BIOZONE

CLASSROOM GUIDE

# EARTH AND SPACE SCIENCES FOR NGSS

# Contents

## CLASSROOM GUIDE



**Teacher's notes**



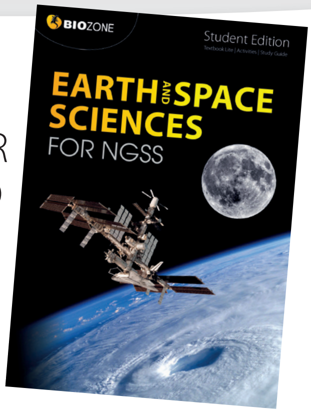
## STUDENT EDITION



## LONG ANSWERS



# FAQs
## ABOUT OUR EARTH AND SPACE SCIENCES FOR NGSS







BIOZONE

**BIOZONE** Corporation
USA and Canada
**FREE phone:** 1-855-246-4555
**FREE fax:** 1-855-935-3555
**Email:** sales@thebiozone.com
**Web:** www.thebiozone.com

# Creating Lifelong Learners

We want today's science students to be self-motivated, lifelong learners, to develop a sound grasp of how we do science, to plan and evaluate their work, and to think critically and independently. In developing *Earth and Space Sciences for NGSS*, we have utilized the 5Es instructional model as a basis for developing materials to specifically address the three dimensions of the NGSS framework: **disciplinary core ideas** (DCIs), **science and engineering practices**, and **crosscutting concepts**. By successfully completing the activities, which make up the bulk of the student book, students can demonstrate competence in skills and ideas. This is central to meeting the NGSS performance expectations, which incorporate all three dimensions from the framework. BIOZONE's suite of resources for the HS-ESS component of NGSS can help your students achieve key competencies in all areas of Earth and space sciences.


BIOZONE encourages the development of the NGSS learner profile using the 5 Es model

## The Five Es

| | |
|---|---|
| **E**ngage: | make connections between past and present learning experiences. |
| **E**xplore: | become actively involved in the activity. |
| **E**xplain: | communicate the learning experience. |
| **E**laborate: | expand on the concepts learned. |
| **E**valuate: | assess understanding of the concepts. |

| | |
|---|---|
| **ENGAGE: Highly visual activities** | Use activities in class to engage a student when introducing a topic, or to consolidate student understanding and summarize the material covered by other methods. Using activities in class provides valuable opportunities for peer-to-peer learning. |
| **ENGAGE: A connected plan of study** | Students can use the concept maps to develop a mental picture of the topics they will study and how they are interrelated. The check-box format of the contents pages and the chapter introductions provides a focus for planning achievement. |
| **EXPLORE: Independent, self directed study** | Activities are self-contained so students are encouraged to be independent learners and seek the answers to questions posed by the activity. Capable students can work quickly and independently through the core material and can use the time for extension. Less able students can review or finish activities at home. Most activities are supported by web-based resources in the form of animations and video clips. |
| **EXPLAIN: Communicating is the key to consolidation** | All activities first engage the student with a key idea and a visually inviting delivery of content. Student engagement with this material leads them to the questions in which they must communicate their understanding of the content. Students are encouraged to use appropriate biological terms as referenced in the chapter introduction (key terms). |
| **ELABORATE: Building up** | Most introductory activities are supported by activities in which students apply their understanding of core ideas to a new situation. These 'follow-on' activities often involve data analysis, and support specific science and engineering practices. |
| **EVALUATE: Easy assessment** | Encourage self assessment with chapter reviews (these can be graded if desired) or use specific activities to evaluate a student's skills and understanding or core ideas. |
| **WHAT ABOUT HOMEWORK?** | Assign activities as homework to review a completed topic, explore a crosscutting concept, or introduce a topic prior to in-class practical work. |

# The Contents: A Plan of Action

The contents pages are not merely a list of the activities in the student edition. Encourage your students to use them as a planning tool for their program of work. Students can identify the activities they are to complete and then tick them off when completed. The teacher can also see at a glance how quickly the student is progressing through the assigned material.

## Contents



CODES: **Activity** is marked: to be done

Photocopying Prohibited

The teacher can see at a glance how this student is progressing through this unit of work. Any concerns with progress can be addressed early.


ESS1.C
**The History of Planet Earth**

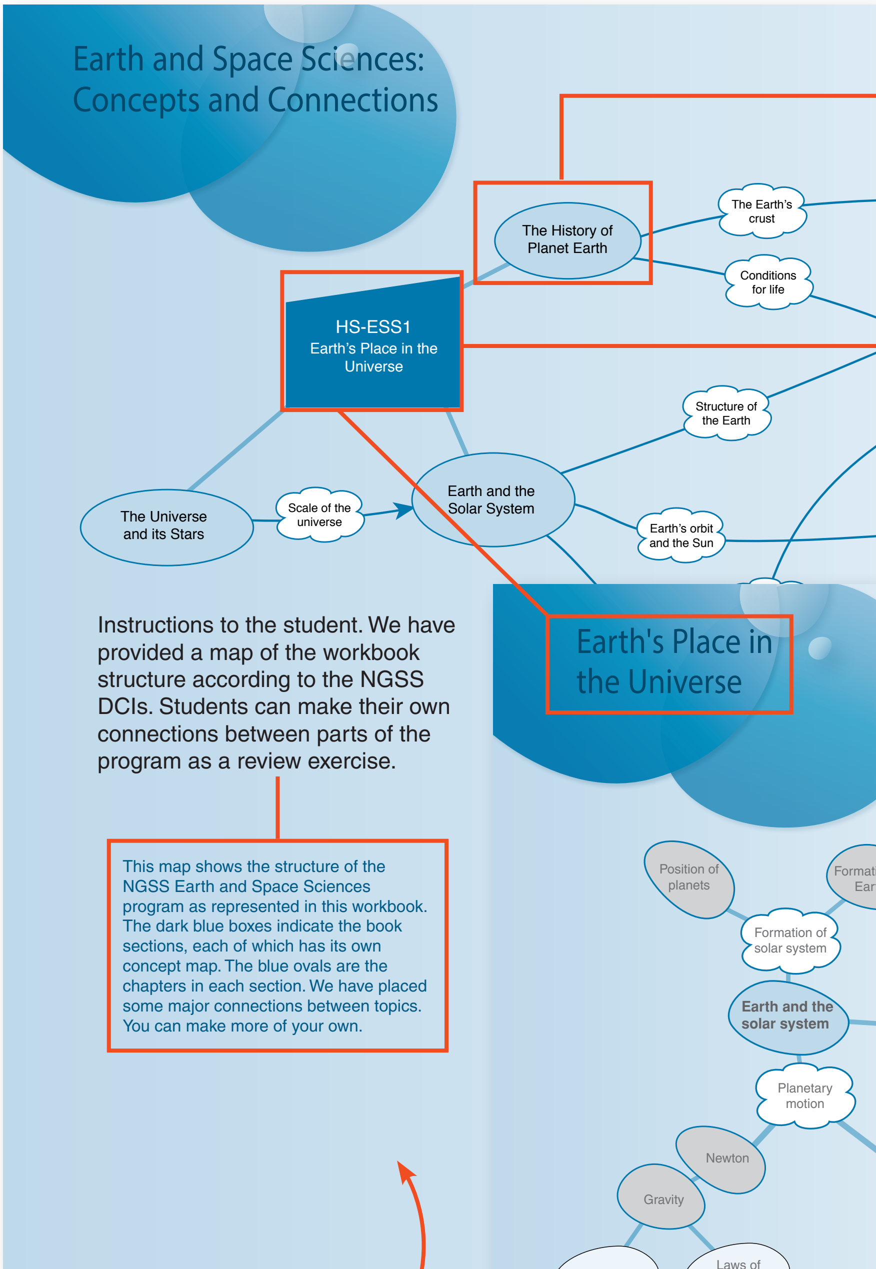
*DCIs, CCCs, SEPs* ... 82
48 The Earth ... 83
49 The Earth's Crust ... 84
50 Dating the Earth ... 86
51 What Can Mars Tell Us? ... 88
52 Information from Probe Missions ... 90
53 The Earth's History ... 92
54 The Goldilocks Planet ... 94
55 Models of the Earth's Age ... 95
56 Chapter Review ... 96
57 KEY TERMS AND IDEAS: Did You Get It? ... 97
58 Summative Assessment ... 98


Students can mark the check boxes to indicate the activities they should complete. This helps them to quantify the work to be done and plan their work.

Ticking off the activities as they are completed gives students a sense of progression and helps them to be more personally organized in their work.

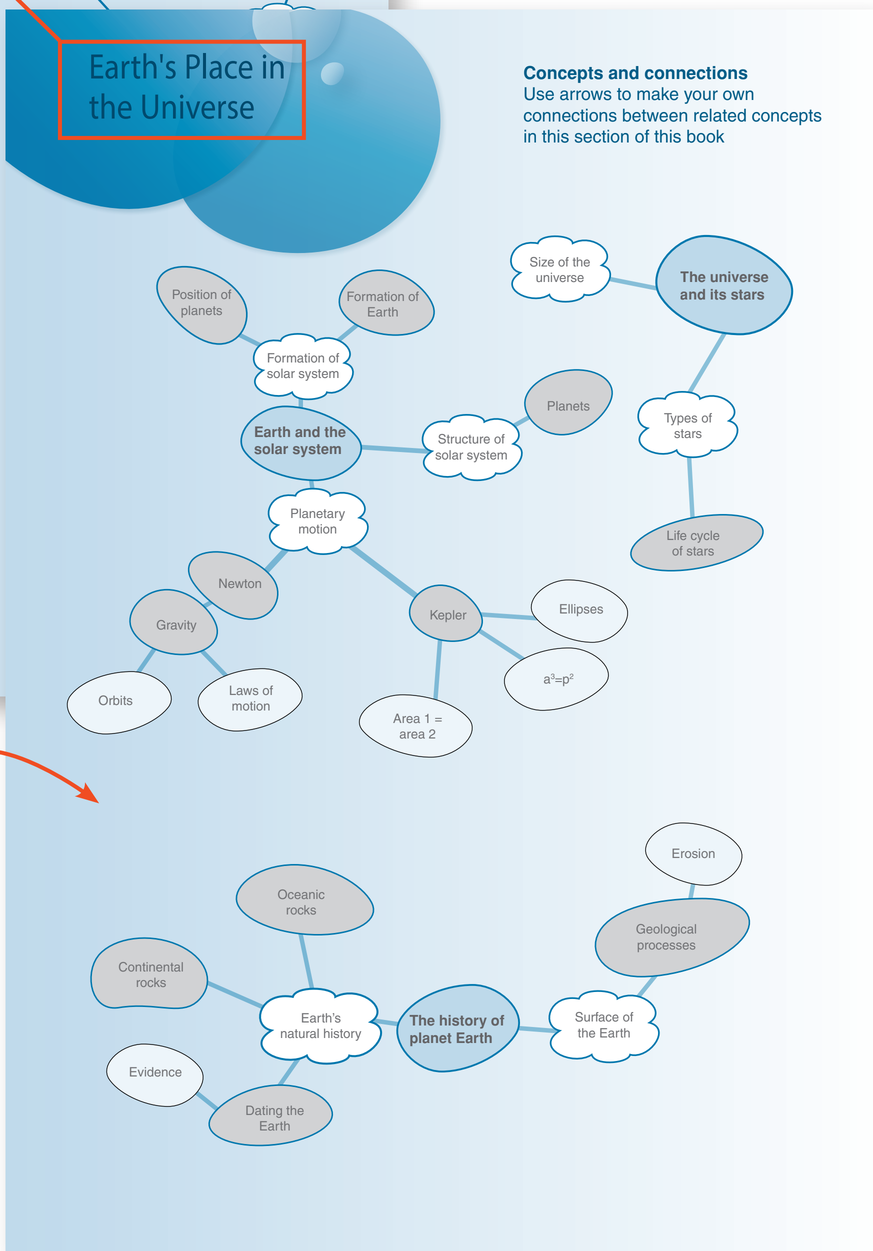
# The Concept Maps

The concept maps in *Earth and Space Sciences for NGSS* have two broad purposes: to provide a map of ideas covered in the program and to provide a vehicle for students to make their own connections between those ideas. The introductory map provides an overview of the structure of the NGSS Earth and Space Sciences program. Section concept maps divide the book into three parts, each providing a visual summary of one of three broad areas within the program, corresponding to ESS1-ESS3. Students can make their own connections between ideas on the concept maps as they work through the topics.




Each chapter of the book corresponds to specific major DCI of the NGSS-ESS program.

Each major section of the workbook corresponds to an overarching DCI. There are three sections: ESS1-ESS3.




There is one concept map for the entire program and one for each major DCI.

Content coverage indicated in hierarchical order. The blue ovals represent chapter headings. The content covered in each chapter is indicated in the clouds and gray ovals.

Encourage your students to make their own connections between topics and populate the map with notes and diagrams.

# Introducing the NGSS Content

In developing *Earth and Space Sciences for NGSS*, we have embraced the three dimensions of the new framework, emphasizing the application of ideas and skills to new scenarios. The activities in *Earth and Space Sciences for NGSS* have been specifically designed to address the **disciplinary core ideas, science and engineering practices**, and **crosscutting concepts** in a way that helps students to meet the performance expectations incorporating them.

ESS1.A

## The Universe and its Stars

The DCI for this chapter.

**Key terms**

atomic nuclei
Big Bang theory
cosmic microwave background
Doppler effect
electromagnetic radiation
element
event horizon
Hertzsprung–Russell diagram
light spectra
main sequence star

The list of **key terms** can be used to create a glossary for revision and encourages appropriate use of the correct terms when answering questions.

### Disciplinary Core Ideas

*Show understanding of these core ideas* — Activity number

**The Sun is changing and will burn out**

1 Recognize that our understanding of the universe continues to increase as the tools and technology available to us advance. — 12 13

2 Describe the life cycle of the Sun, a main sequence star with a life span of ~10 billion years. Include reference to the changes during its existence, including variations in radiation, sunspot cycles, and non-cyclic variations. — 18

3 Describe the evidence for changes in a star's luminosity during its lifetime and explain differences between the lifetimes of stars of different masses. — 17 18 19

4 Describe how the study of stars' light spectra and brightness is used to identify their features, such as composition, movements and distance from Earth. Include reference to O, B, A, F, G, K, and M standard stellar types. — 16 19

**The Big Bang theory is supported by many lines of evidence**

5 Describe the Big Bang theory and the astronomical evidence supporting it. Include reference to the red shift, the cosmic microwave background, and the measured composition of stars and non-stellar gases. — 13-16

**Elements are produced by nucleosynthesis**

6 Explain how nucleosynthesis creates new atomic nuclei from pre-existing nucleons (protons and neutrons) and releases electromagnetic energy. Distinguish between Big bang, stellar, and supernova nucleosynthesis. — 22

7 Explain how nucleosynthesis and the different elements created varies as a function of the star's mass and the stage of its life cycle. — 20 21 22


### Crosscutting Concepts

*Understand how these fundamental concepts link different topics* — Activity number

1 SPQ The significance of a phenomenon, such as nucleosynthesis, depends on the scale, proportion, and quantity at which it occurs. — 17 20 21 22

2 SPQ The concept of orders of magnitude can be used to understand models of the universe at different scales. — 13 16-19

3 EM In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. — 14 17-22

### Science and engineering practices

*Demonstrate competence in these science and engineering practices* — Activity number

1 Develop and use an evidence-based model to illustrate the life span of the Sun and the role of nuclear fusion in the Sun's core. — 17 18 19 22 25

2 Use an evidence-based model to describe the origin and nature of the universe. — 13 14 21

3 Construct an explanation of the Big Bang theory based on evidence from a variety of sources and uniformitarianism. — 14 15

4 Use multiple formats (e.g. oral presentation, text, diagrams, mathematics) to communicate scientific ideas about the way stars produce elements. — 20 21 22

Students can mark the check boxes to indicate the objective they should complete. They can be ticked off when finished.

**For students**:
The core ideas are purposefully brief, with enough information to provide a framework, but not so much that students are overwhelmed.

**For teachers**:
An equivalent matched set of achievement outcomes, for teacher's-only reference, is provided in the classroom guide for each chapter. These provide extra explanatory detail and examples.

The activities in the student book pertaining to this disciplinary core idea.

The activities in the student book pertaining to this crosscutting concept.

The activities in the student book pertaining to this science and engineering practice.

## Disciplinary core ideas: Teacher's notes

### The Sun is changing and will burn out

1. Students should realize that our understanding of the universe is based on observation and that what we can observe and how accurately we observe and record it depends on the technology we are using. Students should also realize that each piece of technology or observational hardware has its own strengths, weaknesses and limitations of use. (**HS-ESS1-1, HS-ESS1-2**)

2. The Sun formed from a nebula comprising mostly hydrogen and helium. Nuclear fusion of hydrogen into helium powers the Sun. The size of the Sun is an equilibrium between gravity pulling inwards and the heat and light produced by nuclear fusion pushing outwards. Eventually the hydrogen in the core will be used up and the core will contract. Helium will ignite and fuse to carbon and oxygen in a shell around the core. The outer layers will swell and the Sun will become a red giant star. When nuclear fusion stops the outer layers will be lost and the core will remain as a white dwarf. (**HS-ESS1-1**)

3. As stars evolve and become red giants or super giants their surface temperature drops but their overall luminosity increases. Luminosity tends to increase with size (large stars are brighter than small stars) and mass (massive stars burn hotter and brighter than lighter stars). Very large massive stars use up their hydrogen fuel quickly (sometimes within a billion years). They continually fuse heavier elements at a faster and faster rate (carbon fusion lasts 600 years, oxygen fusion lasts 6 months, and silicon fusion lasts 1 day), until iron is reached. At this point fusion

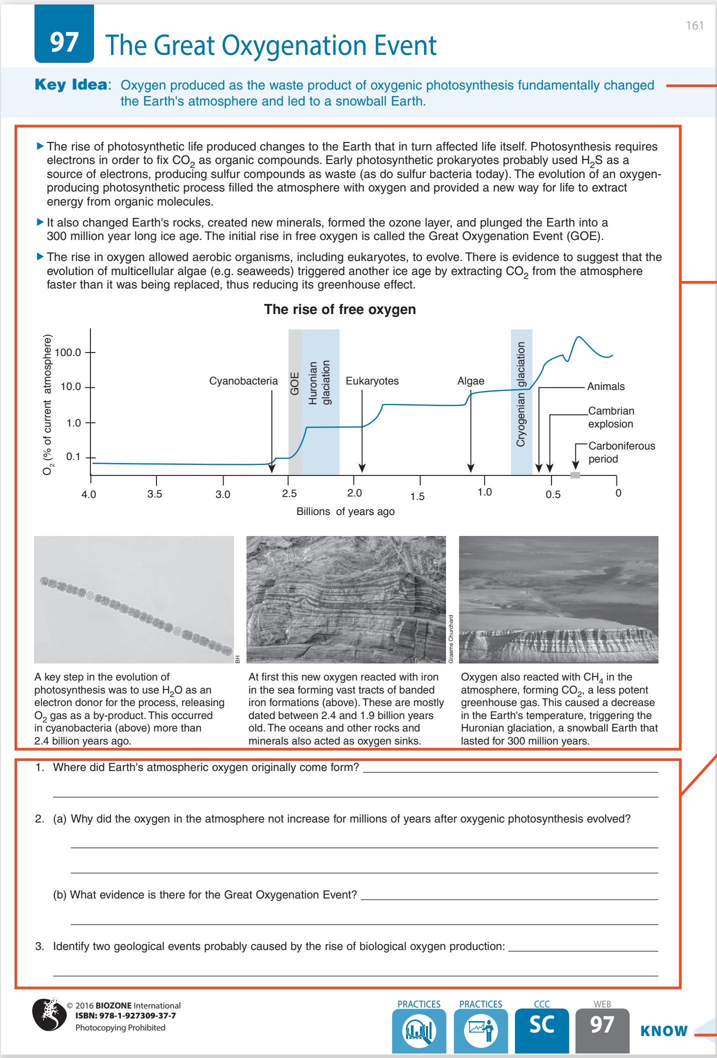
**For teachers**:
The **Disciplinary core ideas-Teacher's notes** provide teachers with additional content and helpful information, including important focus areas and examples. Importantly, the numbered objectives are aligned to those provided in the student edition. Point-by-point, they provide explanatory notes for each chapter, for the teacher to use at their discretion. The Teacher's notes also include points for *Nature of Science* and *Engineering, Technology, and Applications of Science*.

