This scope and sequence document was developed to assist teachers with the implementation of the Louisiana Student Standards for Science. This tool is not full curriculum and will need to be further built out by science educators. It has been designed to help in the initial transition to the new standards.

This document is considered a "living" document, as we believe that teachers and other educators will find ways to improve it as they use it. Please send feedback to classroomsupporttoolbox@la.gov so that we may use your input when updating this tool.



Updated August 13, 2019

## About the Sample Scope and Sequence Tools

The Louisiana Student Standards for Science represent the knowledge and skills needed for students to successfully transition to postsecondary education and the workplace. The standards call for students to:

- Apply content knowledge
- Investigate, evaluate, and reason scientifically
- Connect ideas across disciplines

This scope and sequence document is designed to assist teachers, schools, and districts with the development of instructional resources that align with the Louisiana Student Standards for Science. This scope and sequence is only a sample; it does not illustrate the only appropriate sequence to teach the standards or the only possible ways to bundle the standards. The bundles can be reorganized around different phenomenon, including phenomenon specific to Louisiana or to a region in Louisiana.

Based on the instructional shifts, this tool uses phenomena to drive 3-dimensional science instruction. The incorporated phenomena are observable events that occur in the universe and can be explained by science. They establish the purpose for learning and help students to connect their learning to real-world events.

- The standards are bundled into units.
- The units are built around an anchor phenomenon.
- One unit has been built out further to contain a series of investigative phenomena, which have been sequentially organized to reinforce one another and build toward the performance expectations.

Throughout each unit, students should have multiple opportunities to apply the science and engineering practices, make sense of the crosscutting concepts, and develop a deep understanding of disciplinary core ideas.

## Building out the Science Scope and Sequences for Classroom Instruction

### How to Use the Anchor and Investigative Phenomena[1]

1. Explore the anchor phenomenon
2. Attempt to make sense of the phenomenon
3. Identify related phenomena
4. Develop questions and next steps
5. Explore investigative phenomena to help make sense of the anchor phenomenon
6. Communicate scientific reasoning around the anchor phenomenon

**Instructional Process**


### Choosing an Anchor Phenomenon

Students should be able to make sense of anchoring phenomenon, but not immediately, and not without investigating it using sequences of the science and engineering practices. With instruction and guidance, students should be able to figure out, step-by-step, how and why the phenomenon works. [2]

A good anchor phenomenon[3]:

☐ is too complex for students to explain or design a solution for after a single lesson.

- The explanation is just beyond the reach of what students can figure out without instruction.
- Searching online will not yield a quick answer for students to copy.

☐ can be a case (pine beetle infestation, building a solution to a problem), something that is puzzling (why isn't rainwater salty?), or a wonderment (how did the solar system form?).

☐ has relevant data, images, and text to engage students in the range of ideas students need to understand. It should allow them to use a broad sequence of science and engineering practices to learn science through first-hand or second-hand investigations.

☐ will require students to develop an understanding of and apply multiple performance expectations while also engaging in related acts of mathematics, reading, writing, and communication.

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[1] adapted from How do we bring 3-dimensional learning into our classroom?

[2] Using Phenomena

[3] Qualities of a Good Anchor Phenomenon

- ☐ is observable to students. “Observable” can be with the aid of scientific procedures (e.g., in the lab) or technological devices to see things at very large and very small scales (telescopes, microscopes), video presentations, demonstrations, or surface patterns in data.

## Choosing Investigative Phenomena

Students should be able to make sense of investigative phenomenon, but not immediately, and not without investigating it using sequences of the science and engineering practices. With instruction and guidance, students should be able to figure out, step-by-step, how and why the phenomenon works.[4]

A good investigative phenomenon:

- ☐ helps students make sense of one or two parts of the anchor phenomenon.
- ☐ has relevant data, images, and text to engage students in the range of ideas students need to understand.
- ☐ can be understood or explained by students using the science and engineering practices.

## Investigating the Phenomena

When a phenomenon is introduced, whether anchor or investigative, students should have the opportunity to make observations, discuss current understandings, and pose questions about the phenomenon. Once questions are compiled, it may be helpful to categorize questions as follows:

- Questions that can be investigated by our class
- Questions that can be investigated but not with our current resources and equipment
- Questions that can be researched
- Questions that cannot be answered (due to current technologies or scientific limitations)

## Other Useful Questions When Designing a Sequence of Learning[5]

- How do we kick off investigations in a unit?
- How do we work with students to motivate the next step in an investigation?
- How do we help students use practices to figure out the pieces of the science ideas?
- How do we push students to go deeper and revise the science ideas we have built together so far?
- How do we help students put together pieces of the disciplinary core ideas and crosscutting concepts?

