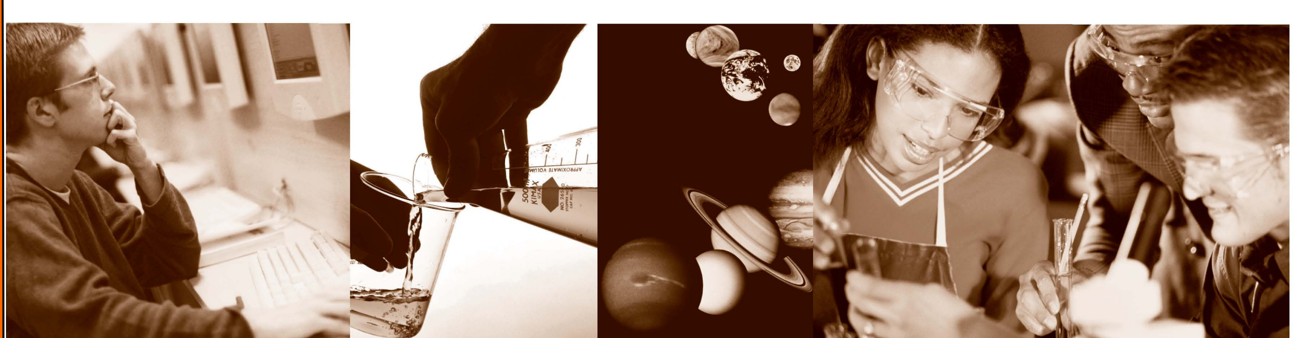
High School Content Expectations

Companion Document



SCIENCE

- Biology
- Chemistry
- **Earth Science**
- Physics

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MICHIGAN Department of Education

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HSSCE Companion Document

OVERVIEW

The Michigan High School Science Content Expectations establish what every student is expected to know and be able to do by the end of high school and outline the parameters for receiving high school credit as recently mandated by the Merit Curriculum legislation in the state of Michigan. The Science Content Expectations Documents and the Michigan Merit Curriculum Document have raised the bar for our students, teachers and educational systems.

In an effort to support these standards and help our science teachers develop rigorous and relevant curricula to assist students in mastery, the Michigan Science Leadership Academy, in collaboration with the Michigan Mathematics and Science Center Network and the Michigan Science Teachers Association, worked in partnership with Michigan Department of Education to develop this companion document. Our goal is for each student to master the science content expectations as outlined in the merit curriculum.

This companion document is an effort to clarify and support the High School Science Content Expectations and the Michigan Merit Curriculum. The Merit Curriculum has been organized into twelve teachable units – organized around the big ideas and conceptual themes in each of the four discipline areas. The document is similar in format to the Science Assessment and Item Specifications for the 2009 National Assessment for Educational Progress (NAEP). The companion document is intended to provide boundaries to the content expectations. These boundaries are presented as "notes to teachers", not comprehensive descriptions of the full range of science content; they do not stand alone, but rather, work in conjunction with the content expectations. The boundaries use five categories of parameters:

a. **Real World Context** refers to breadth and depth of topic coverage and includes those ideas that are "common" or "familiar" to students and appear frequently in curriculum materials and in most students' experiences outside of school. This section is not intended to guide assessment, but rather, may be used as a context for assessment.

a. **Instruments, measurements, and representations** refer to instruments students are expected to use and the level of precision expected to measure, classify, and interpret phenomena or measurement. This section contains assessable information.

b. **Technical vocabulary** refers to the vocabulary for use and application of the science topics and principles that appear in the content statements and expectations. The words in this section along with those presented within the standard, content statement and content expectation comprise the assessable vocabulary.

c. **Clarification** refers to the restatement of a "key idea" or specific intent or elaboration of the content statements. It is not intended to denote a sense of content priority. The clarifications guide assessment.

d. **Instructional Examples** are included as exemplars of five different modes of instruction appropriate to the unit in which they are listed. These examples include inquiry, reflection, general instruction, enrichment and intervention strategies. These examples are intended for instructional guidance only and are not assessable.