Each point is aligned to the relevant Performance Expectation (where appropriate) for the DCIs, crosscutting concepts, and the science and engineering practices.

# Using the Activities

The content of the *Earth and Space Sciences for NGSS* is organized into 12 chapters, each beginning with an introduction and all except *Science Practices* concluding with a student review, a test of understanding and vocabulary, and a summative assessment. Inviting, concept-based activities make up the bulk of each chapter, with each activity focusing on the student developing understanding of a concept, applying that understanding to another scenario, and/or developing skill an essential science practice, such as graphing or data analysis.

An important feature of each activity is the key idea, which encapsulates the main focus of the activity's content. Annotated diagrams and photographs are a major part of most activities and the student's understanding of the information is evaluated through questions and/or tasks involving data handling and interpretation. The task code for each activity identifies the nature of the activity, and the tabs identify crosscutting concepts and science and engineering practices as appropriate. Tabs also indicate if the activity is paired with a weblink, which provides online support for the activity.



161

97 The Great Oxygenation Event

**Key Idea**: Oxygen produced as the waste product of oxygenic photosynthesis fundamentally changed the Earth's atmosphere and led to a snowball Earth.

- The rise of photosynthetic life produced changes to the Earth that in turn affected life itself. Photosynthesis requires electrons in order to fix $CO_2$ as organic compounds. Early photosynthetic prokaryotes probably used $H_2S$ as a source of electrons, producing sulfur compounds as waste (as do sulfur bacteria today). The evolution of an oxygen-producing photosynthetic process filled the atmosphere with oxygen and provided a new way for life to extract energy from organic molecules.
- It also changed Earth's rocks, created new minerals, formed the ozone layer, and plunged the Earth into a 300 million year long ice age. The initial rise in free oxygen is called the Great Oxygenation Event (GOE).
- The rise in oxygen allowed aerobic organisms, including eukaryotes, to evolve. There is evidence to suggest that the evolution of multicellular algae (e.g. seaweeds) triggered another ice age by extracting $CO_2$ from the atmosphere faster than it was being replaced, thus reducing its greenhouse effect.

The rise of free oxygen



A key step in the evolution of photosynthesis was to use $H_2O$ as an electron donor for the process, releasing $O_2$ gas as a by-product. This occurred in cyanobacteria (above) more than 2.4 billion years ago.

At first this new oxygen reacted with iron in the sea forming vast tracts of banded iron formations (above). These are mostly dated between 2.4 and 1.9 billion years old. The oceans and other rocks and minerals also acted as oxygen sinks.

Oxygen also reacted with $CH_4$ in the atmosphere, forming $CO_2$, a less potent greenhouse gas. This caused a decrease in the Earth's temperature, triggering the Huronian glaciation, a snowball Earth that lasted for 300 million years.

1. Where did Earth's atmospheric oxygen originally come form? ______

2. (a) Why did the oxygen in the atmosphere not increase for millions of years after oxygenic photosynthesis evolved? ______

   (b) What evidence is there for the Great Oxygenation Event? ______

3. Identify two geological events probably caused by the rise of biological oxygen production: ______

© 2016 **BIOZONE** International
ISBN: 978-1-927309-37-7
Photocopying Prohibited

PRACTICES PRACTICES CCC SC WEB 97 KNOW

The **key idea** provides a focus for each activity. It summarizes the focus of the activity and provides a clear take-home message for the student.

Annotated diagrams, photographs, and graphs explain the content of the page, providing the information necessary to complete the activity.

Understanding of content is tested through questions, data handling, analysis, prediction, or summary. Students are often required to apply their understanding to a new scenario or draw on knowledge acquired through completing earlier, related material (e.g. material sharing the same crosscutting concept). Students must interact with the information on the page in order to complete the activity. It is this interaction that provides the valuable learning experience and reinforcement and explanation of the key idea.

Questions for gifted and talented students (or for extension) are identified with blue text.

The tab system identifies the nature of the task, crosscutting concepts, and SEPs for the activity. This activity also has a **weblink** assigned to it (see below).



## PRACTICES

Code for the SEP that applies to this activity. There may be more than one (see pages CG12-14).

## Weblinks

www.thebiozone.com/weblink/NGSS-ESS-9377

Bookmark this site to access the external URLs provided.

## Crosscutting concept

Code for the cross cutting concept that applies to this activity. There may be more than one (see pages CG10-11).

## TASK CODES

These identify the nature of the activity

**COMP** = comprehension of text

**DATA** = data handling and interpretation

**KNOW** = content you need to know

**PRAC** = a paper practical or a practical focus

**REFER** = reference - use this for information

**REVISE** = review the material in the section

**TEST** = test your understanding

# Integrating the Three Dimensions of the Framework

Students achieve understanding of the **disciplinary core ideas** by completing their corresponding activities. These are written and presented so that students progressively extend and deepen their understanding of core ideas, developing competence in **science and engineering practices** and an understanding of the **crosscutting concepts** that unite all branches of science. Students draw on what they have learned in earlier activities to complete later related activities and to solve new problems.

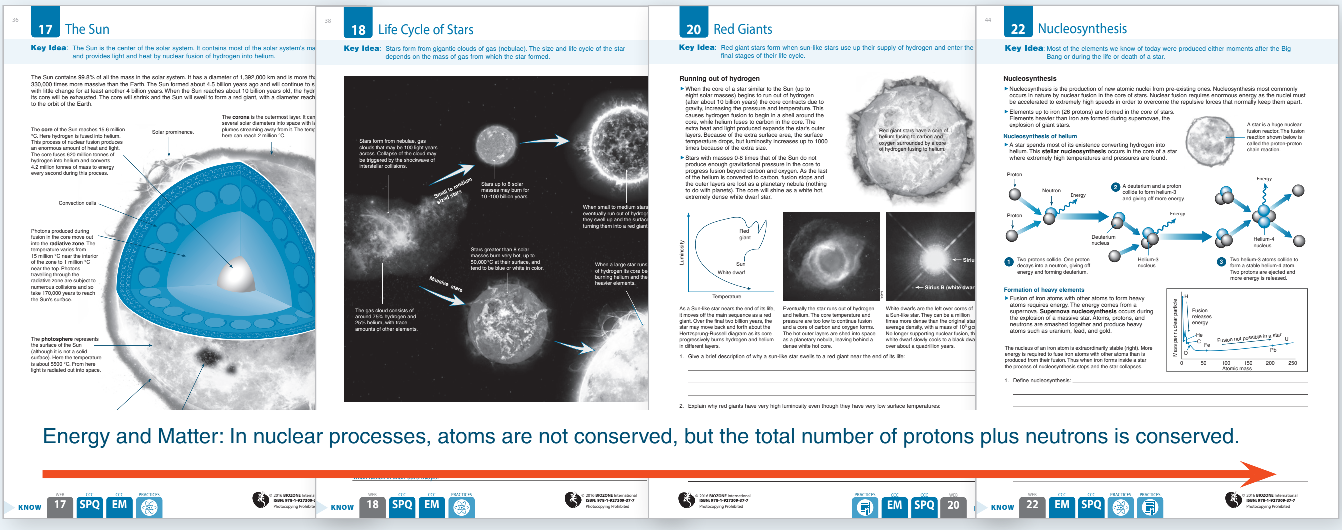
## Activities incorporate the three dimensions of the framework…

Activities integrate all three dimensions of the standards and collectively prepare students to meet performance expectations.

**DCI** *HS-ESS1-A: The universe and its stars.*

**SEP** *Developing and using models. Obtaining, evaluating, and communicating information.*

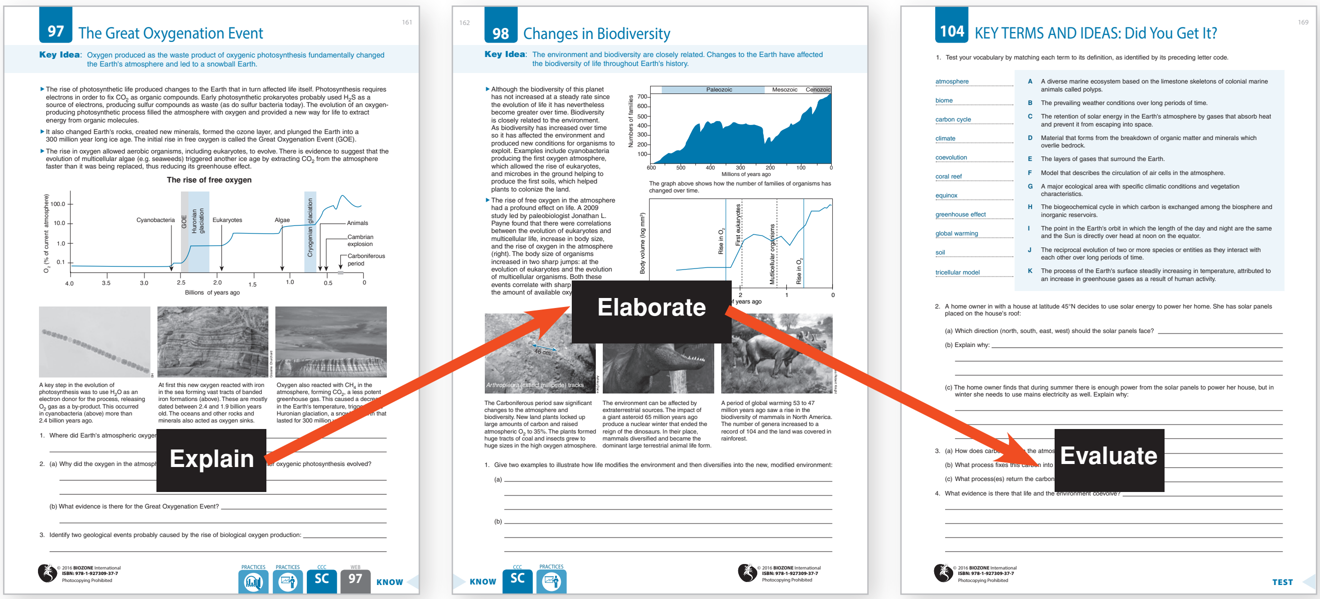
**CCC** *Energy and Matter. Scale, Proportion, Quantity.*




**PE** *HS-ESS1-3: Communicate scientific ideas about the way stars, over their life cycle, produce elements.*

## Using instructional sequences to build deeper understanding

The activities in the book form short instructional sequences designed to scaffold learning as students first **engage** and **explore** a concept, then **explain, elaborate, and evaluate**. An introductory activity introduces and builds understanding of a core idea, and subsequent activities apply that understanding to a new situation, e.g. analyzing data, finding a solution, or interpreting new information. Students can use the reviews and "Did You Get It?" tasks to evaluate their understanding and these can be followed by the more formal summative assessments.



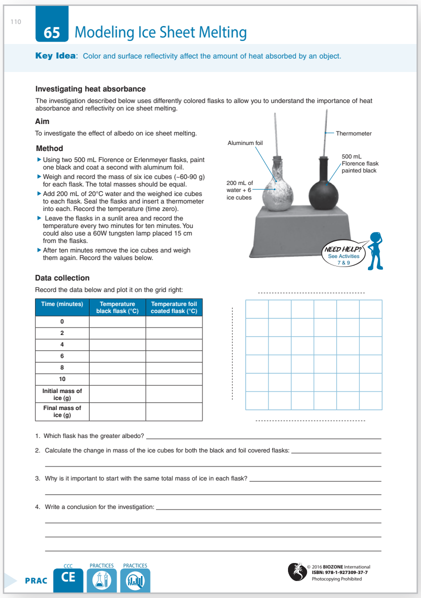

In this introductory activity, students are introduced to the Great Oxygenation Event, a period in Earth's history where photosynthetic organisms released free oxygen into the environment.

Students look in more depth how free oxygen affected biodiversity on Earth. Students also study the interrelatedness of the biosphere and the environment.

The student's understanding of the topic can be evaluated at the end of the chapter with a "KEY TERMS AND IDEAS: Did You Get It?" activity near the end of the chapter sequence.

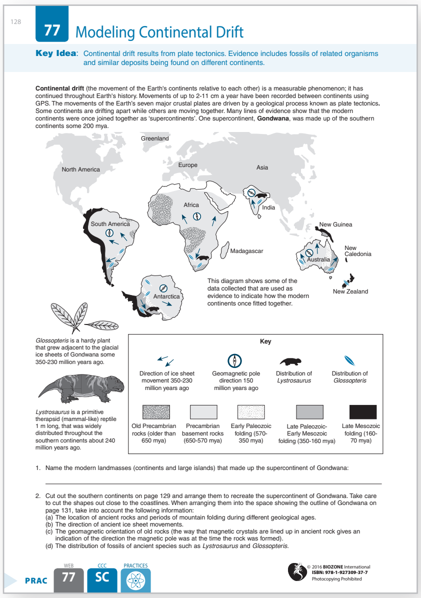
## Using SEPs to consolidate understanding of DCIs

Throughout the book, activities with a primary focus on the DCI content are followed and supported by activities that have a practical or modeling focus, allowing students to demonstrate competence in essential SEPs, many of them relevant to specific performance expectations. Many of these activities involve collaboration (in pairs or groups). Examples are illustrated below:


65 Modeling Ice Sheet Melting

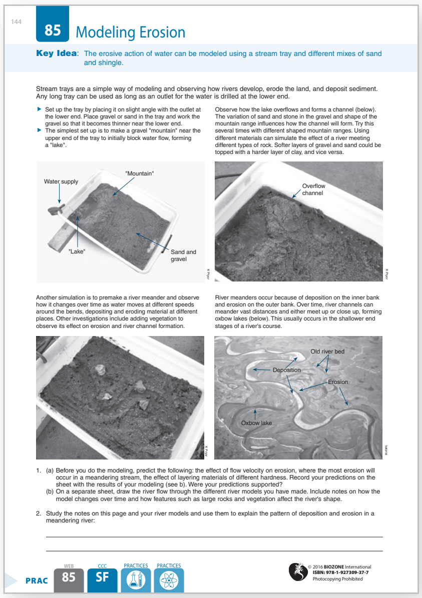
Key Idea: Color and surface reflectivity affect the amount of heat absorbed by an object.

Students collaborate to carry out a practical investigation of the ice albedo effect. This reinforces what they have learned about feedback in Earth's systems (Planning and carrying out investigations, analyzing and interpreting data, ESS2.A, HS-ESS2-2).


77 Modeling Continental Drift

Key Idea: Continental drift results from plate tectonics. Evidence includes fossils of related organisms and similar deposits being found on different continents.

Students use a variety of presented evidence to model how the continents have moved during part of Earth's history. This activity shows the importance of using many lines of evidence to explain a theory (Developing and using models, ESS2.B, HS-ESS2-1).

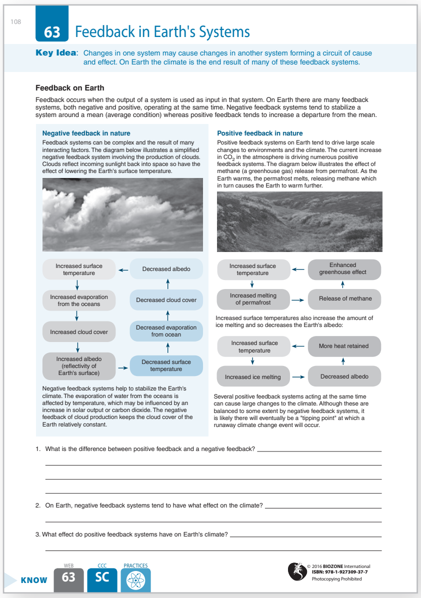

85 Modeling Erosion

Key Idea: The erosive action of water can be modeled using a stream tray and different mixes of sand and shingle.

Students collaborate to study the physical effects of water on Earth's materials and surface processes. The model can be manipulated to show how the changes affect erosion (Planning and carrying out investigations, developing and using models ESS2.C, HS-ESS2-5).

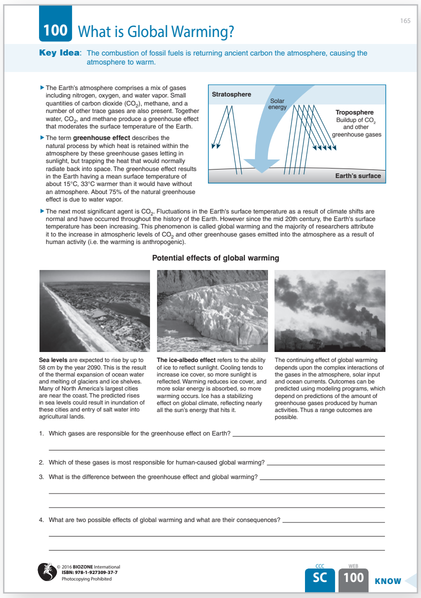
## Crosscutting concepts unite different topics

Activities with the same crosscutting concept are easily identified throughout the book and students can see how that concept applies across the same and different topics. For example, "Stability and Change" is a crosscutting concept that students encounter time and time again. In *Earth's Materials and Systems* they learn about the factors that cause systems to change or remain the same and develop explanations of phenomena based on this knowledge. They then carry this understanding to subsequent chapters where stability and change is once again an important concept.


63 Feedback in Earth's Systems

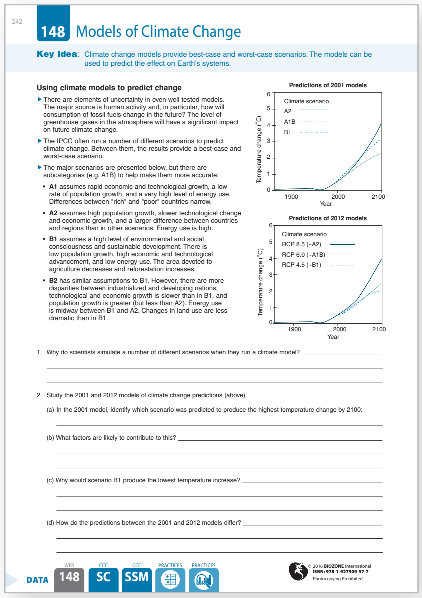
Key Idea: Changes in one system may cause changes in another system forming a circuit of cause and effect. On Earth the climate is the end result of many of these feedback systems.

Students are introduced to positive and negative feedback systems and look at how they can alter the Earth's systems (Stability and change, ESS2.A, HS-ESS2-2).


100 What is Global Warming?

Key Idea: The combustion of fossil fuels is returning ancient carbon the atmosphere, causing the atmosphere to warm.

Students are introduced to the topic of global warming, its role in maintaining Earth's temperature, and the potential effects of global warming (Stability and change, ESS3.D, HS-ESS3-5).


148 Models of Climate Change

Key Idea: Climate change models provide best-case and worst-case scenarios. The models can be used to predict the effect on Earth's systems.

Climate models can be used to manipulate the various factors contributing to climate change and make predictions as to how they may influence rates of climate change (Stability and change, ESS3.D, HS-ESS3-5).