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[4] Using Phenomena

[5] Questions to Guide the Development of a Classroom Culture That Supports “Figuring Out”

## Environmental Science Standards Overview

The Environmental Science course focuses on the study of Resources and Resource Management, Environmental Awareness and Protection, Personal Responsibilities, Earth's Systems, Human Sustainability, and Ecosystems: Interactions, Energy, and Dynamics.

| | | Science and Engineering Practices | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Crosscutting Concepts | | Asking Questions and Defining Problems | Developing and Using Models | Planning and Carrying Out Investigations | Analyzing and Interpreting Data | Using Mathematics and Computational Thinking | Constructing Explanations and Designing Solutions | Engaging in Argument from Evidence | Obtaining, Evaluating, and Communicating Information | All Domains |
| | Patterns | | | | | | | | | |
| | Cause and Effect | | HS-EVS2-2 | | HS-EVS1-3<br>HS-ESS2-4 | | HS-ESS3-1 | HS-EVS2-3 | | |
| | Scale, Proportion and Quantity | | | | | HS-LS2-1 | | | | |
| | Systems and System Models | | | | | HS-ESS3-6 | HS-ESS3-2 | | HS-EVS1-2 | |
| | Energy and Matter | | HS-ESS2-6 | | | HS-LS2-4 | | HS-EVS3-1 | | |
| | Structure and Function | | | HS-ESS2-5 | | | HS-EVS2-1 | | | |
| | Stability and Change | | | | HS-EVS1-1<br>HS-ESS2-2 | HS-ESS3-3 | HS-ESS3-4<br>HS-LS2-7 | HS-LS2-6 | | |

## Overview of Sample Units

| | Unit 1<br><br>Environmental Systems | Unit 2<br><br>Environmental Awareness and Protection | Unit 3<br><br>Ecosystems | Unit 4<br><br>Resources and Resource Management | Unit 5<br><br>Succession | Unit 6<br><br>Human Impact and Sustainability |
|---|---|---|---|---|---|---|
| **Anchor Phenomenon** | A mass of glacier ice suddenly breaks away from a larger glacier and causes sea levels to rise. | The largest Gulf of Mexico dead zone measured 22,720 square kilometers on July 24-30, 2017. | Wolves were absent from Yellowstone National Park for approximately 70 years. In 1995, wolves were reintroduced to the park and as a result the behaviors of rivers changed. | For approximately 100 million years, sediment deposition to the Mississippi River gradually increased the size of the Mississippi River Delta. However, over the past few decades, the Mississippi River Delta has greatly decreased. | The eruption of Mount Saint Helen in 1980 destroyed most life and more than 230 square miles of forests, lakes, meadows, and streams. However, pocket gophers and salamanders managed to survive the blast. | The Deepwater Horizon oil spill disrupted the cellular function of killifish. |
| **Standards** | HS-ESS2-2 *<br>HS-ESS2-4<br>HS-ESS3-4*<br>HS-ESS3-6<br>HS-ESS2-6 | HS-ESS2-2*<br>HS-ESS3-4*<br>HS-EVS2-1<br>HS-EVS2-2 | HS-LS2-1<br>HS-LS2-4<br>HS-LS2-6*<br>HS-LS2-7 | HS-ESS2-5<br>HS-EVS1-1<br>HS-EVS1-3<br>HS-EVS2-3 | HS-ESS3-1<br>HS-LS2-6* | HS-EVS1-2<br>HS-EVS3-1<br>HS-ESS3-2<br>HS-ESS3-3 |

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

# Unit 1: Environmental Systems

## About the Standards

### Performance Expectations

- HS-ESS2-2 Earth's Systems: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.
- HS-ESS2-4 Earth's Systems: Analyze and interpret data to explore how variations in the flow of energy into and out of Earth's systems result in changes in atmosphere and climate.
- HS-ESS3-4 Human Sustainability: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- HS-ESS3-6 Human Sustainability: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.
- HS-ESS2-6* Earth's Systems: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

### Disciplinary Core Ideas

| DCI | Partial Unpacking of the DCI |
|---|---|
| Earth's systems, being dynamic and interacting, include feedback effects that can increase or decrease the original changes. (DCI: HS.ESS2A.a; PE: HS-ESS2-2) | • Earth has interconnected spheres: lithosphere or geosphere, hydrosphere, biosphere, atmosphere and cryosphere.<br>• The lithosphere or geosphere refers to all of the rocks on planet earth.<br>• The hydrosphere refers to all of the water at or near the Earth's surface.<br>• The biosphere refers to the layer of planet Earth where life exists.<br>• The atmosphere refers to all of the gases that surround planet earth.<br>• The spheres are continuously interacting.<br>• Changes can occur in the interconnected spheres.<br>• A change in one sphere can cause changes to other spheres, resulting in positive or negative feedback loops. |