EARTH SCIENCE
Table of Contents

Earth Science Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Standard E1	**INQUIRY, REFLECTION, AND SOCIAL IMPLICATIONS**		
Statement E1.1	**Scientific Inquiry**		
E1.1A	Generate new questions that can be investigated in the laboratory or field.		Lesson 1 i
E1.1B	Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.		Lesson 8 i
E1.1C	Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).		
E1.1D	Identify patterns in data and relate them to theoretical models.		Lesson 2 i Lesson 3 i Lesson 6 i Lesson 7 i Lesson 9 i Lesson 10 i Lesson 12 i
E1.1E	Describe a reason for a given conclusion using evidence from an investigation.		Lesson 1 ii Lesson 4 i Lesson 10 i Lesson 11 i
E1.1f	Predict what would happen if the variables, methods, or timing of an investigation were changed.		Lesson 2 i
E1.1g	Based on empirical evidence, explain and critique the reasoning used to draw a scientific conclusion or explanation.		Lesson 10 i
E1.1h	Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.		
E1.1i	Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.		Lesson 5 i

Earth Science Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Statement E1.2	**Scientific Reflection and Social Implications**		
E1.2A	Critique whether or not specific questions can be answered through scientific investigations.		
E1.2B	Identify and critique arguments about personal or societal issues based on scientific evidence.		Lesson 9 ii Lesson 10 ii
E1.2C	Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.		Lesson 6 ii Lesson 8 ii Lesson 12 ii
E1.2D	Evaluate scientific explanations in a peer review process or discussion format.		
E1.2E	Evaluate the future career and occupational prospects of science fields.		Lesson 1 ii
E1.2f	Critique solutions to problems, given criteria and scientific constraints.		Lesson 2 ii
E1.2g	Identify scientific tradeoffs in design decisions and choose among alternative solutions.		Lesson 10 ii
E1.2h	Describe the distinctions between scientific theories, laws, hypotheses, and observations.		
E1.2i	Explain the progression of ideas and explanations that lead to science theories that are part of the current scientific consensus or core knowledge.		Lesson 3 ii Lesson 5 ii
E1.2j	Apply science principles or scientific data to anticipate effects of technological design decisions.		
E1.2k	Analyze how science and society interact from a historical, political, economic, or social perspective.		Lesson 4 ii Lesson 7 ii Lesson 11 ii
Standard E2	**EARTH SYSTEMS**		
Statement E2.1	**Earth Systems Overview**		
E2.1A	Explain why the Earth is essentially a closed system in terms of matter.	Unit 8	
E2.1B	Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.	Unit 1 Unit 3 Unit 7 Unit 8	
E2.1C	Explain, using specific examples, how a change in one system affects other Earth systems.	Unit 1 Unit 3 Unit 7 Unit 8 Unit 9	

Earth Science Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Statement E2.2	**Energy in Earth Systems**		
E2.2A	Describe the Earth's principal sources of internal and external energy (e.g., radioactive decay, gravity, solar energy).	Unit 3 Unit 6	
E2.2B	Identify differences in the origin and use of renewable (e.g., solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy.	Unit 10	
E2.2C	Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.	Unit 2 Unit 3 Unit 6 Unit 7 Unit 10	
E2.2D	Identify the main sources of energy to the climate system.	Unit 10	
E2.2e	Explain how energy changes form through Earth systems.	Unit 7 Unit 8 Unit 10	
E2.2f	Explain how elements exist in different compounds and states as they move from one reservoir to another.	Unit 8 Unit 10	
Statement E2.3	**Biogeochemical Cycles**		
E2.3A	Explain how carbon exists in different forms such as limestone (rock), carbon dioxide (gas), carbonic acid (water), and animals (life) within Earth systems and how those forms can be beneficial or harmful to humans.	Unit 1 Unit 8	Lesson 1 iii Lesson 1 iv Lesson 1 v
E2.3b	Explain why small amounts of some chemical forms may be beneficial for life but are poisonous in large quantities (e.g., dead zone in the Gulf of Mexico, Lake Nyos in Africa, fluoride in drinking water).	Unit 9	
E2.3c	Explain how the nitrogen cycle is part of the Earth system.	Unit 1 Unit 9	
E2.3d	Explain how carbon moves through the Earth system (including the geosphere) and how it may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society.	Unit 1 Unit 8	

