mechanisms and implications of climate change. Students analyze and interpret geoscience data to construct explanations for factors that drive climate change over a wide range of time scales.

## Earth Science

### Topic 1: History of Earth

Students who demonstrate understanding can:

- ES-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 using the tectonic history of Arkansas as part of the global history.]
- ES-ESS1-6 Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth’s formation and early history.** [AR Clarification Statement: Emphasis is on evidence found in the Americas. Examples of formations caused by impacts could include Manicouagan, Quebec; Chicxulub, Yucatan; Chesapeake Bay, Virginia; Beaver Head, Idaho and Montana. Examples of dating methods (e.g., Carbon-14 or Rubidium – Strontium) to gather evidence are the absolute ages of ancient or modern materials.]
- ES-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 the constructive and destructive forces responsible for the formation of the Arkansas physiographic regions (Ozark Plateaus, Arkansas River Valley, Ouachita Mountains, West Gulf Coastal Plain, and Mississippi River Alluvial Plain). ]
- ES1-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 major global challenges could include fossil fuel analysis, coastal flooding solutions, and pandemic management and safety solutions.]

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
<p><b>Constructing Explanations and Designing Solutions</b> 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.</p> <ul style="list-style-type: none"> <li>Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (ES-ESS1-6)</li> </ul> <p><b>Engaging in Argument from Evidence</b> 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 scientific or historical episodes in science.</p>	<p><b>ESS1.C: The History of Planet Earth</b></p> <ul style="list-style-type: none"> <li>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. (ES-ESS1-5)</li> <li>Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth’s formation and early history. (ES-ESS1-6)</li> </ul> <p><b>ESS2.A: Earth Materials and Systems</b></p> <ul style="list-style-type: none"> <li>Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (ES-ESS2-1, ES-ESS2-2)</li> </ul>	<p><b>Patterns</b></p> <ul style="list-style-type: none"> <li>Empirical evidence is needed to identify patterns. (ES-ESS1-5)</li> </ul> <p><b>Stability and Change</b></p> <ul style="list-style-type: none"> <li>Much of science deals with constructing explanations of how things change and how they remain stable. (ES-ESS1-6)</li> <li>Feedback (negative or positive) can stabilize or destabilize a system. (ES-ESS2-2)</li> </ul> <p>-----</p> <p><b>Connections to Engineering, Technology, and Applications of Science</b></p>

- Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (ES-ESS1-5)

### Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences 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. (ES-ESS2-2)

### 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. (ES1-ETS1-1)

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### Connections to Nature of Science

#### Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (ES-ESS1-6)
- Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (ES-ESS1-6)

### 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. (ES-ESS1-5)

### ESS2.D: Weather and Climate

- The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space. (ES-ESS2-2)

### PS1.C: Nuclear Processes

- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (HS-ESS1-5, ES-ESS1-6)

### 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. (ES1-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. (ES1-ETS1-1)

### Influence of Engineering, Technology, and Science 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. (ES-ESS2-2, ES1-ETS1-1)

### 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. (ES-ESS1-5, ES-ESS1-6)

- 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. (ES1-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. (ES-ESS1-5, ES-ESS1-6, ES1-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. (ES1-ETS1-1)
- WHST.9-12.1** Write arguments focused on discipline-specific content. (ES-ESS1-6)
- WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (ES-ESS1-5)

*Connections to the Arkansas English Language Arts Standards:*

- SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (ES-ESS2-1)