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| | • The changes (negative or positive) can stabilize or destabilize a system. |
| 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, hydrosphere, and land systems, and this energy's re-radiation into space. (DCI: HS.ESS2D.a; PE: HS-ESS2-2 and HS-ESS2-4) | • Sunlight is a portion of the electromagnetic radiation given off by the sun.<br>• Sunlight that reaches Earth's surface is filtered through Earth's atmosphere and/or reflected back to space.<br>• The sunlight that enters Earth's atmosphere heats land and oceans and drives biological and physical processes on the planet.<br>• The amount of sun that is reflected, absorbed, stored, or redistributed on Earth impact its climate systems.<br>• Several factors can impact the input, output, storage or redistribution of energy on Earth (e.g. changes in Earth's orbit and the orientation of its axis with respect to the sun, changes in the sun's energy output, configuration of continents resulting from tectonic activity, ocean circulation, atmospheric composition (water vapor, carbon dioxide, methane), atmospheric circulation, volcanic activity, glaciation, changes in the extent of type of vegetation cover, and human activities). |
| 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 Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (DCI: HS.ESS1B.b; PE: HS-ESS2-4) | • Earth's global temperatures can warm up or cool down if the amount of sunlight that enters the atmosphere is significantly altered.<br>• Cyclic variations of Earth's orbit around the sun impact the amount of sunlight that reaches Earth's surface. Gradual changes to the tilt of Earth's axis relative to its orbit around the sun have produced different weather patterns. |

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| 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, hydrosphere 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. (DCI: HS.ESS2A.d; PE: HS-ESS2-4) | • The geological record (ice cores, sediment deposits, fossil evidence, and paleovegetation restorations) shows that changes to global and regional climate can be caused by several factors (Earth's orbit, tectonic events, volcanic glaciers, vegetation, etc.).<br>• Several factors can impact the input, output, storage or redistribution of energy on Earth (e.g. changes in Earth's orbit and the orientation of its axis, changes in the sun's energy output, configuration of continents resulting from tectonic activity, ocean circulation, atmospheric composition (water vapor, carbon dioxide, methane), atmospheric circulation, volcanic activity, glaciation, changes in the extent of type of vegetation cover, and human activities).<br>• Changes to the input, output, storages or redistribution of energy on Earth can occur over a short or extended time frame and can cause extreme weather conditions. Changes occur at a variety of spatial and temporal scales.<br>• Variations in the intensity and timing of heat from the sun are the most likely cause of the glacial/interglacial cycles. |
| Gradual atmospheric changes were occurred due to plants and other organisms that captured carbon dioxide and released oxygen. (DCI: HS.ESS2D.b; PE: HS-ESS2-4 and HS-ESS2-6) | • Plants use carbon dioxide from the atmosphere to produce food and release oxygen.<br>• Carbon continuously cycles from one sphere to another.<br>• In the past, the relative amount of carbon that cycled through the hydrosphere, atmosphere, lithosphere or geosphere, and biosphere was partially due to the activity of plants and other organisms. |
| Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (DCI: HS.ESS2D.c; PE: HS-ESS2-4 and HS-ESS2-6) | • A large amount of carbon dioxide has been released into Earth's atmosphere by human-related fossil fuel combustion.<br>• The relative amount of and the rate at which carbon is transferred between spheres has been dramatically altered by human activity.<br>• An increase in atmospheric carbon can increase the amount of heat energy stored in the system. |
| Scientists and engineers can make major contributions by | • Scientists and engineers produce technological solutions to reduce humans' impact on Earth's systems. |

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| developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (DCI: HS.ESS3C.b; PE: HS-ESS3-4) | • The technological solutions stabilize and/or destabilize Earth's systems.<br>• Engineers and scientists use scientific knowledge and reasoning to produce technological solutions.<br>• Scientist and engineers have developed fuel-efficient automobiles that reduce harmful emissions into the atmosphere. |
| 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. (DCI: HS.ETS1B.a; PE: HS-ESS3-4) | • When scientists and engineers create solutions to problems, they use specific criteria to guide the development of their solutions.<br>• When scientists and engineers create solutions to problems, they consider the constraints of their design solutions including cost, safety, aesthetics, and reliability.<br>• Scientists and engineers consider cost, safety, reliability, and aesthetics when developing electric automobiles that have very little impact on the environment. |
| 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. (DCI: HS.ESS2D.d; PE: HS-ESS3-6) | • Current models of Earth's natural systems include system boundaries, initial conditions, inputs and outputs, and relationships that determine the interaction (e.g. the relationship between atmospheric carbon dioxide and production of photosynthetic biomass and ocean acidification).<br>• The models are used to predict negative and positive feedback loops in Earth's natural systems.<br>• A change in one sphere can cause changes to other spheres, resulting in positive or negative feedback loops.<br>• The models illustrate and describe the relationships between at least two systems, including how the relevant components in each individual Earth system can drive changes in another.<br>• Based on current models, Earth's average global temperatures will continue to rise due to an increase in human-generated greenhouse gases (e.g. carbon dioxide and methane) in Earth's atmosphere and associated feedbacks. |
| Important discoveries are still being made about how the | • Scientists and engineers use human-generated models including computer simulations, to predict how the |