# Addressing the Crosscutting Concepts

Crosscutting concepts are unifying ideas that apply across all disciplines of science. A crosscutting concept connects topics where the same unifying concept underpins the content. The crosscutting statements in the NGSS documentation are provided as bulleted points. These points have been used to produce relevant, meaningful crosscutting statements for each chapter. The activities to which the statements apply are identified in the chapter introductions as previously described.

For the most part, we have based the crosscutting statements for each chapter on the points linked specifically to performance expectations (**PE** in the tables below), so the list is not exhaustive and we have identified others not incorporated into performance expectations. These are summarized in the tables below and opposite. Each crosscutting concept below is accompanied by a progression statement, taken directly from the NGSS document.

CCC **P**

## Patterns

Progression in grades 9-12

"In grades 9-12, students observe pattens in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize that classifications or explanations used at one scale may not be useful or may need revision using a different scale, thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system".

| Crossing cutting statement(s) | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. | ESS1.A | HS-ESS1-1 | 17, 20-22 |
| Empirical evidence is needed to identify patterns. | ESS1.C | HS-ESS1-5 | 49-50, 53 |

CCC **CE**

## Cause and effect

Progression in grades 9-12

"In grades 9-12, students understand that empirical evidence is required to differentiate between cause and correlations and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller-scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects".

| Crossing cutting statement(s) | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. | | | 8 |
| | ESS1.B | | 31-32, 34-35, 42-44 |
| | ESS2.A | HS-ESS2-4 | 65, 68-70 |
| | ESS2.D | HS-ESS2-4 | 91-94 |
| | ESS3.A | HS-ESS3-1 | 107-109, 120 |
| | ESS3.B | HS-ESS3-1 | 125-127, 130 |

CCC **SSM**

## Systems and system models

Progression in grades 9-12

"In grades 9-12 ,students investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They use models (e.g. physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They also use models and simulations to predict the behavior of a system and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent to the models. They also design systems to do specific tasks".

| Crossing cutting statement(s) | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| Models can simulate systems and interactions- including energy, matter, and information flows- within and between systems at different scales. | | | 1-2 |
| 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. | ESS3.D | HS-ESS3-6 | 146-149 |

CCC **SF**

## Structure and function

Progression in grades 9-12

"In grades 9-12, students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal a system's function and/or solve a problem. They infer the functions and properties of natural and designed objects and systems from their overall structure, the way their components are shaped and used, and the molecular substructures of their various materials".

| Crossing cutting statement(s) | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| 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 their various materials. | ESS2.C | HS-ESS2-5 | 81-87 |

CCC **SPQ**

## Scale, proportion and quantity

Progression in grades 9-12

"In grades 9-12, students understand that the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. They recognize that patterns observable at one scale many not be observable or exist at other scales and that some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. They use algebraic thinking to examine scientific data and predict the effect of a change in one variable on another".

| Crossing cutting statement(s) | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| The significance of a phenomenon depends on the scale, proportion, and quantity at which it occurs. | ESS1.A | HS-ESS1-1 | 17, 20-22 |
| | ESS3.B | | 125, 127 |
| Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. | ESS1.A | | 13, 16-19 |
| Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another. | ESS1.B | HS-ESS1-4 | 38-41, 43 |

CCC **EM**

## Energy and matter

Progression in grades 9-12

"In grades 9-12, students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter ina system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between system. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved".

| Crossing cutting statement(s) | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| Energy cannot be created or destroyed - only moved between one place and another place, between objects and/or fields, or between systems. | | | 4 |
| | ESS1.A | HS-ESS1-2 | 14 |
| | | | |
| In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. | ESS1.A | HS-ESS1-3 | 17-22 |
| | | | |
| Energy drives the cycling of matter within and between systems. | ESS2.A | HS-ESS2-3 | 59, 61 |
| | ESS2.B | HS-ESS2-3 | 74-75 |
| | ESS2.C | | 82-83 |
| The total amount of energy in a closed system is conserved. | ESS2.D | HS-ESS2-6 | 99 |
| | | | 91 |

CCC **SC**

## Stability and change

Progression in grades 9-12

"In grades 9-12, students understand that much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over short or very periods of time. They see that some changes are irreversible and that negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize that systems can be designed for more or less stability".

| Crossing cutting statement(s) | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| Much of science deals with constructing explanations of how things change and how they remain stable. | ESS1.C | HS-ESS1-6 | 49-53 |
| | ESS2.D | | 92, 94 |
| | | HS-ESS2-7 | 95-98 |
| | ESS2.E | HS-ESS2-7 | 95-98, 101-102 |
| Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changed is irreversible. | ESS2.A | HS-ESS2-1 | 62, 66-70 |
| | ESS2.B | HS-ESS2-1 | 75-77, 80 |
| | ESS2.C | HS-ESS3-3 | 135, 142, 145 |
| | ESS3.D | HS-ESS3-5 | 147-149 |
| Feedback (negative or positive) can stablilize or destabilize a system. | ESS2.A | HS-ESS2-2 | 63-64, 66 |
| | ESS2.D | HS-ESS2-2 | 91, 100 |
| | ESS2.C | HS-ESS3.4 | 134-136, 138-142 |

# Addressing the Science and Engineering Practices

Science and Engineering Practices (SEPs) for NGSS are overlapping and interconnected practices that students should know and understand. While this student book cannot provide wet lab practical experiences, we have provided numerous opportunities to prepare students for those experiences and develop and refine their skills in planning investigations and analyzing and evaluating data. There are also many opportunities for students to participate in collaboration and discourse. SEPs are supported throughout the book, beginning with an introductory chapter covering basic computational, analytical, and design skills, to a variety of activities focusing on the development of specific skills within the framework of the DCIs.

The SEP statements in the NGSS documentation are provided as bulleted points. These points have been used to produce relevant, meaningful statements for each chapter. The activities to which the statements apply are identified in the chapter introductions as previously described. For the most part, we have based these SEP statements on the points linked specifically to performance expectations, so the list is not exhaustive and we have identified others not incorporated into performance expectations.  These are summarized in the tables following. The teacher's notes for each chapter also identify the performance expectations incorporating each SEP point. Each SEP below is accompanied by a progression statement, taken directly from the NGSS document.

PRACTICES

## PRACTICE 1: 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."

| | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| Most activities in the student edition incorporate aspects of this SEP. | | | |
| Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. | | | 1, 6 |

PRACTICES

## PRACTICE 2: 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)."

<table>
<tr><th></th><th>DCI</th><th>Applies to PE#</th><th>Activity number</th></tr>
<tr><td rowspan="15">Develop, revise, and or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.</td><td rowspan="4">ESS1.A</td><td></td><td>1-2, 4</td></tr>
<tr><td rowspan="2">HS-ESS1-1</td><td>17-19, 22, 25</td></tr>
<tr><td>14-15</td></tr>
<tr><td></td><td>13, 21</td></tr>
<tr><td>ESS1.B</td><td></td><td>27, 42-44</td></tr>
<tr><td rowspan="3">ESS2.A</td><td>HS-ESS2-1</td><td>61-62, 66-67</td></tr>
<tr><td>HS-ESS2-3</td><td>59-60</td></tr>
<tr><td>HS-ESS2-4</td><td>63-64, 68-70</td></tr>
<tr><td rowspan="2">ESS2.B</td><td>HS-ESS2-1</td><td>77, 79-80</td></tr>
<tr><td>HS-ESS2-3</td><td>74-76, 79</td></tr>
<tr><td>ESS2.C</td><td></td><td>81-86</td></tr>
<tr><td rowspan="4">ESS2.D</td><td></td><td>68-70</td></tr>
<tr><td>HS-ESS2-4</td><td>91, 94, 105</td></tr>
<tr><td>HS-ESS2-6</td><td>99,105</td></tr>
<tr><td></td><td>92, 94</td></tr>
</table>

PRACTICES

## PRACTICE 3: 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".

| | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| 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. | | | 10-11 |
| | ESS2.A | | 65 |
| | ESS2.C | HS-ESS2-5 | 85-86 |
| | ESS2.D | | 92 |
| Select appropriate tools to collect, record, analyze and evaluate data. | | | 11 |
| Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. | | | 11 |

PRACTICES

## PRACTICE 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."

| | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| 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. | | | 8-11 |
| | ESS2.A | HS-ESS2-2 | 65, 68-70 |
| | ESS2.D | HS-ESS2-2 | 95, 97 |
| | ESS2.E | | 97 |
| | ESS3.D | HS-ESS3-5 | 148, 155 |
| Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. | | | 10 |

PRACTICES

## PRACTICE 5: 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 non-linear 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."

| | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims or explanations. | | | 3, 5, 7 |
| | ESS1.B | HS-ESS1-4 | 35-43, 47 |
| | ESS3.D | HS-ESS3-6 | 148, 155 |
| Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units. | | | 3, 5 |
| Create a computational model or simulation of a phenomenon, designed device, process, or system. | ESS3.C | HS-ESS3-3 | 145 |

PRACTICES

## PRACTICE 6: 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".

| | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including student's 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. | | | 9, 11 |
| | ESS1.A | HS-ESS1-2 | 14-15 |
| | ESS2.C | | 87, 90 |
| | ESS2.D | | 92 |
| | ESS3.A | HS-ESS3-1 | 107-110 |
| | ESS3.B | HS-ESS3-1 | 125-127 |
| Apply scientific reasoning, principles, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. | ESS1.C | | 58 |
| | | HS-ESS1-6 | 49-53 |
| 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. | ESS3-A | | 110, 112-113, 116-120 |
| | ESS3-A | | 128 |
| | ESS3-C | HS-ESS3-4 | 135-137, 140-142 |

PRACTICES

## PRACTICE 7: Engaging in argument from evidence

"Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science."

| | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. | | | 9 |
| | | | |
| Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. | ESS1.C | HS-ESS1-5 | 49-50, 53 |
| | | | 51-52 |
| | ESS2.D | | 94 |
| | ESS2.E | HS-ESS2-7 | 96-98, 101-102 |
| 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). | ESS3.A | HS-ESS3-2 | 110, 112-114, 116-120, 123 |
| | ESS3.D | | 152 |

PRACTICES

## PRACTICE 8: Obtaining, evaluating, and communicating information

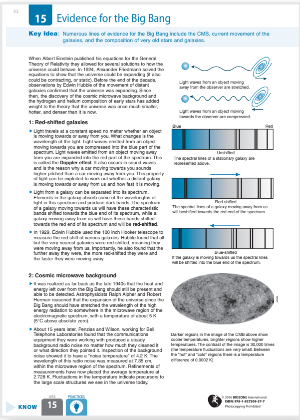
"Obtaining, evaluating, and communicating information in 9-12 builds on K-8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs."

| | DCI | Applies to PE# | Activity number |
|---|---|---|---|
| Evaluate the validity and reliability of, and/or synthesize, multiple claims, methods, and/or designs that appear in scientific and technical texts,or media reports, verifying the data where possible. | | | 11 |
| | ESS3.B | | 131 |
| Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e. orally, graphically, textually, mathematically). | ESS1.A | HS-ESS1-3 | 20-22 |

# The Nature of Science

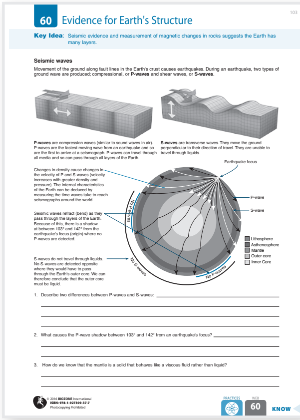
The Nature of Science combines established information with new knowledge to constantly refine what we know about the natural world. Eight Nature of Science understandings are presented in the NGSS document. Four are associated most closely with Science and Engineering Practices, and four with the Crosscutting Concepts. Because the Nature of Science understandings have been incorporated into most activities in the *Earth and Space Sciences for NGSS Student Edition* we have not identified them specifically on the activity page. Some examples of activities relating to the eight Nature of Science understandings are illustrated below. The subheading to which they relate is also given.

## Nature of science understandings most closely associated with science and engineering practices



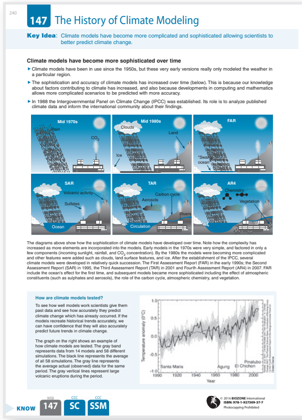

**Scientific investigations use a variety of methods.**

- Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge



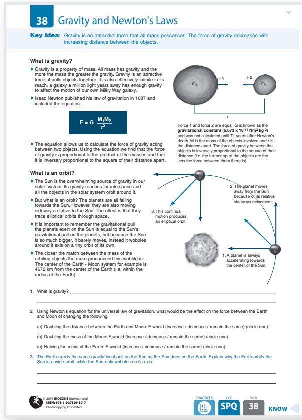

**Scientific knowledge is based on empirical evidence.**

- Scientific knowledge is based on empirical evidence.




**Scientific knowledge is open to revision in light of new evidence.**

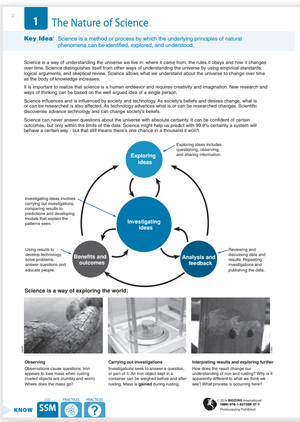
- Most scientific knowledge is quite durable but, in principle, is subject to change based on new evidence and/ or reinterpretations of existing evidence.




**Science models, laws, mechanisms, and theories explain natural phenomena.**

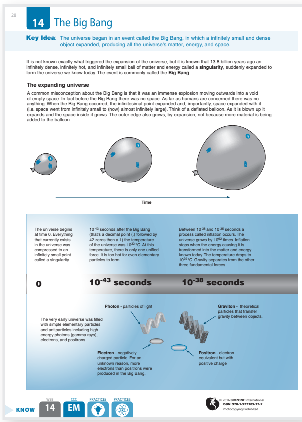
- Laws are statements or descriptions of the relationships among observable phenomena.

## Nature of science understandings most closely associated with crosscutting concepts



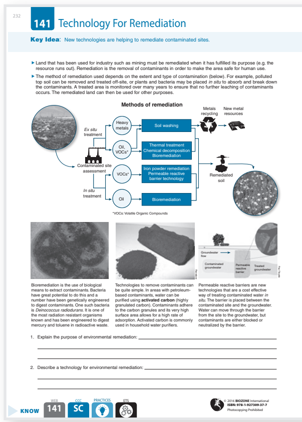

**Science is a way of knowing.**

- Scientific knowledge has a history that includes refinement of, and changes to, theories, ideas, and beliefs over time.



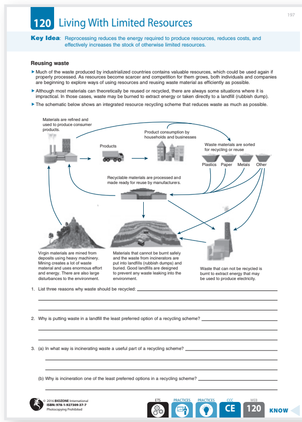

**Scientific knowledge assumes an order and consistency in natural systems.**

- Science assumes the universe is a vast single system in which basic laws are consistent.




**Science is a human endeavor.**

- Technological advances have influenced the progress of science and science has influenced advances in technology.



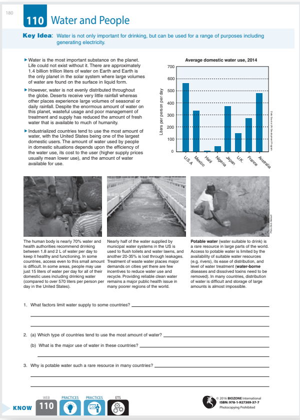

**Science addresses questions about the natural and material world.**

- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.

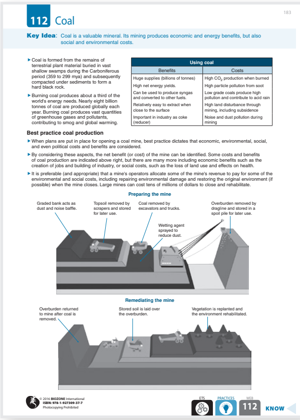
# Engineering, Technology, and Applications of Science

ETS

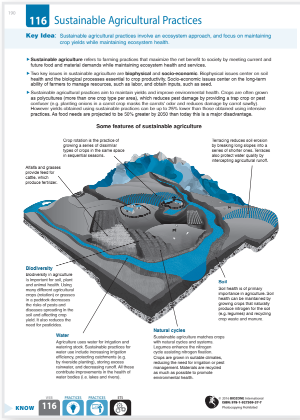
Activities designed for Engineering, Technology, and Applications of Science (ETS) examine global challenges affecting society. They require you to design and evaluate solutions incorporating knowledge gained through science and engineering. Solutions require consideration of cost, safety, reliability, aesthetics, as well as social, cultural, and environmental impacts. *Earth and Space Sciences for NGSS* has many opportunities for you to design, model, and evaluate technological solutions to the problems facing humanity today.



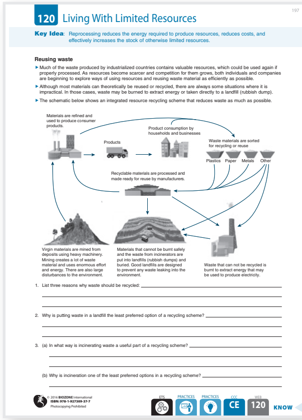

This introductory activity looks at the uses of water. Students investigate the cost/benefits of generating hydroelectric power.



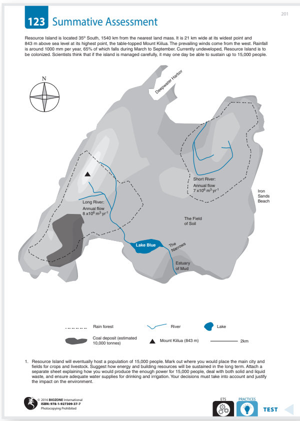

Students utilize knowledge of fossil fuels and their extraction to evaluate the benefits and disadvantages of mining coal from two sites.



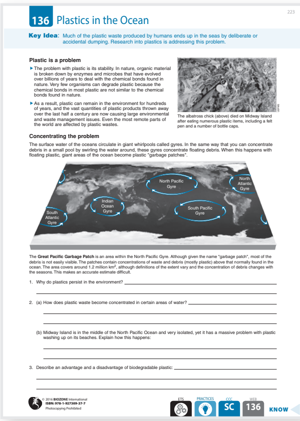

The principles of sustainable agriculture are investigated, including the role of technology in improving efficiencies.



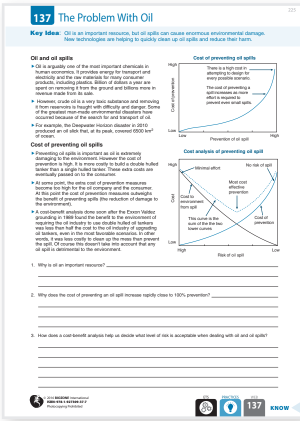

Explore how technology is utilized to make use of the limited resources on Earth (e.g. reusing and recycling).



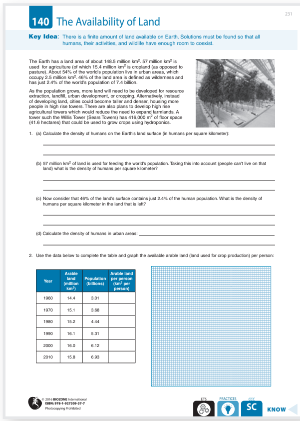

Evaluate resource use and extraction by prioritizing need, cost, social issues, and environmental issues.