*Connections to the Arkansas Mathematics Standards:*

- MP.2** Reason abstractly and quantitatively. (ES-ESS1-5, ES-ESS1-6, ES-ESS2-1, ES1-ETS1-1)
- MP.4** Model with mathematics. (ES-ESS2-1, ES1-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. (ES-ESS1-5, ES-ESS1-6, ES-ESS2-1)
- HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (ES-ESS1-5, ES-ESS1-6, ES-ESS2-1)
- HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (ES-ESS1-5, ES-ESS1-6, ES-ESS2-1)
- 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 of a single entity. (ES-ESS1-1, ES-ESS1-2, ES-ESS1-4)
- HSF.IF.B.5** Relate the domain of a function to its graph; relate the domain of a function to the quantitative relationship it describes. (ES-ESS1-6)
- HSS.ID.B.6** Represent data on two quantitative variables on a scatter plot, and describe how those variables are related; fit a function to the data; use functions fitted to data to solve problems in the context of the data; informally assess the fit of a function by plotting and analyzing residuals. (ES-ESS1-6)

## Earth Science

### Topic 2: Earth's Systems

Students who demonstrate understanding can:

- ES-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.** [Clarification Statement: Examples could include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]
- ES-ESS2-3 Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]
- ES-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [AR Clarification Statement: Emphasis is on conducting investigations involving weathering. Examples of investigations (mechanical) could include analyzing local stream transportation and deposition data, collecting erosion data on various soil types, and evaluating water systems distributions and quality (Google Earth Time lapse feature or USGS National Real-time Stream Gaging and National Water Information System.) Examples of investigations (chemical) could include collecting/analyzing water quality data or accessing water quality data through public data sets (e.g., USGS). Arkansas examples could include surface water (e.g., streams, rivers, lakes), karst terrain (dissolution caverns such as Blanchard Caverns) and the Mississippi river and its tributaries.]
- ES-ESS2-6 Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.** [AR Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through natural (peat bogs) and human engineered reservoirs (composting).]
- ES-ESS2-7 Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.** [AR Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of evidence could include Arkansas's geologic history that documents the existence of tropical plants (landmass equatorial paleo geographic position resulted in palm tree fossils on top of Petit Jean Mountain), fossiliferous limestones with biodiversity (corals, mollusks, brachiopods fossils in the Buffalo National River) and ocean coastal paleo environments (delta deposits of shales near Morrilton).]
- ES2-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 major global challenges for Earth's Systems could include the interrelationships between humans and urban/rural land use, mining practices, and deforestation.]
- ES2-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs 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: Solutions to complex real world issues where realistic criteria and constraints are accounted for could include evaluating energy resources available on other planets, various building configurations/constraints, drip agriculture systems and solar powered fans.]

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 world(s).

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (ES-ESS2-3, ES-ESS2-6)

### 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. (ES-ESS2-5)

### Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences 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. (ES-ESS2-2)

### Engaging in Argument from Evidence

## Disciplinary Core Ideas

### ESS2.A: Earth Materials and Systems

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (ES-ESS2-2)
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. (ES-ESS2-3)

### ESS2.B: Plate Tectonics and Large-Scale System Interactions

- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. (ES-ESS2-3)

### ESS2.C: The Roles of Water in Earth's Surface Processes

- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (ES-ESS2-5)

### ESS2.D: Weather and Climate

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (ES-ESS2-2)

## Crosscutting Concepts

### Energy and Matter

- The total amount of energy and matter in closed systems is conserved. (ES-ESS2-6)
- Energy drives the cycling of matter within and between systems. (ES-ESS2-3)

### Structure and Function

- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (ES-ESS2-5)

### Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (ES-ESS2-7)
- Feedback (negative or positive) can stabilize or destabilize a system. (ES-ESS2-2)

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### *Connections to Engineering, Technology, and Applications of Science*

### Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (ES-ESS2-3)

### Influence of Engineering, Technology, and Science on Society and the Natural World

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 scientific or historical episodes in science.