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| ocean, the atmosphere, and the biosphere interact and are modified in response to human activities (e.g., through computer simulations and other discoveries from satellite imagery). (DCI: HS. HS.ESS3D.b; PE: HS-ESS3-6) | amount of greenhouse gases in Earth's atmosphere impacts the biological and physical processes on Earth (e.g. oceanic acidification, coral bleaching, ocean circulation etc.). |

**Science and Engineering Practices**

- 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.
- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.
- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.
- 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

**Crosscutting Concepts**

- Feedback (negative or positive) can stabilize or destabilize a system.
- 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.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- The total amount of energy and matter in closed systems is conserved.

## Unit 1: Environmental Systems

**Putting the Standards into Practice**

**Sample Anchor Phenomenon**: A mass of glacier ice suddenly breaks away from a glacier and causes sea levels to rise. This phenomenon is known as ice calving.

Explore the anchor phenomenon

**Resources:** A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

Chasing Ice Documentary
Polar Portal: Monitoring Ice and Climate in the Artic
NASA: Oceans Melting Greenland
Antarctic Glacier Calving Rate Increase Caused by Ice Shelf Melting

**Questions students may pose that could be used for future learning or investigations:**

Try to make sense of the anchor phenomenon

- What is ice calving?
- What factors cause ice calving?
- Does the warming of Earth's surface contribute to ice calving?
- How are oceanic temperature and sea level impacted by ice calving?
- What will occur if arctic glaciers continue to melt?
- Will humans and other organisms survive if glaciers continue to melt?
- Can humans reverse or slow down the rate that glaciers melt?
- What steps are scientists and engineers taking to reduce and monitor ice calving?

Teachers should provide Investigative Phenomena based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

**Sample Investigative Phenomena**

Identify related investigative phenomena → Develop questions and next steps → Explore investigative phenomena to help make sense of anchor phenomenon

**Sample 1**: In September 1991, eight scientists and almost 4,000 species of plants and animals were sealed into Biosphere II, a collection of airtight, interconnected domes in the Arizona desert. Within nine months, the scientists struggled to breathe.

Los Angeles Times: Prelude to Biosphere II
How Earth's Spheres Interact?
Ted Talk Biosphere II

Sample questions for students to investigate:

- How does one change in Biosphere II create feedbacks (a situation where part of the output of a situation is used for new input) that cause changes to other systems within the biosphere?
- How does matter cycle among Earth's hydrosphere, atmosphere, lithosphere or geosphere, and cryosphere? Use evidence from Biosphere II to support your response.
- How does one change to Earth's surface create feedbacks that cause changes to other Earth systems? Use evidence from Biosphere II to support your response.
- What is the difference between an open and closed system?
- What type of system is Earth? Use evidence to support your response.
- Develop a mesocosm to demonstrate the cycling of matter among Earth's systems.
- What impact does ice calving have on Earth's feedback cycles and connections? Use evidence to support your response.

3-D learning opportunities:

SEP: Analyze and interpret data; Develop and use models

DCI: HS.ESS2A.a; HS.ESS2D.a; HS.ESS2D.b; HS.ESS2D.c

CC: Stability and change; Energy and matter

**Sample 2**: Global temperatures have increased over the past century.

NASA: A Year in the Life of Earth's Carbon Dioxide
SEPUP Lab Simulation: Greenhouse Effect
Carbon Dioxide Virtual Science Data Environment
Scientific America: Carbon Dioxide and Climate

**Sample questions for students to investigate:**

- How have human activities contributed to the greenhouse effect?
- What impact does the input, output, storage or redistribution of energy on Earth have on Earth's systems and feedback loops?
- How have human activities, specifically the increase in fossil fuel combustion, contributed to Earth's changing systems?
- How do atmospheric variations, specifically the increase of greenhouse gases, impact the flow of energy into and out of Earth's systems? Use evidence from the Greenhouse Effect lab simulation to support your response.
- Are the claims made in *Scientific America's* 1959 article, "Carbon Dioxide and Climate," valid? Use current data to support or refute the claims.
- Analyze and interpret data to make a claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.
- How are atmospheric changes due to human activity contributing to artic ice calving? Use evidence to support your response.