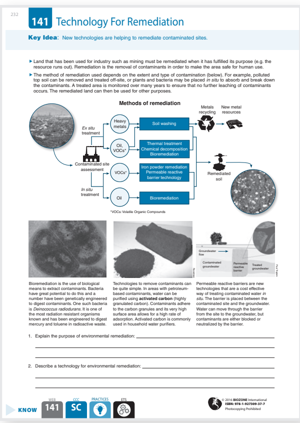

"Plastic eating bacteria" is an example of how technology is used to fix a human problem (plastic garbage patches).



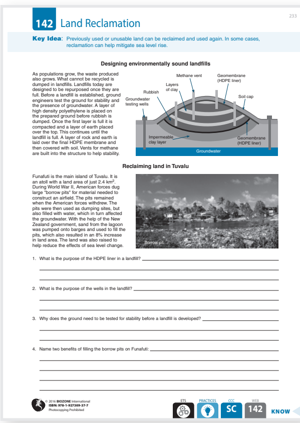

Students apply cost/benefit analysis to ways of preventing oil spills, and technology is used to clean up oil spills.



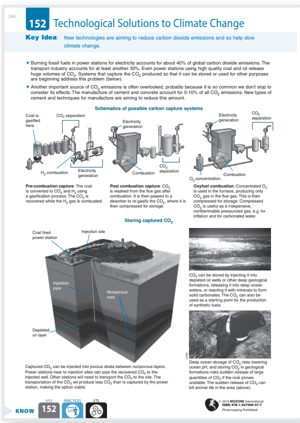

As land becomes an increasingly scarce resource, humans must be innovative to maximize its use.




Technological solutions are used to clean up contaminated land so that it can be used again.




Land reclamation techniques can be used to extend usable land and may help mitigate sea level rise.



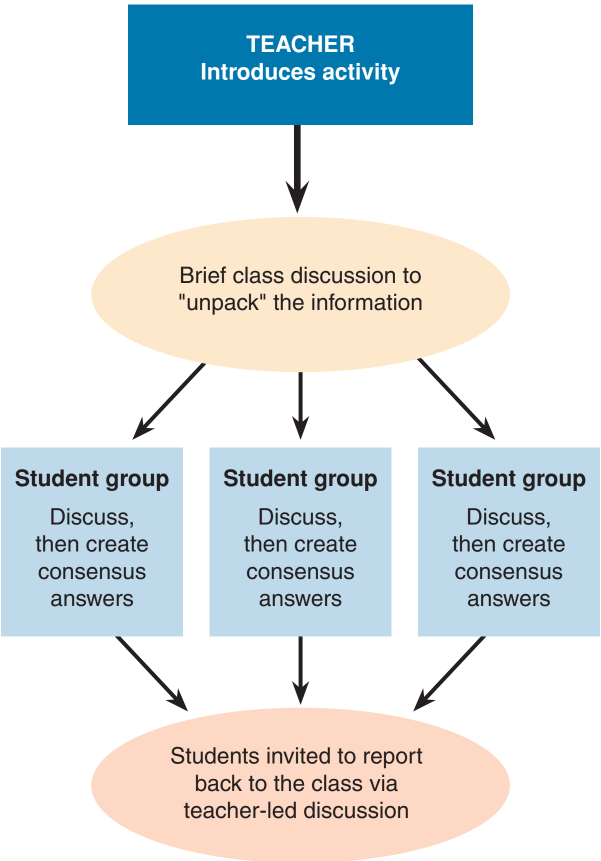

New technologies are aiming to reduce carbon dioxide emissions and so help slow climate change.

# Teaching Strategies for Classroom Use

Achieving effective differential instruction in classes is a teaching challenge. Students naturally have mixed abilities, varying backgrounds in the subject, and different language skills. Used effectively, BIOZONE's student books and supporting resources can make teaching a mixed ability class easier. Here, we suggest some approaches for differential instruction.

## MAKING A START

Regardless of which activity you might be attempting in class, a short introduction to the task by the teacher is a useful orientation for all students. For collaborative work, the teacher can then divide the class into appropriate groups, each with a balance of able and less able students. Depending on the activity, the class may regroup at the end of the lesson for discussion.




## Using collaboration to maximize learning outcomes

- The structure of *Earth and Space Sciences for NGSS* allows for a flexible approach to unpacking the content with your students.
- The content can be delivered in a way to support collaboration, where students work in small groups to share ideas and information to answer and gain a better understanding of a topic, or design a solution to a problem.
- By working together to ask questions and evaluate each other's ideas, students maximize their own and each other's learning opportunities. They are exposed to ideas and perspectives they may not have come up with on their own.
- Use a short, informal collaborative learning session to get students to exchange ideas about the answer to a question. Alternatively, collaboration may take a more formal role that lasts for a longer period of time (e.g. assign groups to work together for a paper practical activity, to research an extension question, or design a solution to a problem).

The teacher introduces the topic. They provide structure to the session by providing background information and setting up discussion points and clear objectives. Collaboration is emphasized to encourage participation from the entire group. If necessary, students in a group can be assigned specific tasks.

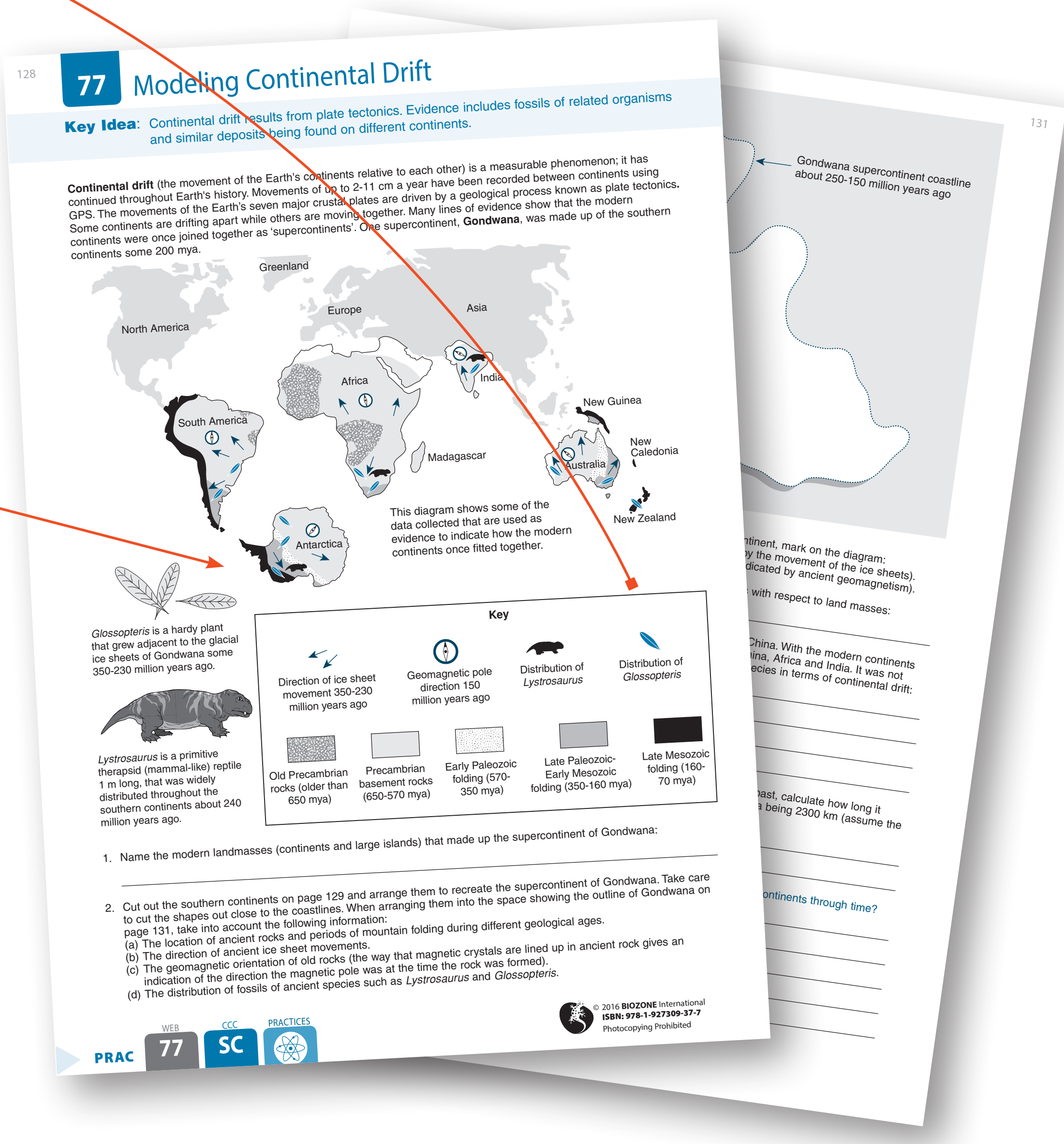
Students work in small groups so everyone's contribution is heard. They collaborate, share ideas, and engage in discourse. The emphasis is on discussing questions and formulating a consensus answer, not just sharing ideas.

At the end of the session, students report back on their findings. Each student should have enough knowledge to report back on the group's findings. Reporting consists primarily of providing answers to questions, but may involve presenting a report, model, or slide show, or contributing to a debate.

## Peer to peer support

- **Peer-to-peer learning** can be used for any activities, but is particularly valuable for more challenging activities in which the content is more complex or the questions require students to draw on several areas of their knowledge to synthesize an answer. Examples of such activities include modeling activities, activities with a design component, or activities involving data analysis, graphing, and evaluation.
- Stronger peers can assist weaker students and both groups benefit from verbalizing their thoughts and presenting them to a group. Students for whom English is a second language can ask their peers to explain unfamiliar terms (both scientific and English) and this benefits both parties.

**Paper practicals** (e.g.*Modeling Continental Drift*) and practicals (e.g. *Modeling Ice Sheet Melting* and *Modeling Erosion*) are an ideal vehicle for this kind of peer-to-peer learning. They are not only enjoyable, but they prompt students to ask questions and think about how they could use the model to answer those questions.



128

# 77 Modeling Continental Drift

**Key Idea**: Continental drift results from plate tectonics. Evidence includes fossils of related organisms and similar deposits being found on different continents.

**Continental drift** (the movement of the Earth's continents relative to each other) is a measurable phenomenon; it has continued throughout Earth's history. Movements of up to 2-11 cm a year have been recorded between continents using GPS. The movements of the Earth's seven major crustal plates are driven by a geological process known as plate tectonics. Some continents are drifting apart while others are moving together. Many lines of evidence show that the modern continents were once joined together as 'supercontinents'. One supercontinent, **Gondwana**, was made up of the southern continents some 200 mya.



This diagram shows some of the data collected that are used as evidence to indicate how the modern continents once fitted together.

*Glossopteris* is a hardy plant that grew adjacent to the glacial ice sheets of Gondwana some 350-230 million years ago.

*Lystrosaurus* is a primitive therapsid (mammal-like) reptile 1 m long, that was widely distributed throughout the southern continents about 240 million years ago.

**Key**

Direction of ice sheet movement 350-230 million years ago

Geomagnetic pole direction 150 million years ago

Distribution of *Lystrosaurus*

Distribution of *Glossopteris*

Old Precambrian rocks (older than 650 mya)

Precambrian basement rocks (650-570 mya)

Early Paleozoic folding (570-350 mya)

Late Paleozoic-Early Mesozoic folding (350-160 mya)

Late Mesozoic folding (160-70 mya)

1. Name the modern landmasses (continents and large islands) that made up the supercontinent of Gondwana:

2. Cut out the southern continents on page 129 and arrange them to recreate the supercontinent of Gondwana. Take care to cut the shapes out close to the coastlines. When arranging them into the space showing the outline of Gondwana on page 131, take into account the following information:
(a) The location of ancient rocks and periods of mountain folding during different geological ages.
(b) The direction of ancient ice sheet movements.
(c) The geomagnetic orientation of old rocks (the way that magnetic crystals are lined up in ancient rock gives an indication of the direction the magnetic pole was at the time the rock was formed).
(d) The distribution of fossils of ancient species such as *Lystrosaurus* and *Glossopteris*.

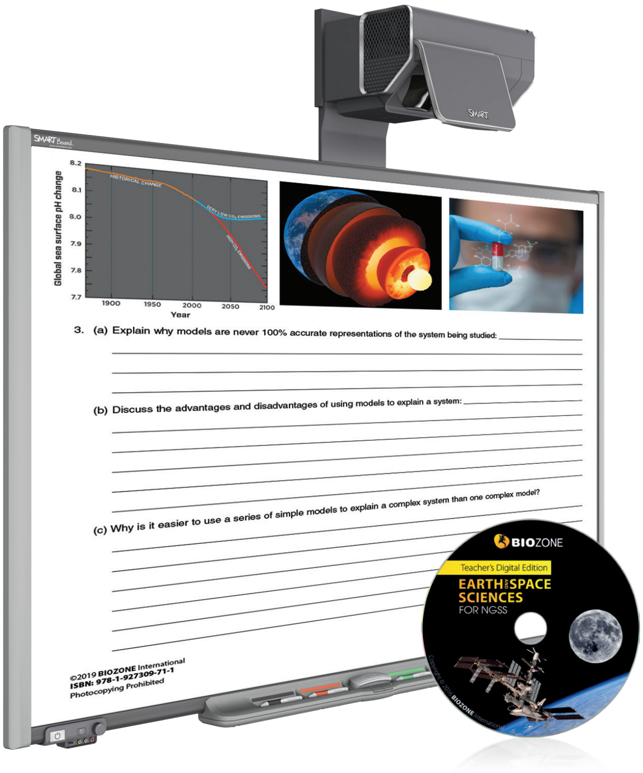
© 2016 **BIOZONE** International
ISBN: 978-1-927309-37-7
Photocopying Prohibited

PRAC WEB 77 CCC SC PRACTICES

131

Gondwana supercontinent coastline about 250-150 million years ago

In *Modeling Continental Drift*, students can **collaborate** to model continental drift. They use several lines of evidence to recreate the positions of the Earth's continents in the past.




## Interactive revision of tasks in class

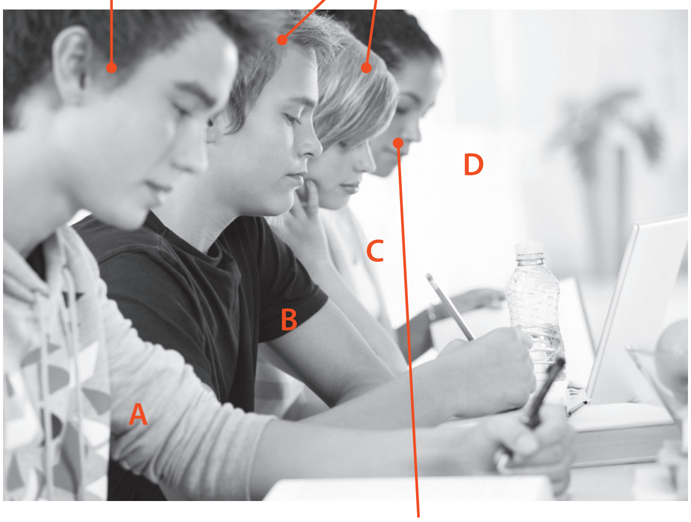
- The **Teacher's Digital Edition** provides a digital rights managed (DRM) version of the student book as PDF files. It features useful HIDE/SHOW answers, which can be used to review activities in class using a data projector or interactive whiteboard (left).
- Students benefit from the feedback in class, where questions can be addressed, and teachers benefit by having students self-mark their work and receive helpful feedback on their responses.
- This approach is particularly suited to activities with questions requiring a discussion, as students will be able to clarify some aspects of their responses. Stronger students can benefit by contributing to the explanatory feedback and class discussion.

**Student A** is capable. He completes all of the activity, including the blue extension questions. Gifted and talented students may use these questions to explore a topic further.

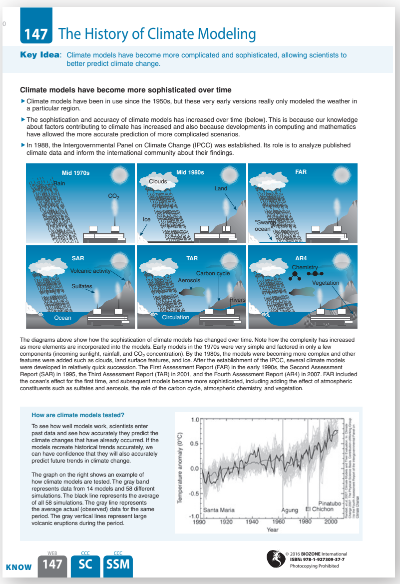
**Students B and C** will work through simpler questions themselves but may require assistance with the more challenging questions in an activity.

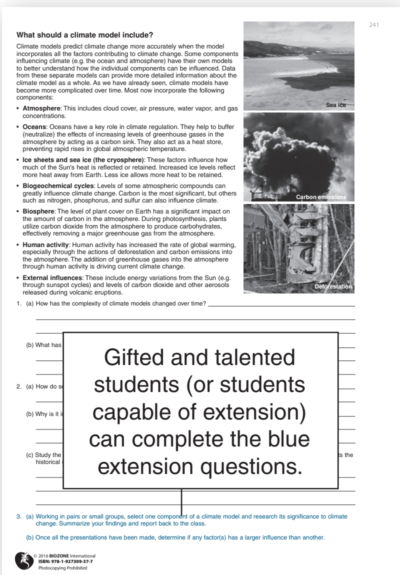
## Gaining confidence

- The questions in the activities have generally been written in a direct questioning style, e.g. "What are the differences between A and B", or "Why are A and B different?". This makes it easier for the students to understand what is required to answer the question.
- Questions are also arranged so that simpler questions (describe, what, identify, name) are generally asked first, followed by questions demanding an explanation (explain, how, why, account for). This allows students to gain confidence from answering the simpler questions first before attempting the questions that require more comprehensive answers.
- Extension questions (marked in blue) can be attempted by gifted and talented students, or could be set as group work to extend all students.
- This arrangement also allows teachers to direct students appropriately so that some may attempt only the simpler questions themselves and work with peers to attempt the more challenging questions.

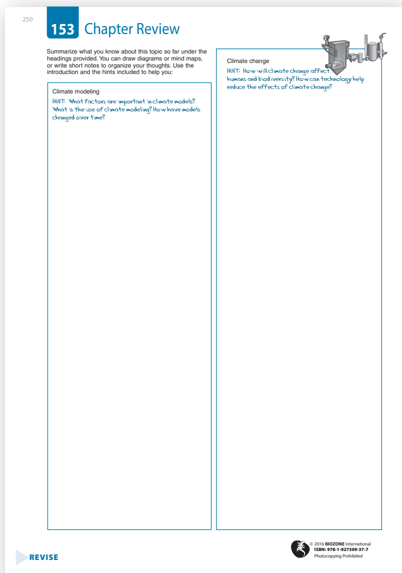



**Student D** (above) is a gifted student. She is very capable and completes the set work quickly, including the blue extension questions. She can assist her peers and demonstrate her understanding in the relevant section of the review sheets.




Gifted and talented students (or students capable of extension) can complete the blue extension questions.

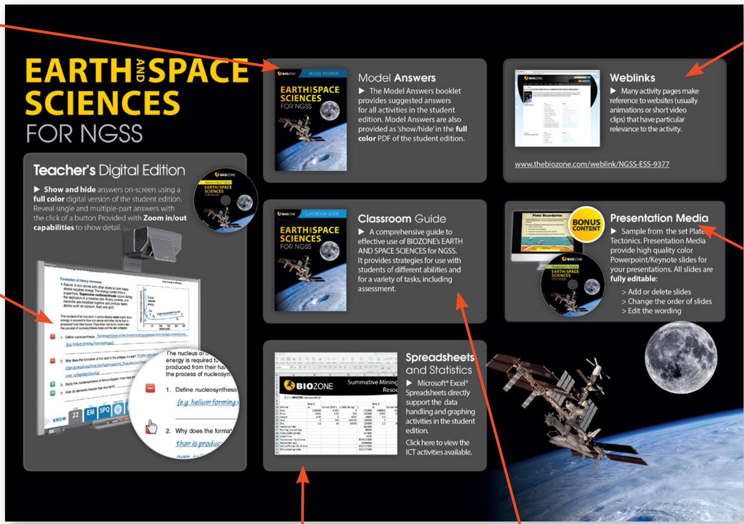


# The Teacher's Digital Edition

The *Teacher's Digital Edition* is a DRM product, sold separately, and aimed primarily at extending the pedagogical tools at a teacher's disposal. Many of the features of this resource have been developed in response to requests from teachers themselves.