- Construct an oral and written argument or counter-arguments based on data and evidence. (ES-ESS2-7)

### **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. (ES2-ETS1-1)

### **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.

- Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (ES2-ETS1-3)

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### **Connections to Nature of Science**

#### **Scientific Knowledge is Based on Empirical Evidence**

- Science knowledge is based on empirical evidence. (ES-ESS2-3)
- Science disciplines share common rules of evidence used to evaluate

- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (ES-ESS2-6, ES-ESS2-7)
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (ES-ESS2-6)

#### **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. (ES-ESS2-7)

#### **PS4.A: Wave Properties**

- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (ES-ESS2-3)

#### **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. (ES2-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. (ES2-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. (ES2-ETS1-3)

- 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. (ES-ESS2-2, ES2-ETS1-1, ES2-ETS1-3)

<p>explanations about natural systems. (ES-ESS2-3)</p> <ul style="list-style-type: none"> <li>▪ Science includes the process of coordinating patterns of evidence with current theory. (ES-ESS2-3)</li> </ul>		
<p><i>Connections to the Arkansas Disciplinary Literacy Standards:</i></p> <p><b>RST.11-12.1</b> 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. (ES-ESS2-2, ES-ESS2-3)</p> <p><b>RST.11-12.2</b> Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (ES-ESS2-2)</p> <p><b>RST.11-12.7</b> 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. (ES2-ETS1-1, ES2-ETS1-3)</p> <p><b>RST.11-12.8</b> 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. (ES2-ETS1-1, ES2-ETS1-3)</p> <p><b>RST.11-12.9</b> 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. (ES2-ETS1-1, ES2-ETS1-3)</p> <p><b>WHST.9-12.1</b> Write arguments focused on discipline-specific content. (ES-ESS2-7)</p> <p><b>WHST.9-12.7</b> 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. (ES-ESS2-5)</p> <p><i>Connections to the Arkansas English Language Arts Standards:</i></p> <p><b>SL.11-12.5</b> Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (ES-ESS2-3)</p> <p><i>Connections to the Arkansas Mathematics Standards:</i></p> <p><b>MP.2</b> Reason abstractly and quantitatively. (ES-ESS2-2, ES-ESS2-3, ES-ESS2-6, ES2-ETS1-1, ES2-ETS1-3)</p> <p><b>MP.4</b> Model with mathematics. (ES-ESS2-3, ES-ESS2-6, ES2-ETS1-1, ES2-ETS1-3)</p> <p><b>HSN.Q.A.1</b> 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. (ES-ESS2-2, ES-ESS2-3, ES-ESS2-6)</p> <p><b>HSN.Q.A.2</b> Define appropriate quantities for the purpose of descriptive modeling. (ES-ESS2-3, ES-ESS2-6)</p> <p><b>HSN.Q.A.3</b> Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (ES-ESS2-2, ES-ESS2-3, ES-ESS2-5, ES-ESS2-6)</p>		

## Earth Science

### Topic 3: Human Sustainability

Students who demonstrate understanding can:

- ES-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: Examples of Arkansas-specific natural resources could include diamonds, novaculite, natural gas, and bauxite-aluminum deposits. Examples of Arkansas-specific natural hazards could include sinkholes in karst terrain, pollution of groundwater aquifers, flashfloods, ice storms, and earthquakes.]
- ES-ESS3-2** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.\* [AR Clarification Statement: Arkansas-specific examples of solutions could include the natural gas industry, hydroelectric, wind farms, urban recycling programs, coal, and nuclear power (Arkansas Nuclear One).]
- ES-ESS3-3** Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity. [AR Clarification Statement: Data on the management of natural resources could be obtained from the Arkansas Natural Resources Commission. Examples of factors that affect human sustainability could include agricultural efficiency, natural resource management, levels of conservation, and urban planning.]
- ES-ESS3-4** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.\* [AR Clarification Statement: Examples of data on the impacts of human activities could include pollutants released (silt and sediments), changes to biomass (clearcutting), and areal changes in land surface use (urban development, agriculture and livestock, earth materials mining). Examples for limiting future impacts could range from local efforts (recycling) to large-scale geoenvironmental design solutions (lock and dam system, state and national parks).]
- ES-ESS3-6** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [AR Clarification Statement: Examples of Earth systems could include the roles water has played in the formation of Arkansas topography, geological change over time, and impacts of human activity on the landscape].
- ES3-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 major global challenges applied to human sustainability could include ground water depletion in Arkansas and its unique rock formations. Examples of solutions broken down into more manageable problems through engineering could include designing methods to solve complex problems by sustaining life on other planets, designing earthquake resistant homes with emphasis on Arkansas rock formations, designing better irrigation systems for plants, and designing flood mitigation prevention techniques.]
- ES3-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: Solutions to complex issues could include evaluating energy resources available on other planets, evaluating various building configurations, evaluating and implementing drip agriculture systems and solar powered fans.]
- ES3-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: Modeling complex problems using computer software could include the following investigations: future population growth with limited resources, viewing and predicting earthquake waveforms, water flow simulation through rock layers, and simulating how gas and particulate emissions affect Earth's temperature.]