**3-D learning opportunities:**

SEP: Analyze and interpret data; Obtain, evaluate, and communicate information; Engage in argument from evidence

DCI: HS.ESS1B.b; HS.ESS2A.a; HS.ESS2A.d; HS.ESS2D.a; HS.ESS2D.b; HS.ESS2D.c; HS.ESS2D.d

CC: Stability and change; Cause and effect

**Sample 3**: The Pacific Blob caused toxic algal blooms to form in the Pacific Ocean resulting in the death of sea otters and the starvation of sea lion pups.

National Geographic: Why Hundreds of Sea Otters Died in the Pacific
NOAA: Environmental Changes Stress West Coast Sea Lions
NASA: The Ocean: A Driving Force for Weather and Climate
West Coast Waters Shifting to Lower Productivity Regime, NOAA Report Finds
Major Effects of Ocean on Climate
Operational SST Anomaly Charts
Climate Assessment Resources
Global Climate Dashboard and Climate Maps

**Sample questions for students to investigate:**

- What impact does the input, output, storage or redistribution of energy on Earth have on Earth's systems and feedback loops?
- How do ocean-atmosphere climate patterns and cloud formations impact the Pacific Ocean surface temperatures?
- What impact do ocean-atmosphere climate patterns and cloud formations have on aquatic species such as sea otters and sea lion pups?
- How have human activities, such as the burning of fossil fuels, contributed to Earth's changing systems?
- Analyze and interpret data to determine if the burning of fossil fuels causes atmospheric changes that affect weather and climate patterns.
- The Pacific Decadal Oscillation caused the Pacific Blob and disrupted aquatic species. Using evidence from research, do you support or refute this claim?
- Are rising sea surface temperatures contributing to ice calving? Why or Why not?

**3-D learning opportunities:**

SEP: Analyze and interpret data; Use mathematical and computational thinking

DCI: HS.ESS2A.d; HS.ESS2D.a; HS.ESS2D.b; HS.ESS2D.c; HS.ESS2D.d

CC: System and system models; Stability and change

**Sample 4**: In 2011, California experienced abnormally dry weather conditions that eventually led to a drought.

California Then and Now
NASA Science Cast: California Drought
State of Urgency Managing California's Historic Drought
California Drought
CBS California Floats Shade Balls to Battle Drought
Shade Balls: What Are They and How Are They Saving Water?

**Sample questions for students to investigate:**

- How did ocean-atmosphere climate patterns and rising global temperatures contribute to California's drought?
- How did the drought impact California's water sources?
- What role did scientists and engineers play in designing solutions to California's drought?
- What design constraints did scientists and engineers have to consider when they designed solutions for California's drought problem?
- Evaluate or refine a technological solution that reduces the impacts of human activities, such as the burning of fossil fuels, on Earth's systems.
- How will your technological solution help to reduce ice calving events in the artic?

**3-D learning opportunities:**

SEP: Construct explanations and designing solutions

DCI: HS.ESS2A.D; HS.ESS2D.a; HS.ESS2D.c; HS.ESS2D.d; HS.ESS3C.b; HS.ESS3D.D; HS.ETS1B.a

CC: Cause and Effect; Stability and change

**Sample Anchor Phenomenon Reflections**

Communicate scientific reasoning around the anchor phenomenon

- How do human activities and an increase in Earth's global temperature contribute to the ice calving phenomenon?
- How does ice calving impact Earth's systems, weather, and atmospheric changes?
- How does ice calving and an increase in Earth's global temperatures impact organisms?
- How do human activities impact the cycling of carbon within Earth's biogeochemical cycles?
- How do scientists and engineers identify and develop technological solutions to identify and solve the impact of human activities on natural systems?

## Unit 2: Environmental Awareness and Protection

### About the Standards

**Performance Expectations**

- HS-ESS2-2* Earth's Systems: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.
- HS-ESS3-4* Human Sustainability: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- HS-EVS2-1 Environmental Awareness and Protection: Design and evaluate a solution to limit the introduction of non-point source pollution into state waterways.
- HS-EVS2-2 Environmental Awareness and Protection: Use a model to predict the effects that pollution as a limiting factor has on an organism's population density.

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

**Science and Engineering Practices**

- Design, evaluate and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria and trade-off considerations.
- Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems and/or solve problems.
- 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.
- 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.

**Crosscutting Concepts**

- 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.
- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.
- Feedback (negative or positive) can stabilize or destabilize a system.

## Putting the Standards into Practice

Explore the anchor phenomenon

**Sample Anchor Phenomenon**: The largest Gulf of Mexico dead zone measured 22,720 square kilometers on July 24-30, 2017.