Digital copy of the Model Answers (non-printable). Suggested answers are provided to all activities. Some include explanatory detail.

A digital (PDF) version of the student edition (non-printable). Use the interactive buttons to HIDE or SHOW the answers.

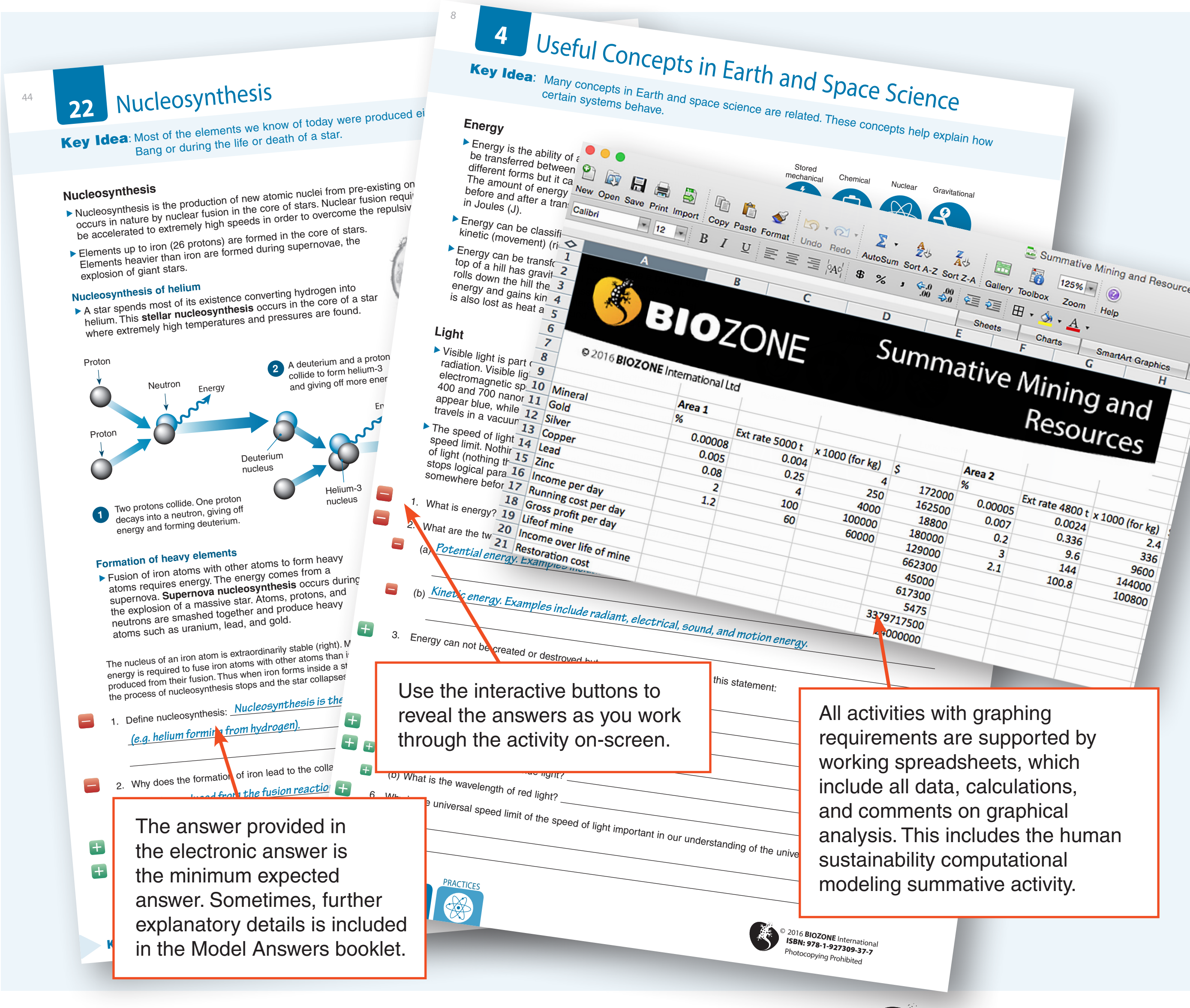



Access the *Weblinks* directly from this link for a range of animations and video clips to support the activities.

A BONUS sample of 10 slides from the *Earth and Space Sciences for NGSS* Presentation Media title, 'Plate Tectonics' (fully editable).

Link to ***Excel***® **spreadsheets** for all activities with a graphing or data analysis component.

This **Classroom Guide** is provided as a printable PDF.




Use the interactive buttons to reveal the answers as you work through the activity on-screen.

All activities with graphing requirements are supported by working spreadsheets, which include all data, calculations, and comments on graphical analysis. This includes the human sustainability computational modeling summative activity.

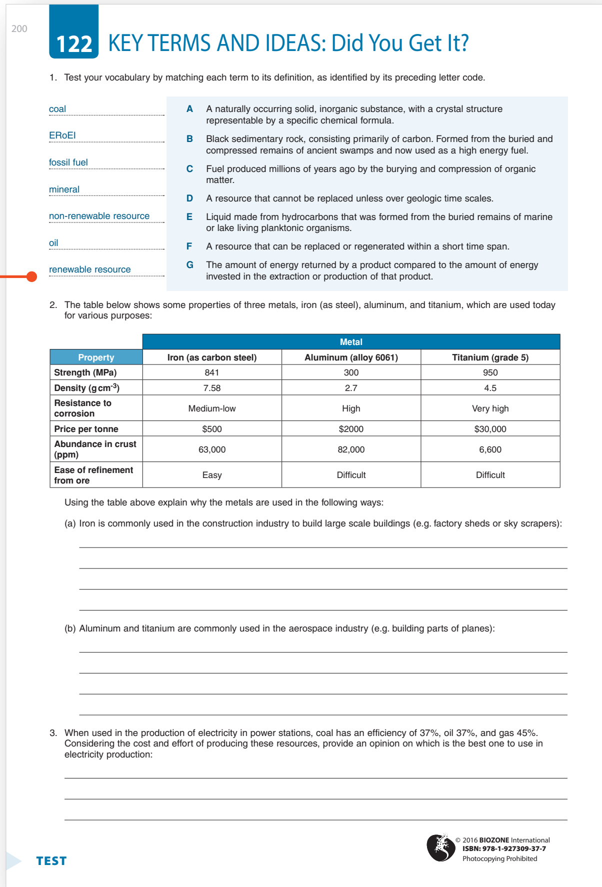
The answer provided in the electronic answer is the minimum expected answer. Sometimes, further explanatory details is included in the Model Answers booklet.

# Formative and Summative Assessment

*Earth and Space Sciences for NGSS* provides ample opportunity for students to demonstrate their understanding and proficiency in all three dimensions of the standards. Most of the activities in the book can be used for formative assessment to provide feedback to the student during the learning process. Summative assessment tasks are clearly identified at the end of each chapter.

## Formative assessment

Individual activities, or an instructional sequence, can be used as formative assessments to determine how a student's knowledge is progressing within a selected topic. Teachers can revise their instruction, revisit material, or set further tasks if a student is having difficulty with the material.
KEY TERMS AND IDEAS: Did You Get It? activities at the end of each chapter can be used for formal testing as a class, or set as an informal check point where students use the activity as a opportunity for self assessment.

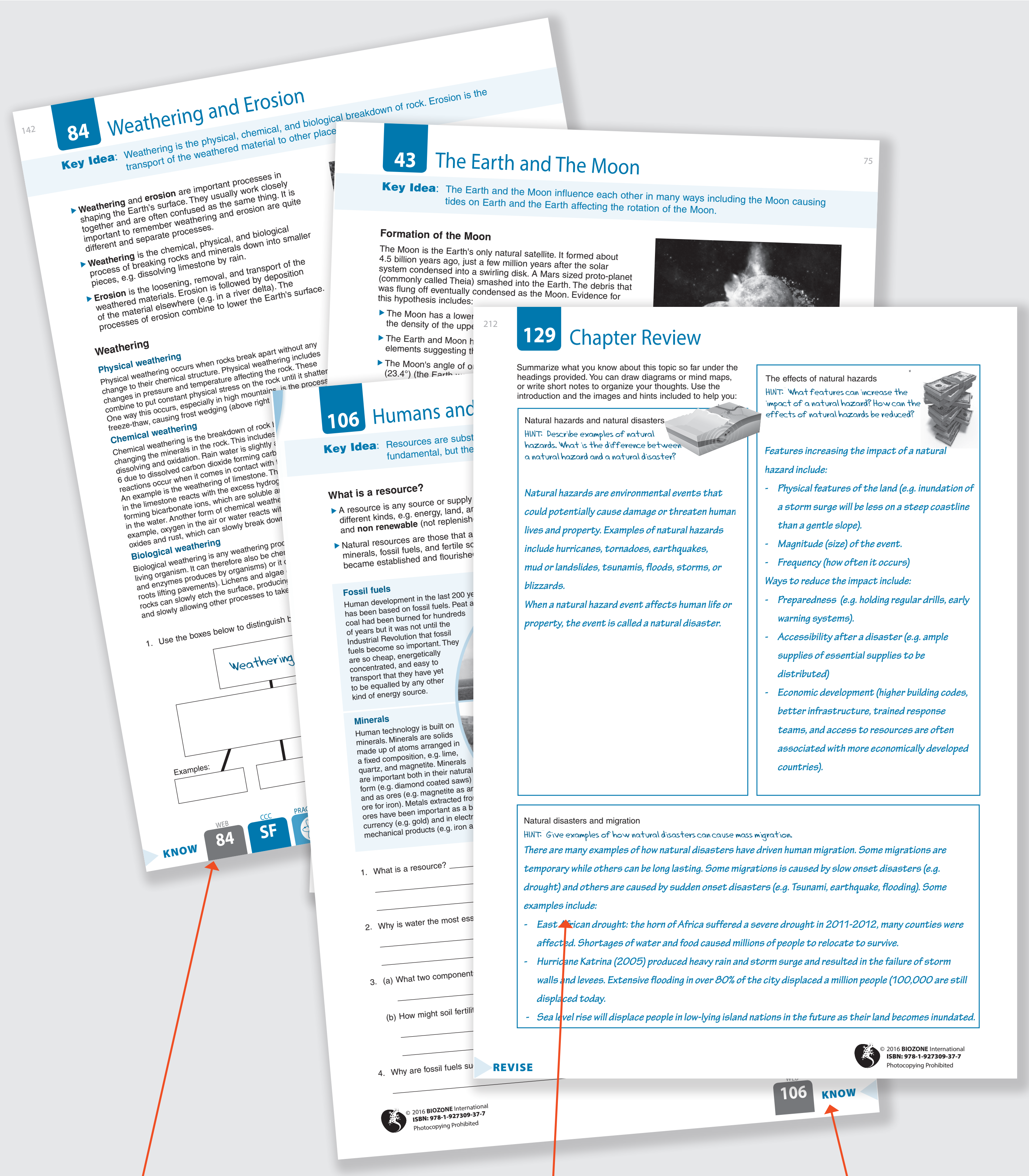



## Summative assessment

All chapters, except *Science Practices*, conclude with a summative assessment task. Summative assessment activities may be administered at the end of a unit of instruction as a formal testing moment. They are designed to test a student's ability to apply their knowledge and understanding of at least two of the three dimensions within a particular topic.

# Choosing Activities for Home Study

Many of the activities in the student edition are ideal for homework or as vehicles for a quick synoptic assessment. Chapter reviews, literacy activities, and follow-on activities are ideal as homework. They provide a way in which to review and consolidate material that has recently been completed, helping learners by presenting the material in a slightly different way. The information for review activities can be found in the content of the chapter, although stronger students may not need to refer back to source material to complete the set work.




Most students will have access to the internet. Encourage them to visit the **weblinks** site they are having trouble understanding a subject or visualizing a process. Weblinks may also provide extension or points of discussion.

Review activities are ideal as homework. Students can produce their own review and then have it checked by the teacher or compare and discuss it with peers if they want to check their thinking.

Set simpler activities or preparatory reading for homework. This encourages less able students to achieve and to be properly prepared for in-class lessons.

# Course Guides by DCI and by Topic

Guides summarizing the location of content for programs by DCI (below) or topic (following).

| NGSS HS-ESS PROGRAM BY DISCIPLINARY CORE IDEA | PERFORMANCE EXPECTATION | CHAPTER IN STUDENT EDITION |
|---|---|---|
| **HS-ESS1 EARTH'S PLACE IN THE UNIVERSE** | | |
| **ESS1.A: The Universe and Its Stars** | | |
| • The Sun is changing and will burn out.<br>• Stars can be studied using their light spectra and brightness.<br>• The Big Bang is supported by many different lines of evidence.<br>• Elements are produced by nucleosynthesis. | HS-ESS1-1<br>HS-ESS1-2, HS-ESS1-3<br>HS-ESS1-2<br>HS-ESS1-2, HS-ESS1-3 | The Universe and Its Stars |
| **ESS1.B: Earth and the Solar System** | | |
| • Kepler's laws describe common features of the motions of orbiting objects. | HS-ESS1-4 | Earth and the Solar System |
| **ESS1.C: The History of Planet Earth** | | |
| • Continental rocks are older than rocks of the ocean floor.<br>• Extraterrestrial objects can provide information about Earth's history. | HS-ESS1-5<br>HS-ESS1-6 | The History of Planet Earth |
| **HS-ESS2 EARTH'S SYSTEMS** | | |
| **ESS2.A: Earth Materials and Systems** | | |
| • Earth's systems cause feedback effects.<br>• Empirical evidence lead to a model of the Earth's structure.<br>• The geological record shows changes to global and regional climates. | HS-ESS2-1, HS-ESS2-2<br>HS-ESS2-3<br>HS-ESS2-4 | Earth Materials and Systems |
| **ESS2.B: Plate Tectonics and Large-Scale Interactions** | | |
| • Radioactive decay provides the heat that drives mantle convection.<br>• Plate tectonics explains the movements of the Earth's surface. | HS-ESS2-3<br>HS-ESS2-1 | Plate Tectonics |
| **ESS2.C: The Role of Water in Earth's Surface Processes** | | |
| • Water is central to Earth's dynamics. | HS-ESS2-5 | The Role of Water in Earth's Surface Processes |
| **ESS2.D: Weather and Climate** | | |
| • Earth's climate is driven by the Sun.<br>• Organisms caused change in the early atmosphere.<br>• Human activity has affected climate. | HS-ESS2-2, HS-ESS2-4<br>HS-ESS2-6, HS-ESS2-7<br>HS-ESS2-4, HS-ESS2-6 | Weather, Climate and Biogeology |
| **ESS2.E: Biogeology** | | |
| • The Earth's surface and the life that exists on it coevolve. | HS-ESS2-7 | Weather, Climate and Biogeology |
| **HS-ESS3 EARTH AND HUMAN ACTIVITY** | | |
| **ESS3.A: Natural Resources** | | |
| • Resource availability has guided development of human societies.<br>• Resource extraction and use has costs, risks, and benefits. | HS-ESS3-1<br>HS-ESS3-2 | Natural Resources |
| **ESS3.B: Natural Hazards** | | |
| • Natural hazards have shaped human history. | HS-ESS3-1 | Natural Hazards |
| **ESS3.C: Human Impacts on Earth Systems** | | |
| • Natural resources must be managed responsibly.<br>• New technologies can contribute to sustainability. | HS-ESS3-3<br>HS-ESS3-4 | Human Impacts on Earth Systems |
| **ESS3.D: Global Climate Change** | | |
| • Humans have the ability to manage their impact on the Earth.<br>• Studies and simulations provide information about Earth's systems. | HS-ESS3-5<br>HS-ESS3-6 | Global Climate Change |

| NGSS HS-ESS PROGRAM BY TOPIC | PERFORMANCE EXPECTATION | CHAPTER IN STUDENT EDITION |
|---|---|---|
| **HS SPACE SYSTEMS** | | |
| **ESS1.A: The Universe and Its Stars** | | |
| • The Sun is changing and will burn out.<br>• Stars can be studied using their light spectra and brightness.<br>• The Big Bang is supported by many different lines of evidence.<br>• Elements are produced by nucleosynthesis. | HS-ESS1-1<br>HS-ESS1-2, HS-ESS1-3<br>HS-ESS1-2<br>HS-ESS1-2, HS-ESS1-3 | The Universe and Its Stars |
| **ESS1.B: Earth and the Solar System** | | |
| • Kepler's laws describe common features of the motions of orbiting objects. | HS-ESS1-4 | Earth and the Solar System |
| **HS HISTORY OF EARTH** | | |
| **ESS1.C: The History of Planet Earth** | | |
| • Continental rocks are older than rocks of the ocean floor.<br>• Extraterrestrial objects can provide information about Earth's history. | HS-ESS1-5<br>HS-ESS1-6 | The History of Planet Earth |
| **ESS2.A: Earth Materials and Systems** | | |
| • Earth's systems cause feedback effects. | HS-ESS2-1, HS-ESS2-2 | Earth Materials and Systems |
| **ESS2.B: Plate Tectonics and Large-Scale Interactions** | | |
| • Plate tectonics explains the movements of the Earth's surface. | HS-ESS2-1 | Plate Tectonics |
| **HS EARTH'S SYSTEMS** | | |
| **ESS2.A: Earth Materials and Systems** | | |
| • Earth's systems cause feedback effects.<br>• Empirical evidence lead to a model of the Earth's structure. | HS-ESS2-2<br>HS-ESS2-3 | Earth Materials and Systems |
| **ESS2.B: Plate Tectonics and Large-Scale Interactions** | | |
| • Radioactive decay provides the heat that drives mantle convection. | HS-ESS2-3 | Plate Tectonics |
| **ESS2.C: The Role of Water in Earth's Surface Processes** | | |
| • Water is central to Earth's dynamics. | HS-ESS2-5 | The Role of Water in Earth's Surface Processes |
| **ESS2.D: Weather and Climate** | | |
| • Earth's climate is driven by the Sun.<br>• Organisms caused change in the early atmosphere.<br>• Human activity has affected climate. | HS-ESS2-2<br>HS-ESS2-6, HS-ESS2-7<br>HS-ESS2-6 | Weather, Climate and Biogeology |
| **ESS2.E: Biogeology** | | |
| • The Earth's surface and the life that exists on it coevolve. | HS-ESS2-7 | Weather, Climate and Biogeology |
| **HS WEATHER AND CLIMATE** | | |
| **ESS2.A: Earth Materials and Systems** | | |
| • The geological record shows changes to global and regional climates. | HS-ESS2-4 | Earth Materials and Systems |
| **ESS2.D: Weather and Climate** | | |
| • Earth's climate is driven by the Sun. | HS-ESS2-4 | Weather, Climate and Biogeology |
| **ESS3.D: Global Climate Change** | | |
| • Humans have the ability to manage their impact on the Earth. | HS-ESS3-5 | Global Climate Change |
| **HS HUMAN SUSTAINABILITY** | | |
| **ESS3.A: Natural Resources** | | |
| • Resource availability has guided development of human societies.<br>• Resource extraction and use has costs, risks, and benefits. | HS-ESS3-1<br>HS-ESS3-2 | Natural Resources |
| **ESS3.B: Natural Hazards** | | |
| • Natural hazards have shaped human history. | HS-ESS3-1 | Natural Hazards |
| **ESS3.C: Human Impacts on Earth Systems** | | |
| • Natural resources must be managed responsibly.<br>• New technologies can contribute to sustainability. | HS-ESS3-3<br>HS-ESS3-4 | Human Impacts on Earth Systems |
| **ESS3.D: Global Climate Change** | | |
| • Studies and simulations provide information about Earth's systems. | HS-ESS3-6 | Global Climate Change |

# Earth and Space Sciences for NGSS Presentation Media

Support your teaching with *Earth and Space Sciences for NGSS* Presentation Media. This title, **sold separately**, provides 12 sets of full color slides corresponding to the 12 chapters of its companion student book. The extent of each set broadly reflects the coverage in the student edition, and may include additional detail and illustrations.