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

<b>Science and Engineering Practices</b>	<b>Disciplinary Core Ideas</b>	<b>Crosscutting Concepts</b>
	<b>ESS2.D: Weather and Climate</b>	<b>Cause and Effect</b>

## 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.

- Create a computational model or simulation of a phenomenon, designed device, process, or system. (ES-ESS3-3)
- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (ES-ESS3-6)
- Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (ES3-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 knowledge, 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. (ES-ESS3-1)
- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (ES-ESS3-4)

- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (ES-ESS3-6)

### ESS3.A: Natural Resources

- Resource availability has guided the development of human society. (ES-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. (ES-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. (ES-ESS3-1)

### ESS3.C: Human Impacts on Earth Systems

- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (ES-ESS3-3)
- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (ES-ESS3-4)

### ESS3.D: Global Climate Change

- Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (ES-ESS3-6)

### ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (ES-ESS3-1)

### 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. (ES-ESS3-6)
- 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. (ES3-ETS1-4)

### Stability and Change

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (ES-ESS3-3)
- Feedback (negative or positive) can stabilize or destabilize a system. (ES-ESS3-4)

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### *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

- Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (ES3-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. (ES3-ETS1-3)

### **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 natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

- 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). (ES-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. (ES3-ETS1-1)

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. (ES3-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. (ES3-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. (ES3-ETS1-3, ES-ESS3-2, ES-ESS3-4)
- 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. (ES3-ETS1-4)

### **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. (ES3-ETS1-2)

technological systems. (HS-ESS3-1),(HS-ESS3-3)

- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (ES-ESS3-2, ES-ESS3-4)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. (ES-ESS3-3, ES3-ETS1-1, ES3-ETS1-3)
- Analysis of costs and benefits is a critical aspect of decisions about technology. (ES-ESS3-2, ES3-ETS1-1, ES3-ETS1-3)

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### **Connections to Nature of Science**

#### **Science is a Human Endeavor**

- Science is a result of human endeavors, imagination, and creativity. (ES-ESS3-3)

#### **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. (ES-ESS3-2)
- Science knowledge indicates what can happen in natural

		<p>systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (ES-ESS3-2)</p> <ul style="list-style-type: none"> <li>▪ Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (ES-ESS3-2)</li> </ul>
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*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. (ES-ESS3-1, ES-ESS3-2, ES-ESS3-4)
- 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. (ES3-ETS1-1, ES3-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. (ES-ESS3-2, ES-ESS3-4, ES3-ETS1-1, ES3-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. (ES3-ETS1-1, ES3-ETS1-3)
- WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (ES-ESS3-1)

*Connections to the Arkansas Mathematics Standards:*

- MP.2** Reason abstractly and quantitatively. (ES-ESS3-1, ES-ESS3-2, ES-ESS3-3, ES-ESS3-4, ES-ESS3-6, ES3-ETS1-1, ES3-ETS1-3, ES3-ETS1-4)
- MP.4** Model with mathematics. (ES-ESS3-3, ES-ESS3-6, ES3-ETS1-1, ES3-ETS1-2, ES3-ETS1-3, ES3-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. (ES-ESS3-1, ES-ESS3-4, ES-ESS3-6)
- HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (ES-ESS3-1, ES-ESS3-4, ES-ESS3-6)
- HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (ES-ESS3-1, ES-ESS3-4, ES-ESS3-6)