**Resources:** A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

- CBS: Massive Dead Zone in Gulf of Mexico
- Gulf of Mexico Dead Zone
- Eutrophication
- The Problem of Hypoxia in the Northern Gulf of Mexico
- The Causes of Hypoxia in the Northern Gulf of Mexico
- Hypoxia in the Gulf of Mexico
- The Times-Picayune: Gulf of Mexico Dead Zone is Going in the Wrong Direction
- Louisiana Universities Marine Consortium: Dissolved Oxygen Maps
- Louisiana Universities Marine Consortium: Graphs
- Louisiana Universities Marine Consortium: Mississippi River Discharge

**Questions students may pose that could be used for future learning or investigations:**

Try to make sense of the anchor phenomenon

- What is a dead zone?
- How do dead zones form?
- What impact does the Gulf of Mexico dead zone have on Louisiana residents and the economy?
- What can Louisiana citizens do to fix the Gulf of Mexico dead zone problem?
- Do dead zones occur in other areas? How are other states or communities dealing with the issue?
- Does eutrophication in the Gulf of Mexico create feedbacks that cause changes to its ecosystem?
- Does agriculture contribute to the Gulf of Mexico dead zone?
- Do hypoxic conditions impact aquatic organisms in the Gulf of Mexico?
- Can engineers and scientists design solutions to reduce the impact of eutrophication in the Gulf of Mexico?

Teachers should provide Investigative Phenomena based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

**Sample Anchor Phenomenon Reflections**

Communicate scientific reasoning around the anchor phenomenon

- Make a claim supported by evidence that eutrophication in the Gulf of Mexico create feedbacks that cause changes to its ecosystem.
- Describe how farming and other human activities contribute to the Gulf of Mexico Dead Zone.
- Create a model and use mathematics and computational data to explain that hypoxic conditions impact aquatic organisms in the Gulf of Mexico.
- Design a solution to limit the impact of eutrophication in the Gulf of Mexico.

## Unit 3: Ecosystems

### About the Standards

**Performance Expectations**

- HS-LS2-1 Ecosystems: Interactions, Energy and Dynamics: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity, biodiversity and populations of ecosystems at different scales.
- HS-LS2-4 Ecosystems: Interactions, Energy and Dynamics: Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
- HS-LS2-6* Ecosystems: Interactions, Energy and Dynamics: Evaluate the claims, evidence and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2-7 Ecosystems: Interactions, Energy and Dynamics: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

**Science and Engineering Practices**

- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
- Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

**Crosscutting Concepts**

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.
- Much of science deals with constructing explanations of how things change and how they remain stable.

## Putting the Standards into Practice

**Sample Anchor Phenomenon**: Wolves were absent from Yellowstone National Park for approximately 70 years. In 1995, wolves were reintroduced to the park and as a result the behaviors of rivers changed.

Explore the anchor phenomenon

**Resources:** A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

- Yellowstone Science: Celebrating 20 Years of Wolves
- How Wolves Change Rivers
- Ted Talk: For More Wonder, Rewild the World
- National Geographic: Exposure Yellowstone Wolves
- NPS: Wolves
- Yellowstone In-depth: The Northern Range
- Wolf Restoration
- U.S. Fish and Wildlife Service: Wolf Recovery Under the Endangered Species Act
- Yellowstone Wolf Project Annual Report 1995-1996
- Yellowstone Wolf Project Annual Report 2003
- Yellowstone Wolf Project Annual Report 2016

**Questions students may pose that could be used for future learning or investigations:**

Try to make sense of the anchor phenomenon

- How did the removal of wolves from Yellowstone National Park cause its rivers to change?
- Why were the banks of rivers in Yellowstone National Park less stable when wolves were removed from the park?
- How did the reintroduction of wolves to Yellowstone National Park help stabilize river banks and rivers meander?
- Why were wolf populations removed from Yellowstone National Park?
- Why are wolves considered to be a keystone species in Yellowstone National Park?
- Did the removal of wolves from Yellowstone National Park impact populations?
- How did the removal of wolves from Yellowstone National Park impact the flow of matter and energy in the park?
- What is a trophic cascade and how are wolves in Yellowstone National Park an example of this phenomenon?
- What factors impact carrying capacity, biodiversity, and populations in Yellowstone National Park?
- How can engineers and scientists design a solution to preserve a healthy ecosystem in Yellowstone National Park?

Teachers should provide Investigative Phenomena based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon

**Sample Anchor Phenomenon Reflections**

Communicate scientific reasoning around the anchor phenomenon

- Use mathematics and computational data to describe how the removal of wolves from Yellowstone National Park impacted the cycling of matter and flow of energy in the park.
- Use mathematical and computational representations to explain how the removal of wolves from Yellowstone National Park impacted its carrying capacity, biodiversity and populations.
- Make a claim supported by evidence that the complex interactions in Yellowstone National Park maintain relatively consistent numbers and types of organisms in stable conditions.
- Communicate information supported by evidence that geographical changes in Yellowstone National Park affected its ecosystem.
- Evaluate and/or refine the Endangered Species Act to reduce the impact of human activities on the environment and biodiversity.