The slide sets are in full color, fully editable, and sold as a **campus licence**. It includes both **Keynote** and **PPT** formats.


SEPs
Background

# Science Practices

## Science and engineering practices: Teacher's notes

### Asking questions and defining problems

☐ 1. Students should be able to recognize the basic features of science as a discipline involving rigor but also creativity and serendipity. They should understand the role of observation in science; it is through observation that scientists collect data to test their hypothesis. Students should also understand that observation often involves the use of tools (e.g. taking measurements). They should apply a critical, open minded approach to their own investigations and recognize that unexpected results during their own investigations do not represent failure, but an opportunity to ask new questions.

☐ 2. Hypotheses put forward to explain observations about a system should be based on sound prior knowledge. For students, this usually involves provided information and background reading. Students should formulate questions and hypotheses that are appropriate to the system they are investigating and that they can feasibly investigate with the time and resources available. While recognizing its limitations, a sound approach at this level could be: 1) to ask a question about a phenomenon, 2) to make observations about that phenomenon, 3) to construct a hypothesis to explain the phenomenon, 4) to test, 5) to collect and interpret data, 6) to draw conclusions and communicate findings, 7) to discuss (peer review).

### Develop and use models

☐ 3. The model is central to science. A model is any representation, simplification, or substitute for what you are actually studying or trying to predict. Examples of models in science include the planetary orbit model of atoms and models of geochemical cycles. A good model must be able to explain as many characteristics of the observed system as possible, but also be as simple as possible. Students should recognize the range of things that act as models of a system or its components, e.g. physical models, abstracts, analogies, drawings, and simulations. Students should be aware of the limitations of models and understand that models, like the laws and explanations they represent, are constantly being revised in science.

### Plan and carry out investigations

☐ 4. Students should plan investigations with consideration to making a fair test where possible or (e.g. in the field) accounting for factors that are beyond their ability to control. They should be aware of assumptions they are making about the system and evaluate how reasonable these are.

☐ 5. Students should understand that accuracy refers to how close a value is to the true value. The same applies with inferential statistics, when we want to assess how close a statistic is to the true value of a parameter (e.g. mean length). With widespread use of dataloggers and measuring instrumentation, accuracy is often a feature of instrument calibration. Precision is an indication of how close measurements are to each other. To improve precision, students should always assign the same person to make measurements in an experiment.

☐ 6. Students should distinguish quantitative data (numbers) from qualitative data (descriptions), but recognize that some data are categorical by nature (e.g. color). They should be able to explain why it is desirable to collect quantitative data rather than qualitative data. They can think about how they could convert qualitative to quantitative data. Qualitative data such as color can instead be measured as a wavelength (quantitative).

☐ 7. Students should distinguish between and explain the range and the purpose of independent, dependent, and controlled variables in a controlled experiment. Students should understand that the purpose of the experimental control is to establish the effect of one variable of interest on a system. Thus the control (or control groups) is not exposed to the changes in the independent variable of interest.

### Analyze and interpret data

☐ 8. Graphs present data in a way that makes trends and patterns in the data evident to the reader. Different graph types are appropriate for different types of data, e.g. a line graph is inappropriate for discontinuous data. Students should review the guidelines for presenting data graphically.

☐ 9. Students should recognize the value of basic descriptive statistics as a way to describe their data. Measures of central tendency provide a key to the most appropriate further analysis. Tabulating descriptive statistics and plotting data with an indication of dispersion (spread) are among the best early analyses and, at this level, are often sufficient to show trends and patterns in the data.

☐ 10. Students should understand how statistics and probability can be used to evaluate the reliability of findings and so increase confidence in statements of cause and effect.

### Use mathematics and computational thinking

☐ 11. Students should be able to recognize and use appropriate units in calculations and convert between units and between decimal and standard form. They should be comfortable using computational tools such as spreadsheets to analyze, represent and model data. The Teacher's Digital Edition provides many sample spreadsheets that can be used for this purpose.

☐ 12. Simple data manipulations, including percentages, rates, frequencies, means, and logarithms are a way to summarize data and enable samples to be meaningfully compared. Students should be comfortable with these basic calculations.

### Construct explanations and design solutions

☐ 13. Many of the activities in the book require students to explain results based on real evidence presented and using their understanding of basic principles previously covered.

### Engage in argument from evidence

☐ 14. Many of the activities in the book present real world second hand data to support the concepts presented. Students are often asked to evaluate explanations based on the evidence and are encouraged to propose explanations for any inconsistencies in the data (as real world data is seldom a perfect story).

### Obtain, evaluate, and communicate information

☐ 15. Throughout the book, students are encouraged to evaluate the validity and reliability of designs, methods, claims, and evidence. These evaluations are integral to most of the data handling and interpretation activities presented.

# ESS1.A The Universe and its Stars

## Disciplinary core ideas: Teacher's notes

### The Sun is changing and will burn out

- ☐ 1. Students should realize that our understanding of the universe is based on observation. What and how accurately we can observe and record depends on the technology we are using. Students should also realize that each piece of technology or observational hardware has its own strengths, weaknesses, and limitations of use. (**HS-ESS1-1, HS-ESS1-2**)
- ☐ 2. The Sun formed from a nebula comprising mostly hydrogen and helium. Nuclear fusion of hydrogen into helium powers the Sun. The size of the Sun is an equilibrium between gravity pulling inwards and the heat and light produced by nuclear fusion pushing outwards. Eventually the hydrogen in the core will be used up and the core will contract. Helium will ignite and fuse to carbon and oxygen in a shell around the core. The outer layers will swell and the Sun will become a red giant star. When nuclear fusion stops the outer layers will be lost and the core will remain as a white dwarf. (**HS-ESS1-1**)
- ☐ 3. As stars evolve and become red giants or super giants their surface temperature drops but their overall luminosity increases. Luminosity tends to increase with size (large stars are brighter than small stars) and mass (massive stars burn hotter and brighter than lighter stars). Very large massive stars use up their hydrogen fuel quickly (sometimes within a million years). They continually fuse heavier elements at a faster and faster rate (carbon fusion lasts 600 years, oxygen fusion lasts 6 months, and silicon fusion lasts 1 day), until iron is reached. At this point fusion stops and gravity causes the star to collapse. Collapse can be rapid, taking just a few seconds. The in falling layers rebound off the dense core as a supernova while the core may form a neutron star (neutrons held up against gravity by the repulsive strong nuclear force) or, if the core is large enough, a black hole. The shock wave of the supernova smashes lighter elements together to form heavier elements. (**HS-ESS1-1, HS-ESS1-3**)
- ☐ 4. A star's luminosity can be plotted against its temperature on a Hertzsprung-Russell diagram. Most stars fall along a line from the upper left to the lower right of the graph (main sequence stars). The temperature of a star can be related to its spectral color. Massive stars burn hot and tend produce light in the blue end of the spectrum, low mass stars produce light at the red end of the spectrum. (**HS-ESS1-1**)

### The Big Bang theory is supported by many lines of evidence

- ☐ 5. The Big Bang theory states that the universe began 13.8 billion years ago as a hot dense singularity that underwent inflation. Evidence for the Big Bang includes the current observed expansion of the universe, confirmed by red-shift in distant galaxies, indicating they are moving away from us. The cosmic microwave background (CMB) is the light from 380,000 years after the Big Bang, with its wavelength stretched into the microwave area of the EM spectrum by the expansion of the universe. Measurement of the composition of gases in distance and therefore old galaxies confirms they have the same percentages of hydrogen and helium as predicted by Big Bang theory. (**HS-ESS1-2**)

### Elements are produced by nucleosynthesis

- ☐ 6. Nucleosynthesis of helium in stars occurs by the proton-proton chain reactions. Two protons collide to produce a deuterium nucleus. Two deuterium nuclei collide to form a helium 3 nucleus. Two helium 3 nuclei collide to form a helium 4 nucleus In total six protons collide, forming 4 protons and two neutrons. Each collision releases electromagnetic energy. (**HS-ESS1-1**)
- ☐ 7. When the hydrogen fuel runs out in a star, helium begins fusion. How long stars can maintain burning (fusing) heavier and heavier elements depends on the size of the star. Large stars are able to fuse elements up to iron. Smaller stars can maintain fusion only to carbon or oxygen. Elements heavier than iron can only be formed during a supernova (supernova nucleosynthesis). (**HS-ESS1-2**)

## Crosscutting concepts

- ☐ 1. **Scale, proportion and quantity**: The significance of a phenomenon, such as nucleosynthesis, depends on the scale, proportion, and quantity at which it occurs. (**HS-ESS1-1**)
- ☐ 2. **Scale, proportion and quantity**: The concept of orders of magnitude can be used to understand models of the universe at different scales (**HS-ESS1-1**)
- ☐ 3. **Energy and matter**: In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (**HS-ESS1-3**)

## Science and engineering practices

- ☐ 1. Develop and use an evidence-based model to illustrate the life span of the Sun and the role of nuclear fusion in the Sun's core.
  **SEP**: Developing and using models (**HS-ESS1-1**)
- ☐ 2. Use an evidence-based model to describe the origin and nature of the universe.
  **SEP**: Developing and using models (**HS-ESS1-1**)
- ☐ 3. Construct an explanation of the Big Bang theory based on evidence from a variety of sources and uniformitarianism.
  **SEP**: Constructing explanations and designing solutions (**HS-LS1-2**)
- ☐ 4. Use multiple formats (e.g. oral presentation, text, diagrams, mathematics) to communicate scientific ideas about the way stars produce elements.
  **SEP**: Obtaining, evaluating, and communicating information (**HS-ESS1-3**)

## Engineering, technology, and applications of science

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects involve scientists and engineers with a wide range of expertise. (**HS-ESS1-2**)

## Nature of science

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on facts that have been repeatedly confirmed through observation and experiment. Theories are modified as new information is discovered. (**HS-ESS1-2**)
- Scientific knowledge is based on the assumption that natural laws operate the same way now as they did in the past as they will in the future, and that they are the same everywhere in the universe. (**HS-ESS1-2**)

ESS1.B

# Earth and the Solar System

## Disciplinary core ideas: Teacher's notes

### The motions of orbiting objects show common features

- ☐ 1. The nebula theory states our solar system formed from a huge cloud of dust and gas that contracted under its own gravity. Evidence for this includes the planets all rotate in the same direction, they all orbit within 6 degrees of a common plane, and all the inner planets are rocky whereas the outer planets are mostly gaseous.
- ☐ 2. The Sun contains 99% of all matter in the solar system. It is orbited by eight planets. Until 2006 Pluto was considered a planet but the discovery of many other Pluto sized objects orbiting the Sun in the Kuiper belt prompted its reclassification as a dwarf planet.
- ☐ 3. The asteroid belt marks the line between the inner and outer planets. The inner planets are also often called the terrestrial or rocky planets. Other than the Earth, Mars is the most explored of these planets, with many more orbiters, landers, and rovers being sent there than to the other planets.
- ☐ 4. The outer planets has been visited by space probes less often than the inner planets. Juno reached Jupiter in 2016 and is only the fifth probe to reach Jupiter, of which three were brief flybys. Uranus and Neptune have only been visited in flybys by Voyager 2 in 1986 and 1989 respectively. The Grand Tour by Voyagers 1 and 2 took extensive advantage of the planets being aligned in such a way that gravity assists could be used to move the probes from one planet to the next.
- ☐ 5. 2006 saw the International Astronomical Union (IAU) adopt new rules for defining a planet. As a result Pluto was redefined as a dwarf planet, along with several other similar sized celestial bodies. Many planets have also been discovered belonging to other solar systems (exoplanets). As of 2016 there are about 3493 exoplanets in 2617 planetary systems. 590 multiple planetary systems have been confirmed. The most Earth-like of these is believed to be Kepler-186f. It is the first planet with a radius similar to Earth's to be discovered in the habitable zone of another star.

**Points 1-5 are background for HS-ESS1-4**

- ☐ 6. Students should recognize that the planets as we see them in the night sky do not move uniformly. Because their orbits are slower or faster than the Earth's, their position in the sky changes as we approach and then move away. This causes them to transcribe loops and zig zags in the sky. The geocentric model of the solar system explains this by stating that the planets perform epicycles along their orbits. The heliocentric model states that the loops are caused by the planet's position relative to and observer and Earth. (**HS-ESS1-4**)
- ☐ 7. Kepler's three laws of planetary motion were worked out using astronomer Tycho Brahe's extensive observations of the night sky. Kepler was Brahe's assistant and eventual successor as imperial mathematician for Emperor Rudolph II. Kepler originally thought the planets orbited in circles, but could not reconcile observations with circular orbits. From the precise observations of Mars by Tycho Brahe, Kepler realized that only an elliptical orbit would fit the observations. (**HS-ESS1-4**)
- ☐ 8. Kepler's laws helped Isaac Newton produce his Law of Universal Gravitation. The works of Brahe, Kepler, and Newton provide a classic example of how science often works: observation, followed by analysis and explanation, followed by refinement. Newton's Law of Universal Gravitation can be rearranged to produce Kepler's third law, but in respect to any mass, rather than just the Sun. (**HS-ESS1-4**)
- ☐ 9. The orbits of planets and satellites are a result of the numerous gravitational forces acting upon them. Orbits can change if the object encounters a strong enough field. Examples include comet Shoemaker-Levy and comet Tempel 1, both pulled out of previous orbits by Jupiter's gravity. (**HS-ESS1-4**)

### Cyclical changes in the Earth's orbit and tilt cause climate cycles

- ☐ 10. Students should realize that the periodic changes to Earth's orbit and tilt have major effects on the Earth's climate. When the extremes of these cycles coincide they can trigger glacial or interglacial periods. (**HS-ESS2-4**)

## Crosscutting concepts

- ☐ 1. **Scale, proportion and quantity**: Algebraic thinking can be used to examine data and predict the motion of orbiting objects in the solar system. (**HS-ESS1-4**)
- ☐ 2. **Cause and effect**: Empirical evidence enables us to support claims about the causes of planetary orbits and environmental cycles. (**Not aligned to a performance expectation**)

## Science and engineering practices

- ☐ 1. Use mathematical representations to describe and predict the motion of orbiting objects in the solar system
  **SEP**: Using mathematical and computational thinking (**HS-ESS1-4**)
- ☐ 2. Use a model to describe the behavior of planetary bodies and their satellites.
  **SEP**: Developing and using models (**Not aligned to a performance expectation**)

## Engineering, technology, and applications of science

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects involve scientists and engineers with a wide range of expertise. (**HS-ESS1-4**)

# ESS1.C The History of Planet Earth

## Disciplinary core ideas: Teacher's notes

### Continental rocks are older than the rocks of the ocean floor

- ☐ 1. Students should understand that determining the age of the Earth is difficult due to its dynamic nature. The continents are older than the seafloor because they are less dense and tend to "float" above subduction zones, making it less likely their rocks will be recycled into the mantle. (**HS-ESS1-5**)
- ☐ 2. The Earth's crust is the solid outer layer of the Earth. It is relatively thin, ranging from 5 - 50 km thick. The crust is divided into several large plates and a number a smaller ones. By composition the crust is 46.6% oxygen, 27.7% silicon, 8.1% aluminum, and 5% iron. The last 12% is made of a mixture of less common elements. Silicon dioxide makes up 60.6% of all minerals in the crust, with aluminum oxide making up 15.9%. (**HS-LS1-5**)
- ☐ 3. The crust can be divided into continental crust and oceanic crust. Students should understand that the oceanic crust is younger than the continental crust because the oceanic crust is constantly being formed at mid-ocean ridges and being recycled at subduction zones, whereas the continental crust is hardly ever recycled. (**HS-ESS1-5**)

### Extraterrestrial objects can provide information about Earth's history

- ☐ 4. Students should understand that rocks formed from cooled magma contain a certain ratio of radioactive elements. This ratio changes as the rocks age and radioactive elements decay. Because the surface rocks are constantly being eroded, melted, and reformed the ratio is constantly "reset" making radiometric dating of the Earth difficult. By dating objects we know are likely to be unchanged since the beginning of the solar system we can estimate when the Earth formed. (**HS-ESS1-6**)
- ☐ 5. Students should realize that celestial bodies that have little geological activity can be used to date the age of the Earth and the solar system. This is because their rocks are not being reformed and so the ratios of elements are a direct result of radioactivity. These ratios can be used to calculate the age of the rocks. (**HS-ESS1-6**)
- ☐ 6. Evidence from landers and rovers on, and orbiters above Mars have collected substantial geological data on Mars. This data can be used to compare to and help model geological processes on Earth and help explain processes in the early solar system. (**HS-ESS1-6**)
- ☐ 7. Students should realize that the Earth's early environment was very dynamic and that it underwent large scale changes early on. The Earth has had at least three different atmospheres, The original atmosphere at time of formation, the second after the impact of Theia, and third formed after the evolution of oxygenic photosynthesis. Earth's active geology constantly recycles minerals and aids the evolution of the planet. (**HS-ESS1-6**)

## Crosscutting concepts

- ☐ 1. **Patterns**: Empirical evidence is needed to identify patterns, e.g. patterns of past and current movements of Earth's crust. (**HS-ESS1-5**)
- ☐ 2. **Stability and change**: Scientific reasoning and evidence can be used to construct an explanation of changes during Earth's History. (**HS-ESS1-6**)

## Science and engineering practices

- ☐ 1. Evaluate the evidence for explanations of the ages of crustal rocks.
  **SEP**: Developing and using models (**Not aligned to a performance expectation**)
- ☐ 2. Use scientific reasoning to link evidence to accounts of Earth's formation and early history and assess the extent to which the account is supported.
  **SEP**: Constructing explanations and designing solutions. (**HS-ESS1-6**)

## Nature of science

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on facts that have been repeatedly confirmed through observation and experiment. Theories are modified as new information is discovered. (**HS-ESS1-6**)
- Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (**HS-ESS1-6**)

# ESS2.A Earth Materials and Systems

## Disciplinary core ideas: Teacher's notes

### Earth's systems cause feedback

☐ 1. Students should understand that feedback systems play an important role in regulating the Earth's climate and various systems. Negative feedback keeps the environment stable but positive feedback may soon overcome this in the warming of the planet as carbon dioxide added to the atmosphere heats the Earth, melting permafrost and releasing methane into the atmosphere, which further warms the planet. (**HS-ESS2-1**, **HS-ESS2-2**)

☐ 2. Students should understand that constructive forces are those that build features on the Earth. They generally raise the average height of the land. Destructive features are those that break down features and lower the average height of the land. Students should also realize the varying time scales in which these operate. For example, rocks may form very quickly in a volcanic eruption, but take thousands of years to erode. (**HS-ESS2-1**)

### Empirical evidence lead to a model of the Earth's structure

☐ 3. Students should be able to recall and identify the layers of the Earth. There is a central iron core surrounded by a liquid outer core. This is surrounded by the lower and upper mantle and finally the crust. The crust and upper mantle include the lithosphere (the crust and uppermost solid layer of the mantle) and the asthenosphere (plastic layer of the upper mantle). (**HS-ESS2-3**)