Earth Science Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Statement E2.4	**Resources and Human Impacts on Earth Systems**		
E2.4A	Describe renewable and nonrenewable sources of energy for human consumption (electricity, fuels), compare their effects on the environment, and include overall costs and benefits.	Unit 10	Lesson 10 ii Lesson 10 iii Lesson 10 iv Lesson 10 v
E2.4B	Explain how the impact of human activities on the environment (e.g., deforestation, air pollution, coral reef destruction) can be understood through the analysis of interactions between the four Earth systems.	Unit 10	Lesson 1 i Lesson 9 iii
E2.4c	Explain ozone depletion in the stratosphere and methods to slow human activities to reduce ozone depletion.	Unit 10	Lesson 10 i
E2.4d	Describe the life cycle of a product, including the resources, production, packaging, transportation, disposal, and pollution.	Unit 10	
Standard E3	**THE SOLID EARTH**		
Statement E3.1	**Advanced Rock Cycle**		
E3.1A	Discriminate between igneous, metamorphic, and sedimentary rocks and describe the processes that change one kind of rock into another.	Unit 4	Lesson 4 ii
E3.1B	Explain the relationship between the rock cycle and plate tectonics theory in regard to the origins of igneous, sedimentary, and metamorphic rocks.	Unit 4	Lesson 4 i Lesson 4 iii Lesson 4 iv Lesson 4 v
E3.1c	Explain how the size and shape of grains in a sedimentary rock indicate the environment of formation (including climate) and deposition.	Unit 4	Lesson 4 i
E3.1d	Explain how the crystal sizes of igneous rocks indicate the rate of cooling and whether the rock is extrusive or intrusive.	Unit 4	Lesson 4 i
E3.1e	Explain how the texture (foliated, nonfoliated) of metamorphic rock can indicate whether it has experienced regional or contact metamorphism.	Unit 4	Lesson 4 i
Statement E3.2	**Interior of the Earth**		
E3.2A	Describe the interior of the Earth (in terms of crust, mantle, and inner and outer cores) and where the magnetic field of the Earth is generated.	Unit 2	
E3.2B	Explain how scientists infer that the Earth has interior layers with discernable properties using patterns of primary (*P*) and secondary (*S*) seismic wave arrivals.	Unit 2	Lesson 2 i
E3.2C	Describe the differences between oceanic and continental crust (including density, age, composition).	Unit 2	

Earth Science Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
E3.2d	Explain the uncertainties associated with models of the interior of the Earth and how these models are validated.	Unit 2	
Statement E3.3	**Plate Tectonics Theory**		
E3.3A	Explain how plate tectonics accounts for the features and processes (sea floor spreading, mid-ocean ridges, subduction zones, earthquakes and volcanoes, mountain ranges) that occur on or near the Earth's surface.	Unit 3	Lesson 3 i Lesson 3 ii
E3.3B	Explain why tectonic plates move using the concept of heat flowing through mantle convection, coupled with the cooling and sinking of aging ocean plates that result from their increased density.	Unit 1 Unit 3	
E3.3C	Describe the motion history of geologic features (e.g., plates, Hawaii) using equations relating rate, time, and distance.	Unit 3	Lesson 3 iii Lesson 3 iv Lesson 3 v
E3.3d	Distinguish plate boundaries by the pattern of depth and magnitude of earthquakes.	Unit 3	
E3.r3e	Predict the temperature distribution in the lithosphere as a function of distance from the mid-ocean ridge and how it relates to ocean depth. *(recommended)*	R	
E3.r3f	Describe how the direction and rate of movement for the North American plate has affected the local climate over the last 600 million years. *(recommended)*	R	
Statement E3.4	**Earthquakes and Volcanoes**		
E3.4A	Use the distribution of earthquakes and volcanoes to locate and determine the types of plate boundaries.	Unit 3	
E3.4B	Describe how the sizes of earthquakes and volcanoes are measured or characterized.	Unit 2 Unit 3	Lesson 2 iii Lesson 2 iv Lesson 2 v
E3.4C	Describe the effects of earthquakes and volcanic eruptions on humans.	Unit 2 Unit 3	Lesson 2 ii
E3.4d	Explain how the chemical composition of magmas relates to plate tectonics and affects the geometry, structure, and explosivity of volcanoes.	Unit 3	
E3.4e	Explain how volcanoes change the atmosphere, hydrosphere, and other Earth systems.	Unit 3	
E3.4f	Explain why fences are offset after an earthquake, using the elastic rebound theory.	Unit 2	