## Unit 4: Resources and Resource Management

### About the Standards

**Performance Expectations**

- HS-ESS2-5 Earth's Systems: Plan and conduct an investigation on the properties of water and its effects on Earth materials and surface processes.
- HS-EVS1-1 Resources and Resource Management: Analyze and interpret data to identify the factors that affect sustainable development and natural resource management in Louisiana.
- HS-EVS1-3 Resources and Resource Management: Analyze and interpret data about the consequences of environmental decisions to determine the risk-benefit values of actions and practices implemented for selected issues.
- HS-EVS2-3 Environmental Awareness and Protection: Use multiple lines of evidence to construct an argument addressing the negative impacts that introduced organisms have on Louisiana's native species

**Science and Engineering Practices**

- Plan an investigation (science) or test a design (engineering) individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.
- 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.
- Construct, use, and/or present an oral and written argument or counterarguments based on data and evidence.

**Crosscutting Concepts**

- 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.
- Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

## Putting the Standards into Practice

**Sample Anchor Phenomenon**: For approximately 100 million years, sediment deposition to the Mississippi River Delta gradually increased the size of the Mississippi River Delta. However, over the past few decades, the Mississippi River Delta has greatly decreased.

Explore the anchor phenomenon

**Resources:** A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students are they are due to length, content, or accessibility of the content.

ABC News: Mississippi Flooding: River Cresting
How River Spillways Protect Major Cities
Bonnet Carre Spillway Opening Shunts Mississippi River Water Away from New Orleans
CBS: Massive Intentional Flooding in Louisiana Begins
Morganza Spillway Opens 2011
Bonnet Carre Spillway Opening 2016
USGS: 2011 Floods in Louisiana
Mississippi River Delta
How a Delta is Formed
NASA Earth Observatory: Mississippi River
Google Maps: Mississippi River Delta
NPR: The Wily Mississippi Cuts New Paths
Life on the Mississippi by Mark Twain
National Wildlife Federation: Sediment Going South
NASA Earth Observatory: Taming the Mississippi River
Learning to Manage, Not Fight, the Mississippi River
National Wildlife Federation: Managing the Mississippi
National Wildlife Federation: Land without Levees

**Questions students may pose that could be used for future learning or investigations:**

Try to make sense of the anchor phenomenon

- What is the rate of land lost along Louisiana's coast?
- What factors are contributing to the reduction of the Mississippi River Delta?
- Are levee systems and spillways contributing to the decrease of the Mississippi River Delta?
- How has the Mississippi River changed over time?
- Did scientists and engineers consider the negative outcomes of hydrological modifications and/or levee systems on the Mississippi River Delta?
- Did the physical and chemical properties of water contribute to the decrease and/or increase of the Mississippi River Delta?

- What does current evidence show about the unintended negative impacts of water runoff and soil erosion along Louisiana's coast?
- What other factors are impacting the Mississippi River Delta and the wetlands?
- How does the presence of invasive species impact our coastline and interfere with efforts to preserve it?
- Does the presence of invasive species in Louisiana's waterways and the reduction of the Mississippi River delta our seafood industry?
- Have scientists and engineers suggested the removal of levees and spillways in certain areas to increase the rate of soil deposition to the Mississippi River?

Teachers should provide Investigative Phenomena based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

**Sample Anchor Phenomenon Reflections**

Communicate scientific reasoning around the anchor phenomenon

- Describe the properties of water and its effects on Earth materials and surface processes.
- Describe the consequences of building levees and hydrological modifications on the Mississippi River Delta and Louisiana.
- Make a claim supported by evidence that invasive species are impacting Louisiana wetlands and native species.
- Explain how the Mississippi River Delta and/or Louisiana wetlands supply ecosystem capital. Identify factors that affect its sustainable development and natural resource management and solutions to overcome them.

## Unit 5: Succession

**Performance Expectations**

- HS-ESS3-1 Human Sustainability: 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.
- HS-LS2-6 Ecosystems: Interactions, Energy and Dynamics: Evaluate the claims, evidence and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

**Science and Engineering Practices**

- 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.
- Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of argument

**Crosscutting Concepts**

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Much of science deals with constructing explanations of how things change and how they remain stable

## Putting the Standards into Practice

Explore the anchor phenomenon

**Sample Anchor Phenomenon**: The eruption of Mount Saint Helen in 1980 destroyed most life and more than 230 square miles of forests, lakes, meadows, and streams. However, pocket gophers and salamanders managed to survive the blast.