☐ 4. Students should be able to explain the structure of the Earth from evidence of seismic waves. Importantly, students should understand that P-waves travel through both solids and liquids, whereas S-waves only travel through solids. Waves bend (refract) as they pass through boundaries between different layers. Waves also travel faster in denser material. This leads them to arriving at seismographs at different times to what would be expected if the Earth was uniform. (**HS-ESS2-3**)

☐ 5. Students should understand that the Earth's internal heat produces convection currents that cause the mantle to deform. This brings material from deeper in the mantle close to the surface and also cycles surface material down into the mantle, which results in the movement of the crust's tectonic plates. (**HS-ESS2-3**)

### The geological record shows changes to global and regional climates

☐ 6. The dynamic nature of Earth's systems, e.g. atmospheric circulation, energy received from the Sun, and ocean circulation, cause continual change. When extremes in the dynamics of these systems coincide there can be large scale changes in climate. Evidence for these events can be found in the geological record as sediments and changes to radioisotope ratios. Changes in Earth's orbit and solar output play major roles in changing the Earth's climate. Students should understand that some changes happen quickly and sporadically, while others happen slowly and periodically. (**HS-ESS2-4**)

## Crosscutting concepts

☐ 1. **Stability and change**: Change and rates of change in the Earth's surface features over short and long periods of time can be quantified and modeled. (**HS-ESS2-2**)

☐ 2. **Stability and change**: Feedback between the Earth's systems can stabilize or destabilize those systems, e.g. in the regulation of climate. (**HS-ESS2-2**)

☐ 3. **Energy and matter**: Energy drives the cycling of matter by thermal convection in the mantle. (**HS-ESS2-3**)

☐ 4. **Cause and effect**: Empirical evidence can be used to determine causes of climate change on different time scales. (**HS-ESS2-4**)

## Science and engineering practices

☐ 1. Use a model to illustrate how the Earth's surface features are created.
**SEP**: Developing and using models (**HS-ESS2-1**)

☐ 2. Use an evidence-based model to describe the structure of the Earth.
**SEP**: Developing and using models (**HS-ESS2-3**)

☐ 3. Use a model to describe the multiple causes of climate change.
**SEP**: Developing and using models (**HS-ESS2-4**)

☐ 4. Analyze data to make a valid claim that change to one of Earth's systems can create feedbacks that cause changes to other Earth systems.
**SEP**: Analyzing and interpreting data (**HS-ESS2-2**)

☐ 5. Conduct an investigation to produce data as evidence of the ice albedo effect.
**SEP**: Planning and carrying out investigations (**Not aligned to a performance expectation but relevant to ESS2-2**)

## Engineering, technology, and applications of science

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects involve scientists and engineers with a wide range of expertise. (**HS-ESS2-3**)
- 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. (**HS-ESS2-2**)

## Nature of science

- Science knowledge is based on empirical evidence. Science disciplines share common rules of evidence used to evaluate explanations about nature. Science include the process of coordinating evidence with current theory. (**HS-ESS2-3**)
- Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (**HS-ESS2-4**)

# ESS2.B Plate Tectonics

## Disciplinary core ideas: Teacher's notes

### Radioactive decay provides the heat that drives mantle convection

- ☐ 1. Students should understand that all elements have isotopes - atoms with equal numbers of protons but different numbers of neutrons. Some of these isotopes are radioactive. How quickly the isotopes decay is unique to each isotope. For example uranium 238 (the most common uranium isotope) has a half-life of 4.46 billion years, whereas uranium 234 has a half-life of 245,500 years. As each atom decays it releases heat energy. In the Earth's interior, this heat from decay accounts for about half of Earth's internal heat. (**HS-ESS2-3**)
- ☐ 2. Primordial heat (heat left over from Earth's formation) and heat from radioactive decay provide enough energy to keep the interior of the Earth hot enough to drive convection currents in the mantle and produce geological activity. (**HS-ESS2-3**)
- ☐ 3. Uranium 238 is the most common form of uranium (making up 99.24% of all uranium isotopes). It is radioactive and decays to thorium 234 and an alpha particle. Uranium 238's decay chain ends with lead 206 (which is stable). Thus the daughter product of uranium 238 is lead 206. It takes 4.47 billion years for this process to occur (slightly longer than uranium 238's half life). By measuring the ratios of uranium 238 and lead 206 we can determine the age of various rocks and the Earth. We can also conclude that since the Earth is about 4.5 billion years old about half its original amount of uranium has decayed. (**HS-ESS2-3**)
- ☐ 4. Students should understand that the lithosphere is divided into several large plates that rest on top of the mantle. The movement of these plates is the result of movement of the mantle beneath them by convection currents. (**HS-ESS2-3**)

### Plate tectonics explains the movements of the Earth's surface

- ☐ 5. Plate tectonics is the modern version of continental drift, proposed by Alfred Wegener in 1912. His idea that the continents move failed to gain support because he could not describe a mechanism for the movement. It was not until the 1960s when studies found the rocks on either side of mid ocean ridges were the same age that the idea of plate tectonics took hold. The theory explains that continents move and land formations such as mountains occur because the Earth's crust is divided into plates that are moved by movements in the mantle on which the plates rest (**HS-ESS2-1**)
- ☐ 6. Students should understand that crust is being formed at divergent boundaries (e.g. mid ocean ridges) and being destroyed at convergent boundaries (e.g. subduction zones). Mountain building may occur when two plates converge. The appearance of rifts, such as the East Great Rift Valley in east Africa, are the result of plates diverging. (**HS-ESS2-1**)
- ☐ 7. Students such realize that while crust is lost at subduction zones it is also being replaced at mid ocean ridges. This gain on one side of a plate and loss on another forms a "conveyer belt" which results in the movement of continents associated with the plate. (**HS-ESS2-1**)

## Crosscutting concepts

- ☐ 1. **Energy and matter**: Energy drives the cycling of matter by thermal convection in the mantle. (**HS-ESS2-3**)
- ☐ 2. **Stability and change**: Change and rates of change in the features of the Earth's continental and ocean floor over time can be quantified and modeled. (**HS-ESS2-1**)

## Science and engineering practices

- ☐ 1. Use a model based on evidence to show how radioactive decay provides the primary source of heat that drives convection in the mantle.
  **SEP**: Developing and using models (**HS-ESS2-3**)
- ☐ 2. Develop or use a model based on evidence of the Earth's interior to describe the cycling of matter in the Earth's crust and mantle by thermal convection.
  **SEP**: Developing and using models (**HS-ESS2-3**)
- ☐ 3. Develop or use a model based on evidence to illustrate how plate tectonics explains the continental and ocean floor features of the Earth.
  **SEP**: Developing and using models (**HS-ESS2-1**)

## Engineering, technology, and applications of science

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

## Nature of science

- Science knowledge is based on empirical evidence. Science disciplines share common rules of evidence used to evaluate explanations about natural systems. Science includes the process of coordinating patterns of evidence with current theory. (**HS-ESS2-3**)

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

## Disciplinary core ideas: Teacher's notes

### Water is central to Earth's dynamics

- ☐ 1. Students should understand that the dipole nature of water is responsible for its unique chemical and physical properties. They should be able draw a molecule of water, noting the polarity and explain how water molecules form hydrogen bonds with each other. (**HS-ESS2-5**)
- ☐ 2. Water is the only common substance to exist naturally as a solid, liquid, and gas. Water has a very high specific heat capacity (the amount of energy required to raise temperature 1°C), a very high heat of vaporization (the amount of energy required to transform a substance to a gaseous state), and a very high latent heat of fusion (the amount of energy required to change a substance from a solid to a liquid). These properties allow water to moderate Earth's climate by buffering large fluctuations in temperature and confer resistance to melting on glaciers and ice sheets. The hydrologic cycle, in which water changes states among the Earth's various systems, is therefore important in transporting energy around the globe via the oceans and atmosphere. Students should use the diagram in activity 82 as a model to understand the cycling of water through Earth's systems and the processes involved in this, including evaporation, transpiration, and precipitation. (**HS-ESS2-5**)
- ☐ 3. Water is relatively transparent to visible light, near ultraviolet light, and far-red light, but it absorbs most UV light, infrared light, and microwaves. The transmission of light through water is crucial to the productivity of the Earth's oceans and other water bodies. (**HS-ESS2-5**)
- ☐ 4. Students should outline the role of water in the weathering and transport of rock within the rock cycle. Water is directly involved in chemical weathering (oxidation, dissolving) and physical weathering (freeze-thaw) and indirectly involved in biological weathering by living organisms. Liquid water and ice transports weathered material and has a major role in shaping landscapes. (**HS-ESS2-5**)
- ☐ 5. Students should understand that, in most geological environments, a rock does not melt because its temperature increased. It melts because its boiling point is lowered, while temperature remained high. Most magma (molten rock underground) is formed by two processes:
  1) Decompression, which reduces the melting point and makes rock melt at a lower temperature (just as water boils at lower temperatures at altitude than at sea level due to lower atmospheric pressure). Decompression melting occurs at the mid ocean ridges.
  2) Hydration reduces the temperature at which rocks melt because the bonds in the minerals that make up the rock will be disrupted by the water molecules. In subduction zones for example, the subducting crust releases its water as it heats up. That water then rises up into the mantle above it, causing the mantle material to melt. (**HS-ESS2-5**)
- ☐ 6. Students should distinguish between adhesion (tendency of water to cling to other substances) and cohesion (tendency of water molecules to stick together). Both these properties are important in soil structure, soil stability, and water retention. In soil, water molecules adhere to soil particles, while capillarity (a function of cohesion and adhesion) draws water upwards into the root zone of plants. Soils low in water are vulnerable to wind erosion, whereas soils that are saturated have limited capacity for infiltration and are vulnerable to erosive runoff and slipping. (**HS-ESS2-5**)

## Crosscutting concepts

- ☐ 1. **Structure and function**: The functions and properties of water and its effects on Earth's materials can be inferred from its molecular substructure. (**HS-ESS2-5**)
- ☐ 2. **Energy and matter**: Energy drives the cycling of water within and between the Earth's systems. (**Not aligned to a particular performance expectation**)

## Science and engineering practices

- ☐ 1. Plan and conduct an investigation to produce data to serve as evidence for the effects of water on Earth's materials and surface processes.
  **SEP**: Planning and carrying out investigations (**HS-ESS2-5**)
- ☐ 2. Use a model to describe the behavior of water in its various states.
  **SEP**: Developing and using models (**Not aligned to a particular performance expectation**)
- ☐ 3. Use a model to illustrate how water moves between Earth's systems: the geosphere, hydrosphere, atmosphere, and biosphere.
  **SEP**: Developing and using models (**Not aligned to a particular performance expectation but relevant to HS-ESS2-5**).
- ☐ 4. Develop and use a model to illustrate the processes involved in the rock cycle.
  **SEP**: Developing and using models (**Not aligned to a particular performance expectation but relevant to HS-ESS2-5**).
- ☐ 5. Use quantitative data to support a claim about the effect of soil moisture on wind-induced rate of erosion.
  **SEP**: Constructing explanations and designing solutions (**Not aligned to a particular performance expectation but relevant to HS-ESS2-5**).

ESS2.D
ESS2.E

# Weather, Climate, and Biogeology

## Disciplinary core ideas: Teacher's notes

### Earth's climate is driven by the Sun

☐ 1. Students should appreciate the interrelatedness of climate and energy input. Energy from the Sun drives the Earth's climate systems. The solar radiation that passes through Earth's atmosphere is either reflected off snow, ice, or other surfaces or is absorbed by the Earth's surface. Some of the heat resulting from the absorption of incoming shortwave radiation is emitted as longwave radiation (thermal radiation). Students can complete the diagram in activity 91 to gain an appreciation of energy fluxes due to insolation, reflection, radiation, conduction, and absorption (including absorption by plants). (**HS-ESS2-2, HS-ESS2-4**)

☐ 2. Students should be able to explain, using diagrams if this is helpful, how the shape and tilt of the Earth and its rotation influence the globe's energy distribution and create the seasons. Differential heating between the tropics and the poles drives atmospheric circulation, transferring heat around the globe. This makes temperatures more evenly spread about the globe than they would be in the absence of an atmosphere. (**HS-ESS2-2, HS-ESS2-4**)

☐ 3. Students should have a broad understanding of how differential heating drives atmospheric circulation and understand that the tricellular model is just that, a model of the dynamic events occurring in atmospheric energy transfers. Essentials of the tricellular model include:
- The atmospheric circulation in each hemisphere consists of three cells at polar, mid-latitude, and equatorial regions.
- These different air masses control atmospheric movements and the redistribution of heat energy and produce the belts of prevailing winds around the world.
- Warm air rises at low latitudes and moves poleward (warm, moist, low pressure).
- At the poles, cool air descends (cold dry, high pressure). (**HS-ESS2-2, HS-ESS2-4**)

### Organisms caused change in the early atmosphere

☐ 4. The evidence is clear for the changes in the concentration of gases in the Earth's atmosphere over time. Seasonal changes are recorded in real time at monitoring stations such as those on Mauna Loa. Evidence for long term changes (historical) comes from measurements of fluid or gas inclusions in Antarctic or Greenland ice sheets (ice core records show $CO_2$ changes in the Earth's atmosphere going back 800,000 years), boron and carbon isotope ratios in certain marine sediments, and the number of stomata observed on fossil plant leaves (more stomata when $CO_2$ levels are lower). (**HS-ESS2-7**)

☐ 5. Accumulation of oxygen in the atmosphere oxidized atmospheric methane, triggering the Huronian glaciation, possibly the longest snowball Earth episode, lasting 300-400 million years. The snowball Earth hypothesis was originally devised to explain geological evidence for the apparent presence of glaciers at tropical latitudes. According to models, an ice-albedo feedback would result in glacial ice rapidly advancing to the equator once the glaciers spread to within 25°-30° of the equator. The presence of glacial deposits within the tropics therefore suggests global ice cover. Since a frozen planet reflects heat back into space, it is hard to understand how Earth warmed again. The evolution of aerobic organisms, which used oxygen, would have been important. An increase in $CO_2$ emissions as a result of volcanism is likely to have been crucial too. Life would have survived a snowball (or slushball) Earth in the deep oceans and under the ice layers. The evolution of eukaryotes following the Huronian glaciation was a milestone in the evolution of life, since eukaryotes include all complex cells and almost all multicellular organisms. Melting of the ice would have provided opportunities for symbioses (as per endosymbiotic theory) and diversification. The diversification of multicellular organisms that followed the Cryogenian (the Cambrian explosion) was also a likely response to the opportunities provided by a newly available environments. (**HS-ESS2-7**)

☐ 6. Biological and chemical processes have produced variations in the Earth's atmospheric oxygen levels over the last 540 million years or so. The production and burial of plant matter over long periods causes oxygen levels to rise (e.g. during the Carboniferous). Levels can fall again when that trapped ancient organic matter becomes exposed on land and elements such as iron react with oxygen (oxidative weathering). The Carboniferous oxygen peak is recorded in the fossil record, particularly of insects. The insect respiratory system dictates size and insects during the Carboniferous reached very large sizes relative to those of insects today. That said, there is no significant correlation between atmospheric oxygen and maximum body size elsewhere in the geological record. (**HS-ESS2-7**)

☐ 7. Students can use the diagram in activity 99 as a model for carbon fluxes between different systems on Earth. Respiration and photosynthesis are major contributors to carbon exchanges but students can calculate the contribution of human activity to increasing levels of atmospheric carbon dioxide. (**HS-ESS2-6**)

### Human activity has affected climate

☐ 8. Students should be able to clearly distinguish between the greenhouse effect and global warming as the two terms are frequently confused. The greenhouse effect makes life on Earth possible. Global warming refers to the increase in average global temperatures. The consequences of global warming and its connection to climate change are introduced here. (**HS-ESS2-6, HS-ESS2-4**)

### Current models predict that global temperatures will continue to rise

☐ 9. Students should appreciate that the weight of evidence as a whole supports the statement that the current rise in global temperature is largely a consequence of human activities and this increase is driving climate change. Regional climates may vary and the picture of climate change is a complex one, sometimes with apparent contradictions, so it is important to consider global averages and to understand that, even if carbon emissions were to stop immediately, the greenhouse gases currently present will continue to drive climate change into the future. (**secondary to HS-ESS3-6, relevant to HS-ESS2-6**)

☐ 10. As students will see in the chapter on global climate change, models create different scenarios (with different predictions) based on assumptions about economic and technological development, energy use, and population size. Current climate models show good accuracy in predicting events that have already occurred (hindcasting) so we can have considerable confidence in the ability of models to predict future trends in climate change. (**secondary to HS-ESS3-6, relevant to HS-ESS2-6**)

### The Earth's surface and the life that exists on it coevolve

- ☐ 11. Students should be able to describe examples of feedback between the biosphere and Earth's other systems and explain how change in one contributor produces change in others. Coevolution is a process in which unrelated but mutually interdependent entities change or evolve in a reciprocal fashion. Coevolutionary processes have seen the Earth's systems change from their primordial states to what we see today, creating biosignatures (substances that give evidence of life) that set the Earth apart from uninhabited bodies such as the Moon. Examples of coevolution between the biosphere and other Earth systems include:
  - Alteration of the atmosphere by production of oxygen by photosynthetic life, which in turn increased weathering rates and allowed for the evolution of animal life.
  - Formation of soil by microbial life on land, which in turn allowed for the evolution of land plants.
  - Evolution of corals, which created reefs that subsequently altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms. (**HS-ESS2-7**)

## Crosscutting concepts

- ☐ 1. **Cause and effect**: Empirical evidence enables us to make claims about how variations in the flow of energy into and out of Earth's systems results in climate change. (**HS-ESS2-4**)
- ☐ 2. **Stability and change**: Feedback between the Earth's systems can stabilize or destabilize those systems, e.g. in the regulation of climate. (**HS-ESS2-2**)
- ☐ 3. **Energy and matter**: The total amount of energy and matter in closed systems is conserved. (**Not aligned to a particular performance expectation**)
- ☐ 4. **Stability and change**: Scientific inquiry enables us to construct explanations from evidence for how conditions on Earth change and how they remain stable. (**HS-ESS2-7**)

## Science and engineering practices

- ☐ 1. Develop a model based on evidence to illustrate how changes to the Earth's surface can create feedbacks that can causes changes to one or more of Earth's systems.
  **SEP**: Developing and using models (**HS-ESS2-4**)
- ☐ 2. Develop or use a model to describe how flow of the Sun's energy into and out of Earth's systems varies.
  **SEP**: Developing and using models (**HS-ESS2-4**)
- ☐ 3. Use a model to describe how variations in amount of energy reaching the Earth's surface creates the seasons and affects climate systems.
  **SEP**: Developing and using models (**Not aligned to a particular performance expectation but background for HS-ESS2-4**)
- ☐ 4. Use a model to describe the cycling of carbon within and between the atmosphere, biosphere, geosphere, and hydrosphere.
  **SEP**: Developing and using models (**HS-ESS2-6**)
- ☐ 5. Develop a model to describe carbon fluxes into and out of Earth's systems.
  **SEP**: Developing and using models (**HS-ESS2-6**)
- ☐ 6. Analyze data to make or support a claim that one change to the Earth's surface can create feedbacks that cause changes to other Earth's systems.
  **SEP**: Analyzing and interpreting data (**HS-ESS2-2**)
- ☐ 7. Construct an explanation based on evidence, including data that you have collected, about how the angle of incoming radiation affects the area illuminated.
  **SEP**: Engaging in argument from evidence (**not aligned to any particular performance expectation**)
- ☐ 8. Plan and carry out an investigation to demonstrate how the angle of incoming energy from the Sun affects the area receiving the energy.
  **SEP**: Planning and carrying out investigations (**not aligned to any particular performance expectation**)
- ☐ 9. Use a model to describe how the circulation of the atmosphere and its effects on Earth's climate systems.
  **SEP**: Developing and using models (**HS-ESS2-4**)
- ☐ 10. Construct an argument based on data and evidence to defend the claim that life and Earth's other systems coevolve.
  **SEP**: Engaging in argument from evidence (**HS-ESS2-7**)
- ☐ 11. Construct an argument based on evidence for the transfer of the Sun's energy around the globe.
  **SEP**: Engaging in argument from evidence (**not aligned to any particular performance expectation**)