Earth Science Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Standard E4	**THE FLUID EARTH**		
Statement E4.1	**Hydrogeology**		
E4.1A	Compare and contrast surface water systems (lakes, rivers, streams, wetlands) and groundwater in regard to their relative sizes as Earth's freshwater reservoirs and the dynamics of water movement (inputs and outputs, residence times, sustainability).	Unit 9	Lesson 9 iii Lesson 9 iv Lesson 9 v
E4.1B	Explain the features and processes of groundwater systems and how the sustainability of North American aquifers has changed in recent history (e.g., the past 100 years) qualitatively using the concepts of recharge, residence time, inputs, and outputs.	Unit 9	
E4.1C	Explain how water quality in both groundwater and surface systems is impacted by land use decisions.	Unit 9	Lesson 9 i
Statement E4.2	**Oceans and Climate**		
E4.2A	Describe the major causes for the ocean's surface and deep water currents, including the prevailing winds, the Coriolis effect, unequal heating of the earth, changes in water temperature and salinity in high latitudes, and basin shape.	Unit 7	
E4.2B	Explain how interactions between the oceans and the atmosphere influence global and regional climate. Include the major concepts of heat transfer by ocean currents, thermohaline circulation, boundary currents, evaporation, precipitation, climatic zones, and the ocean as a major CO_2 reservoir.	Unit 7	Lesson 7 iii Lesson 7 iv Lesson 7 v
E4.2c	Explain the dynamics (including ocean-atmosphere interactions) of the El Niño-Southern Oscillation (ENSO) and its effect on continental climates.	Unit 7	
E4.2d	Identify factors affecting seawater density and salinity and describe how density affects oceanic layering and currents.	Unit 7	
E4.2e	Explain the differences between maritime and continental climates with regard to oceanic currents.	Unit 7	Lesson 7 i Lesson 7 ii
E4.2f	Explain how the Coriolis effect controls oceanic circulation.	Unit 7	
E4.r2g	Explain how El Niño affects economies (e.g., in South America). *(recommended)*	R	

Earth Science Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Statement E4.3	**Severe Weather**		
E4.3A	Describe the various conditions of formation associated with severe weather (thunderstorms, tornadoes, hurricanes, floods, waves, and drought).	Unit 6	Lesson 6 v
E4.3B	Describe the damage resulting from and the social impact of thunderstorms, tornadoes, hurricanes, and floods.	Unit 6	
E4.3C	Describe severe weather and flood safety and mitigation.	Unit 6	Lesson 6 ii
E4.3D	Describe the seasonal variations in severe weather.	Unit 6	
E4.3E	Describe conditions associated with frontal boundaries that result in severe weather (thunderstorms, tornadoes, and hurricanes).	Unit 6	Lesson 6 i Lesson 6 iii Lesson 6 iv
E4.3F	Describe how mountains, frontal wedging (including dry lines), convection, and convergence form clouds and precipitation.	Unit 6	
E4.3g	Explain the process of adiabatic cooling and adiabatic temperature changes to the formation of clouds.	Unit 6	
Standard E5	**THE EARTH IN SPACE AND TIME**		
Statement E5.1	**The Earth in Space**		
E5.1A	Describe the position and motion of our solar system in our galaxy and the overall scale, structure, and age of the universe.	Unit 11	Lesson 11 iii Lesson 11 iv Lesson 11 v
E5.1b	Describe how the Big Bang theory accounts for the formation of the universe.	Unit 11	Lesson 11 i
E5.1c	Explain how observations of the cosmic microwave background have helped determine the age of the universe.	Unit 11	
E5.1d	Differentiate between the cosmological and Doppler red shift.	Unit 11	
Statement E5.2	**The Sun**		
E5.2A	Identify patterns in solar activities (sunspot cycle, solar flares, solar wind).	Unit 12	Lesson 12 i Lesson 12 iii Lesson 12 iv Lesson 12 v
E5.2B	Relate events on the Sun to phenomena such as auroras, disruption of radio and satellite communications, and power grid disturbances.	Unit 12	Lesson 12 ii
E5.2C	Describe how nuclear fusion produces energy in the Sun.	Unit 12	

Earth Science Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
E5.2D	Describe how nuclear fusion and other processes in stars have led to the formation of all the other chemical elements.	Unit 12	
Statement E5.2x	**Stellar Evolution**		
E5.2e	Explain how the Hertzsprung-Russell (H-R) diagram can be used to deduce other parameters (distance).	Unit 12	
E5.2f	Explain how you can infer the temperature, life span, and mass of a star from its color. Use the H-R diagram to explain the life cycles of stars.	Unit 12	
E5.2g	Explain how the balance between fusion and gravity controls the evolution of a star (equilibrium).	Unit 12	
E5.2h	Compare the evolution paths of low-moderate-, and high-mass stars using the H-R diagram.	Unit 12	
Statement E5.3	**Earth History and Geologic Time**		
E5.3A	Explain how the solar system formed from a nebula of dust and gas in a spiral arm of the Milky Way Galaxy about 4.6 Ga (billion years ago).	Unit 11	
E5.3B	Describe the process of radioactive decay and explain how radioactive elements are used to date the rocks that contain them.	Unit 5	Lesson 5 ii
E5.3C	Relate major events in the history of the Earth to the geologic time scale, including formation of the Earth, formation of an oxygen atmosphere, rise of life, Cretaceous-Tertiary (K-T) and Permian extinctions, and Pleistocene ice age.	Unit 5	Lesson 5 i
E5.3D	Describe how index fossils can be used to determine time sequence.	Unit 5	Lesson 5 ii Lesson 5 iii Lesson 5 iv
Statement E5.3x	**Geologic Dating**		
E5.3e	Determine the approximate age of a sample, when given the half-life of a radioactive substance (in graph or tabular form) along with the ratio of daughter to parent substances present in the sample.	Unit 5	Lesson 5 iii
E5.3f	Explain why C-14 can be used to date a 40,000 year old tree but U-Pb cannot.	Unit 5	
E5.3g	Identify a sequence of geologic events using relative age dating principles.	Unit 5	Lesson 5 ii Lesson 5 iii Lesson 5 iv Lesson 5 v