**Resources:** A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

NASA: Time Lapse Mount St. Helens
NOVA: Life Returns in Mount Saint Helens
USGS: Mount St. Helens-From 1980 Eruption to 2000
USGS: Mount St. Helens, 1980 to Now-What's Going On?
Mount St. Helens-A Story of Succession
NASA: Devastation and Recovery of Mt. St. Helens
PBS: Mother Nature Rebuilds
Ecological Responses to the 1980 Eruption of Mount St. Helens by Virginia Dale, Fredrick Swanson

**Questions students may pose that could be used for future learning or investigations:**

Try to make sense of the anchor phenomenon

- How did some organisms manage to survive the blast?
- How did organisms survive if the forests, lakes and meadows were completely destroyed?
- What impact did the blast have on human life and the development of new communities?
- Were organisms reintroduced to the ecosystem? How did other organisms eventually reemerge?
- How did the 1980 Mount St. Helen volcanic eruption impact biodiversity?
- How does the condition of the physical environment impact populations of organisms?
- How was Spirit Lake impacted by the eruption?
- Did the eruption of Mt. Saint Helens disrupt the complex interactions in its ecosystem?
- Did the eruption of Mt. Saint Helens influence human activity in the region?
- How do natural hazards impact the availability of resources?

Teachers should provide Investigative Phenomenon based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

**Sample Anchor Phenomenon Reflections**

Communicate scientific reasoning around the anchor phenomenon

- Construct an explanation based on evidence for how the occurrence of natural hazards, changes in climate, and availability of resources drive human activity.
- Make a claim supported by evidence that the complex interactions in Mount Saint Helen ecosystem maintain relatively consistent numbers and types of organisms in stable conditions, but changing those conditions may result in a new ecosystem.

## Unit 6: Human Impact and Sustainability

**Performance Expectations**

- HS-EVS1-2 Resources and Resource Management: Obtain, evaluate and communicate information on the effectiveness of management or conservation practices for one of Louisiana's natural resources with respect to common considerations such as social, economic, technological, and influencing political factors over the past 50 years.
- HS-EVS3-1 Personal Responsibilities: Construct and evaluate arguments about the positive and negative consequences of using disposable resources versus reusable resources.
- HS-ESS3-2 Human Sustainability: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
- HS-ESS3-3 Human Sustainability: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

**Science and Engineering Practices**

- Create a computational model or simulation of a phenomenon, designed device, process, or system.
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
- Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Construct, use, and/or present an oral and written argument or counterarguments based on data and evidence.
- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source

**Crosscutting Concepts**

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Systems can be designed to do specific tasks.
- 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
- 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.

## Putting the Standards into Practice

Explore the anchor phenomenon

**Sample Anchor Phenomenon**: The Deepwater Horizon oil spill disrupted the cellular function of killifish.

**Resources:** A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

Gulf Oil Spill is Sickening Fish Vital to Seafood Industry
Genomic and Physiological Footprint of the Deepwater Horizon Oil Spill on Marsh Fishes
Time: Oil Spill by the Numbers
MSNBC: BP Oil Spill Five Years Later
NPR: Five Years After BP Oil Spill
National Geographic: Gulf Oil Spill Disintegrated This Island
Deepwater Horizon Oil Spill: NOAA Assessment
U.S. Fish & Wildlife: Spill Response
Science Daily: Deepwater Horizon Oil Spill
Economic Impact of BP Oil Spill
CDC: Oil Spill Dispersant Information for Health Professionals
The New York Times: In Gulf of Mexico, Chemicals Under Scrutiny
Washington Post: Chemical Used in BP Oil Spill Cleanup Capable of Injuring People & Wildlife

**Questions students may pose that could be used for future learning or investigations:**

Try to make sense of the anchor phenomenon

- What caused the Deepwater Horizon oil spill?
- Why are killifish experiencing cardiovascular and growth problems?
- Are killifish important to Louisiana's fishing industry?
- How did the oil spill impact ecosystem services?
- What impact did the oil spill have on Louisiana wetlands, barrier islands and the rate of coastal erosion?
- What are the risks and benefits of oil and gas production in Louisiana?
- What factors impact the sustainable development of oil and gas in Louisiana?
- What are the positive and negative consequences of using renewable and nonrenewable energy resources?
- What are the risks and benefits of oil and gas production in Louisiana?
- How do reduced ecological footprints contribute to the management of natural resources and the promotion of biodiversity?
- How did the oil spill impact the environment, economy, and health of Louisiana residents?

Teachers should provide Investigative Phenomenon based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

**Sample Anchor Phenomenon Reflections**

Communicate scientific reasoning around the anchor phenomenon

- Communicate information on the effectiveness of management or conservation practices for oil and gas production in Louisiana with respect to common considerations such as social, economic, technological, and influencing political factors over the past 50 years.
- Construct arguments about the positive and negative consequences of using disposable resources versus reusable resources in Louisiana.
- Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources in Louisiana based on cost-benefit ratios.
- Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity in Louisiana.