## Engineering, technology, and applications of science

- 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. (**HS-ESS2-2**)

## Nature of science

- Science arguments are strengthened by multiple lines of evidence. (**HS-ESS2-4**)

# ESS3.A ETS1.B Natural Resources

## Disciplinary core ideas: Teacher's notes

### Resource availability has guided the development of human societies

- ☐ 1. This point about natural resources is closely allied to the role of ecosystem services (Human Impact on Earth Systems). Natural resources exist without the actions of humans and the availability of resources is an important determinant in a nation's well being and economic wealth. Students should be able to list examples of natural resources and distinguish between those that are renewable and those that are not (e.g. fossil fuels) (**HS-ESS3-1**)
- ☐ 2. As the maps of natural resources (pages 174-175) show, human population centers occur where there are concentrations of resources. The most important of these is water. Regions rich in mineral resources, such as central Australia, remain sparsely populated because of the paucity of water. Fertile soils are usually closely associated with stable water sources, e.g. deltas and floodplains, and these regions tend to support the greatest populations. Overexploitation of a region's natural (but limited) resources, e.g. in Mesoamerica, 800 AD, led to the collapse of human populations in the past. Similar patterns continue today, often in association with depletion of water and soil resources (e.g. recent drought driven mass migrations in eastern African countries). (**HS-ESS3-1**)
- ☐ 3. Human advancements in technology have been associated with increases in the energy available to do work and increases in the human population as a consequence. More power allows more food to be produced, and resources can be transported efficiently between different population centers. The interconnectedness of the world (globalization) has accelerated in recent times. Advances in transportation and telecommunications infrastructure have been major factors in globalization, generating greater economic and cultural interdependence (positive feedback). (**HS-ESS3-1**)

### Resource extraction and use has costs, risks, and benefits

- ☐ 4. Students should appreciate that all resource use has risks and costs as well as benefits and these can be quantified in order to make sound decisions about new or continued use of a resource. Once economically viable resources may become uneconomic if the costs of extraction or the environmental costs become too high. Similarly, resources that may once have been uneconomic may become worth extracting if they become more valuable (e.g. required for a new use) or if new technologies arise to make extraction more cost effective. Resource use can create conflicts too. Water courses frequently cross geopolitical boundaries and issues over use can create conflicts and economic and commercial disputes. (**HS-ESS3-2**)
- ☐ 5. Even renewable resources must be carefully developed and managed to reduce environmental impact (hydroelectric dams, wind farms) and are not exempt from cost-benefit analyses. The social and environmental costs of some proposed renewable energy developments can be prohibitive, especially if the lifetime of the project is limited. (**HS-ESS3-2**)
- ☐ 6. Non-renewable resources are not sustainable, so the world needs to develop new renewable sources of energy at the same time as increasing the efficiency and reducing the impact of fossil fuel use. Soil is sometimes cited as a renewable resource, but the timescales for mature soil landscapes can be thousands of years. (**HS-ESS3-2**)
- ☐ 7. The two concluding activities in this chapter provide opportunity for students to develop their skills in evaluating situations for which the costs and benefits are quantified in economic terms. While their decisions about the resource use and development outcomes for the proposed scenarios will include some subjectivity, there will be an empirical background for their decision. These activities will provide an appreciation of the multiple factors that must be considered when extracting or using resources. (**HS-ESS3-2**)

## Crosscutting concepts

- ☐ 1. **Cause and effect**: Empirical evidence enables us to support claims about how the availability of natural resources has influenced human activities. (**HS-ESS3-1**)

## Science and engineering practices

- ☐ 1. Construct an explanation based on evidence and sound scientific assumptions for how the availability of natural resources has influenced human activities.
  **SEP**: Constructing explanations and designing solutions (**HS-ESS3-1**)
- ☐ 2. Design or evaluate technological solutions to reduce the impacts of human activities on natural systems and their resources.
  **SEP**: Constructing explanations and designing solutions (**ETS1B - HS-ESS3-4**)
- ☐ 3. Use scientific ideas, empirical evidence, and logical argument to evaluate design solutions for developing, managing, and using energy or mineral resources.
  **SEP**: Engaging in argument from evidence (**ETS1B, HS-ESS3-2**)
- ☐ 4. Construct or evaluate a design solution for developing, managing, and using energy or mineral resources based on an analysis of costs and benefits.
  **SEP**: Engaging in argument from evidence (**ETS1B, HS-ESS3-2**)

## Engineering, technology, and applications of science

- Modern civilization depends on major technological systems. (**HS-ESS3-1**)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits (e.g. in developing, managing, and using a resource) while decreasing costs and risks. (**HS-ESS3-2**)
- Analysis of costs and benefits is a critical aspect of decisions about technology. (**HS-ESS3-2**)

## Nature of science

- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. Science knowledge indicates what can happen in natural systems, not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (**HS-ESS3-2**)

ESS3.B

# Natural Hazards

## Disciplinary core ideas: Teacher's notes

### Natural hazards have shaped human history

☐ 1. Natural hazards take many forms and students should distinguish between those that are the result of the Earth's internal processes (e.g. earthquakes, volcanic eruption), surface processes (e.g. tsunamis, landslides), or severe weather (hurricanes, floods). There should be an understanding that the activities of humans themselves can contribute to the magnitude of a natural hazard or the extent to which it endangers human life and property. For example, poor land management practices can make natural flooding events worse, high density coastal communities are at greater risk of inundation during extreme weather events, and increased carbon emissions contribute to global climate change and its coincident hazards (e.g. sea level rise, drought). (**HS-ESS3-1**)

☐ 2. Students can cite numerous examples of the role of natural hazards in shaping human history, from the distant past to modern times. Large scale disasters as a result of natural hazard events such as earthquakes are interesting, not for the death toll and damage, but for the fact that the regions are then repopulated despite the continued risk. For example, the magnitude 8.5+ Arica earthquake (1868), near Arica (now part of Chile) produced multiple tsunamis in the Pacific Ocean, killed more than 25,000 people, and caused damage as far away as Hawaii and New Zealand. Today, Arica is a highly populated busy port despite the continued hazard risk (the region occupies a plate boundary and another earthquake of similar magnitude is predicted in the mid 2020s). (**HS-ESS3-1)**

☐ 3. The science of climate change is complex and the data often appear to be conflicting. What is important is that, overall, the overwhelming evidence points to anthropogenic warming. An increase in the energy in the Earth's systems translates to increased energy in weather events. See the excellent youtube video by Keah Schuenemann, Professor of Meteorology at the Metropolitan State University of Denver (Weblinks: Model of Climate Change) for a simple explanation of climate science. (**HS-ESS3-1)**

☐ 4. Rapid onset disasters caused by geological hazards such as earthquakes, tsunamis, and volcanic eruption tend to cause displacement followed by repopulation (as shown in the map on page 208). Slow onset hazards, such as drought, are more likely to drive the migration and permanent resettlement of populations (often to long term refugee camps). Under a warming climate, the number of climate change refugees is predicted to be in the many millions. Again, students can discuss what aspects of human activity increase the likelihood or impact of natural disasters. For example, some cities, such as New Orleans, have expanded from stable levees to low-lying areas with artificial levees to increase the land area. New Orleans has always been at high hurricane risk, but the risk is much greater now because of coastal erosion and because so much of the city is now below sea level. Moreover, the flooding of the Mississippi River used to keep the region supplied with sediment but flood control programs have prevented this natural deposition and the land continues to subside. (**HS-ESS3-1)**

☐ 5. Students should appreciate that some areas may become more suitable for crops (higher $CO_2$, higher temperature) as long as there is sufficient water, but these advantages generally accrue only to more temperate regions. Tropical crop growing regions are at greater risk from climate warming because most of the crops there are already at or close to their thermal maxima. Genetic modification of crops may offer a technological solution in some instances, but this assumes developing countries can afford the technology. (**HS-ESS3-1)**

☐ 6. There are two aspects to technological innovations:
1) Technologies that provide new cleaner renewable energies and reduce the carbon footprint.
2) Technologies that fix problems already created or limit the risk from natural hazards, such as carbon scrubbers, technologies to create more land, and building designs that withstand natural hazard events. (**Not aligned to any particular performance expectation**)

## Crosscutting concepts

☐ 1. **Cause and effect**: Empirical evidence enables us to explain how the occurrence of natural hazards has influenced patterns of human settlement and migration. (**HS-ESS3-1**)

☐ 2. **Cause and effect**: Empirical evidence enables us to make a claim about the link between global warming and the increased frequency of extreme weather events. (**HS-ESS3-1**)

☐ 3. **Cause and effect**: Empirical evidence enables us to make a link between realized and predicted rates of human displacement and climate change. (**HS-ESS3-1**)

☐ 4. **Scale, proportion and quantity**: The significance of a natural hazard depends on the scale at which it occurs. (**Not aligned to a particular performance expectation but reference to ETS1.B**)

## Science and engineering practices

☐ 1. Construct an explantation based on evidence for how the occurrence of natural hazards has influenced human activity.
**SEP**: Constructing explanations and designing solutions (**HS-ESS3-1**)

☐ 2. Construct an explantation based on evidence for the past and predicted effects of climate change on the location and mass movements of human populations.
**SEP**: Constructing explanations and designing solutions (**ETS1B**, **HS-ESS3-1**)

☐ 3. Evaluate solutions for mitigating the risks and impact of natural hazards.
**SEP**: Engaging in argument from evidence (**Not aligned to a particular performance expectation**)

☐ 4. Evaluate the claims or evidence behind explanations for natural disasters.
**SEP**: Obtaining, evaluating, and communicating information (**Not aligned to a particular performance expectation**). Note that this had the wrong SEP code on the activity page in the first printing.

ESS3.C
ETS1.B

# Human Impacts on Earth's Systems

## Disciplinary core ideas: Teacher's notes

### Natural resources must be managed responsibly

- ☐ 1. Students should understand that the resources we use are ultimately provided by the Earth's ecosystems. Ecosystems provide obvious provisioning services, such as food, raw materials, freshwater, and medicinal resources. These are the things that students would commonly regard as 'resources'. However, ecosystems also serve vital functions through their regulating services, including climate moderation, carbon sequestration and storage, moderation of extreme events such as flooding, waste water treatment, prevention of erosion and maintenance of soil fertility, and pollination. (**HS-ESS3-3 but also relevant to HS-ESS3-1**)
- ☐ 2. Students should develop an appreciation for the relationship between the health of the Earth's ecosystems and their ability to provide the services on which humans (and other life) depend into the future. Depletion and degradation of the Earth's natural systems ultimately jeopardizes the future viability of humans. (**HS-ESS3-3**)
- ☐ 3. Sustainable management is the management of resources to meet needs indefinitely without damage or depletion of the Earth's natural systems. The concept of sustainable management has been applied to the development of sustainable practices in business, agriculture, society, environment, and personal life. Students might like to consider if our current global resource use is sustainable. Why not? How will we meet resource demands indefinitely? How can we live more sustainably? How can technology help us to achieve the goals of sustainability? (**HS-ESS3-3**)
- ☐ 4. The student edition outlines some of the major issues surrounding unsustainable resource use, including pollution (plastics and oil), poor land management practices, deforestation, and overexploitation of fisheries resources. Some of the technologies available for mitigation or remediation are also discussed. Using these as starting points, it is useful to focus on current and future solutions to problems. Finding solutions to the problems of human resource use is the key to sustainability. (**HS-ESS3-3**)

### New technologies can contribute to sustainability

- ☐ 5. Students should recognize the role of science and technology in providing best practice solutions for sustainability. It is worth noting that there is a tendency to rely on technology to solve the problems of resource use and sustainability because of a reluctance (politically) to make the changes necessary to reduce growth in production and consumption. It is also worth pointing out that technological innovations, e.g. the Haber process of artificial nitrogen fixation, have been associated with increases in the human population and have contributed to the current unsustainable growth. Technology must not be used just to mitigate the problems already caused. It must offer relevant, sustainable solutions. (**HS-ESS3-4**)
- ☐ 6. **Sustainable agriculture**: Computer controlled irrigation, directed fertilizer application, genetic engineering of crops, integrated pest management, improved spray technology, using GPS to map the needs of specific areas.
  **Renewable energy**: naturally replenished on a human timescale, e.g. solar, wind, tides, waves, and geothermal heat. In 2015, more than US$286 billion was invested worldwide in renewable technologies, with China and the US investing heavily in wind, hydro, solar and biofuels.
  **Pollution**: Photovoltaic Systems (zero air pollution, zero hazardous waste), hydrogen powered vehicles, hydrogen fuel cell batteries, improved waste water treatment technologies, pollution prevention (P2) technologies that create less pollution than those they replace. P2 technologies include cleaner technologies that reduce environmental impacts but they don't include pollution treatment or pollution control technologies. (**HS-ESS3-4**)
- ☐ 7. The unsustainable consumption and production patterns of developed countries create a challenge for the sustainable development of human societies. For example, per capita ecological footprints in developed countries are 4-9 times greater than carrying capacity. Urbanization provides opportunities for millions and has contributed to poverty eradication worldwide. However, it adds pressure to the resource base and increases demand for energy, water, and sanitation, as well as for public services, education, and health care. Effective urban management is essential for the sustainability of cities. Sustainable development of urban areas must address land-use issues, food security, employment creation, transportation infrastructure, biodiversity conservation, water conservation, sources of renewable energy, waste management, and the provision of education, healthcare and housing. (**HS-ESS3-4**)

## Crosscutting concepts

- ☐ 1. **Stability and change**: The relationship between the management of resources, biodiversity, and the sustainability of human populations can be modeled. (**HS-ESS3-3**)
- ☐ 2. **Stability and change**: Changes or rates of change in resource use, the sustainability of human populations, and biodiversity use can be quantified and modeled. (**HS-ESS3-3**)
- ☐ 3. **Stability and change**: Human activities can act to stabilize or destabilize ecosystems. (**HS-ESS3-4**)

## Science and engineering practices

- ☐ 1. Create a computational model or simulation to illustrate the relationship between the management of natural resources, the sustainability of human populations, and biodiversity.
  **SEP**: Using mathematics and computational thinking (**HS-ESS3-3**)
- ☐ 2. Evaluate or refine a technological solution that reduces the impact of human activities on natural systems.
  **SEP**: Constructing explanations and designing solutions (**ETS1B, HS-ESS3-4**)

## Engineering, technology, and applications of science

- Modern civilization depends on major technological systems. (**HS-ESS3-3**)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits (e.g. in developing, managing, and using a resource) while decreasing costs and risks. (**HS-ESS3-4**)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. (**HS-ESS3-3**)

## Nature of science

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

# ESS3.D Global Climate Change

## Disciplinary core ideas: Teacher's notes

### Humans have the ability to manage their impact on the Earth

☐ 1. Students should be able to describe examples to show their understanding of the extent to which human activities affect all of the Earth's natural systems. Resource extraction and use alters patterns of existing biodiversity and so changes the dynamics of interactions in the biosphere. The impact of human activity on the biosphere is frequently a consequence of effects on other Earth's systems, including on the hydrosphere (e.g. through water extraction, diversion, and use), the atmosphere (greenhouse gas emissions, climate warming, and changes in ocean chemistry), and geosphere (e.g. environmental issues associated with mineral extraction). Human activities create new feedbacks among Earth's systems, altering climate and leading to instabilities. (**HS-ESS3-5**)

☐ 2. Students should appreciate that the weight of evidence as a whole supports the statement that the current rise in global temperature is largely a consequence of human activities and this increase is driving climate change. Regional climates may vary and the picture of climate change is a complex one, sometimes with apparent contradictions, so it is important to consider global averages and to understand that, even if carbon emissions were to stop immediately, the greenhouse gases currently present will continue to drive climate change into the future. (**HS-ESS3-5**)

☐ 3. Students should be able to discuss the extent of agreement between the data and the predictions of climate change models. Our ability to model climate change with increasing accuracy means that (1) better predictions can be made about the extent of climate change and its impact, both globally and regionally, and (2) we are now better able to plan for future climate change providing the political and social willingness is there to commit to solutions.
Issues to discuss around this include:
- How can countries meet their emissions targets?
- How do we finance climate change mitigation?
- What can we do personally? Regionally? Globally?
- What is the role of international policy?
Some 'good news" stories are appropriate, e.g. the C40 partnership is a partnership between different cities globally to share information, best practices, and ideas, as well as provide leadership on tackling climate change. It operates with the Clinton Initiative to support efforts to reduce greenhouse gas emissions through the use of clean energy and energy efficiency programs. Chicago is a C40 city and has set a goal of 25% reduction in carbon emissions below 1990 levels by 2025. It has begun adaptation planning to reduce the likely impact of increased temperature and rainfall by preserving green areas to manage storm water and looking at innovative ways of cooling. (**HS-ESS3-5**)

### Studies and simulations provide information about Earth's systems

☐ 4. The power of computer simulations and the efficiency with which we can now gather information is providing a better understanding of the interactions that influence global and regional climate. The more information we have, the more accurately we can model climate change scenarios and the better able we will be to plan for, reduce, and mitigate further climate change. (**HS-ESS3-6**)

☐ 5. Students should be able to explain why climate modeling requires assumptions to be made about the systems involved. Most of the assumptions made in climate models are associated with the uncertain future behaviors of humans, hence different scenarios are run with different assumptions in the model (e.g. assumptions about economic growth, technological advancement, and fossil fuel use). We don't have the luxury of waiting 30 years to see if a climate model was accurate in its predictions - we have to make decisions based on the best information we have now. This is why models are tested with 'hindcasting'. If the models used to predict future climate change can accurately map past climate changes for which we have data, we can be more confident about their projections. There are good examples of how this has already been used. For example, the eruption of Mt. Pinatubo allowed scientists to test the accuracy of models by feeding in the data about the eruption. The models successfully predicted the climatic response after the eruption. They also correctly predicted other effects subsequently confirmed by observation, including more warming in the Arctic and stratospheric cooling. (**HS-ESS3-6**)

## Crosscutting concepts

☐ 1. **Stability and change**: Rates of global or regional climate change and their associated effects can be quantified and modeled over short or long periods of time. (**HS-ESS3-5**)

☐ 2. **Systems and system models**: The effect of human activities on the relationships among Earth's systems can be modeled using mathematical representations. (**HS-ESS3-6**)

☐ 3. **Systems and system models**: When using models to describe systems, the boundaries and initial conditions need to be defined, and the inputs and outputs analyzed. (**HS-ESS3-6**)

## Science and engineering practices

☐ 1. Analyze geoscience and climate modeling data to make a valid and reliable claim about the projected rates of climate change and its associated future impacts.
**SEP**: Analyzing and interpreting data (**HS-ESS3-5**)

☐ 2. Use a computational representation to describe the relationship among Earth's systems and show how these relationships are being modified by human activity.
**SEP**: Using mathematics and computational thinking (**HS-ESS3-6**)

☐ 3. Evaluate design solutions to reduce the impact of climate change on Earth's systems..
**SEP**: Planning and carrying out investigations (**not aligned to a specific performance expectation**)

## Nature of science

- Scientific investigations use diverse methods and do not always use the same set of procedures to obtain data. New technologies advance scientific knowledge. (**HS-ESS3-5**)
- Science knowledge is based on empirical evidence. Arguments are strengthened by multiple lines of evidence.(**HS-ESS3-5**)