## Earth Science

### Topic 4: Weather and Climate

Students who demonstrate understanding can:

- ES-ESS2-4** Use a model to describe how variations in the flow of energy into and out of Earth’s systems result in changes in climate. [AR Clarification Statement: Emphasis is on the impacts of atmosphere/hydrosphere synergy (ocean currents, weather patterns) on the environment and human activity (farming, fishing). Examples of the causes of climate change differ by timescale, over 1-10 years (drought/non-drought trends), 10s-100s of years (consequences of industrialization and geological events such as volcanic eruptions and glacial changes resulting in solar reflectivity), 10s-100s of thousands of years (deep ocean circulation), and 10s-100s of millions of years (tectonic plate movement of the land masses).]
- ES-ESS3-5** Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth’s systems. [AR Clarification Statement: Emphasis is on multiple examples of evidence, for both data and climate model outputs (NOAA, USGS, InTeGrate-SERC), for regional climate changes in relation to the hydrosphere, geosphere, atmosphere, biosphere and cryosphere, and their associated impacts (temperature, precipitation, sea level, and chemical composition of the atmosphere and ocean).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]
- ES4-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: Solutions to complex issues could include evaluating energy resources available on other planets, evaluating various building configurations, evaluating and implementing drip agriculture systems and solar powered fans.]

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 world(s).

- Use a model to provide mechanistic accounts of phenomena. (ES-ESS2-4)

##### Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences 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 computational models in order to make valid and reliable scientific claims. (ES-ESS3-5)

#### Disciplinary Core Ideas

##### ESS1.B: Earth and the Solar System

- Cyclical changes in the shape of Earth’s orbit around the sun, together with changes in the tilt of the planet’s axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (ES-ESS2-4)

##### ESS2.A: Earth Materials and Systems

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun’s energy output or Earth’s orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (ES-ESS2-4)

##### ESS2.D: Weather and Climate

#### Crosscutting Concepts

##### Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (ES-ESS2-4)

##### Stability and Change

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (ES-ESS3-5)

#### Connections to Engineering, Technology, and Applications of Science

##### Influence of Science, Engineering, and

### **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.

- Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (ES4-ETS1-3)

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### **Connections to Nature of Science**

#### **Scientific Knowledge is Based on Empirical Evidence**

- Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (ES-ESS2-4)

#### **Scientific Investigations Use a Variety of Methods**

- Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (ES-ESS3-5)
- New technologies advance scientific knowledge. (ES-ESS3-5)

#### **Scientific Knowledge is Based on Empirical Evidence**

- Science knowledge is based on empirical evidence. (ES-ESS3-5)
- Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (ES-ESS3-5)

- The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space. (ES-ESS2-4)

- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (ES-ESS2-4)

#### **ESS3.D: Global Climate Change**

- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (ES-ESS3-5)

#### **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. (ES4-ETS1-3)

### **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. (ES4-ETS1-3)

### *Connections to the Arkansas Disciplinary Literacy Standards:*

**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. (ES-ESS2-5)

**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. (ES-ESS3-5)

**RST.11-12.2** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (ES-ESS3-5)

- 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. (ES-ESS3-5, ES4-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. (ES4-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. (ES4-ETS1-3)

*Connections to the Arkansas English Language Arts Standards:*

- SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (ES-ESS2-4)

*Connections to the Arkansas Mathematics Standards:*

- MP.2** Reason abstractly and quantitatively. (ES-ESS2-4, ES-ESS3-5, ES4-ETS1-3)
- MP.4** Model with mathematics. (ES-ESS2-4),(HS-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. (ES-ESS2-4, ES-ESS3-5)
- HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (ES-ESS2-4, ES-ESS3-5)
- HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (ES-ESS2-4, ES-ESS3-5)

## Contributors

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