Earth Science Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Statement E5.4	**Climate Change**		
E5.4A	Explain the natural mechanism of the greenhouse effect including comparisons of the major greenhouse gases (water vapor, carbon dioxide, methane, nitrous oxide, and ozone).	Unit 8	
E5.4B	Describe natural mechanisms that could result in significant changes in climate (e.g., major volcanic eruptions, changes in sunlight received by the earth, meteorite impacts).	Unit 8	
E5.4C	Analyze the empirical relationship between the emissions of carbon dioxide, atmospheric carbon dioxide levels and the average global temperature over the past 150 years.	Unit 8	Lesson 8 ii Lesson 8 iii Lesson 8 iv Lesson 8 v
E5.4D	Based on evidence of observable changes in recent history and climate change models, explain the consequences of warmer oceans (including the results of increased evaporation, shoreline and estuarine impacts, oceanic algae growth, and coral bleaching) and changing climatic zones (including the adaptive capacity of the biosphere).	Unit 8	
E5.4e	Based on evidence from historical climate research (e.g., fossils, varves, ice core data) and climate change models, explain how the current melting of polar ice caps can impact the climatic system .	Unit 8	
E5.4f	Describe geologic evidence that implies climates were significantly colder at times in the geologic record (e.g., geomorphology, striations, and fossils).	Unit 8	
E5.4g	Compare and contrast the heat-trapping mechanisms of the major greenhouse gases resulting from emissions (carbon dioxide, methane, nitrous oxide, fluorocarbons) as well as their abundance and heat trapping capacity.	Unit 8	
E5.r4h	Use oxygen isotope data to estimate paleotemperature. *(recommended)*	R	
E5.r4i	Explain the causes of short-term climate changes such as catastrophic volcanic eruptions and impact of solar system objects. *(recommended)*	R	
E5.r4j	Predict the global temperature increase by 2100, given data on the annual trends of CO2 concentration increase. *(recommended)*	R	

Units by Content Expectation

EARTH SCIENCE

Unit 1: Organizing Principles of Earth Science

Code	Content Expectation
E2.1	*Earth Systems Overview* The Earth is a system consisting of four major interacting components: geosphere (crust, mantle, and core), atmosphere (air), hydrosphere (water), and biosphere (the living part of Earth). Physical, chemical, and biological processes act within and among the four components on a wide range of time scales to continuously change Earth's crust, oceans, atmosphere, and living organisms. Earth elements move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of geochemical cycles.
E2.1B	Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.
E2.1C	Explain, using specific examples, how a change in one system affects other Earth systems.
E2.3	*Biogeochemical Cycles* The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Most elements can exist in several different states and chemical forms; they move within and between the geosphere, atmosphere, hydrosphere, and biosphere as part of the Earth system. The movements can be slow or rapid. Elements and compounds have significant impacts on the biosphere and have important impacts on human health.
E2.3A	Explain how carbon exists in different forms such as limestone (rock), carbon dioxide (gas), carbonic acid (water), and animals (life) within Earth systems and how those forms can be beneficial or harmful to humans.
E2.3c	Explain how the nitrogen cycle is part of the Earth system.
E2.3d	Explain how carbon moves through the Earth system (including the geosphere) and how it may benefi t (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society.

E3.3	*Plate Tectonics Theory* The Earth's crust and upper mantle make up the lithosphere, which is broken into large mobile pieces called tectonic plates. The plates move at velocities in units of centimeters per year as measured using the global positioning system (GPS). Motion histories are determined with calculations that relate rate, time, and distance of offset geologic features. Oceanic plates are created at mid-ocean ridges by magmatic activity and cooled until they sink back into the Earth at subduction zones. At some localities, plates slide by each other. Mountain belts are formed both by continental collision and as a result of subduction. The outward flow of heat from Earth's interior provides the driving energy for plate tectonics.
E3.3B	Explain why tectonic plates move using the concept of heat flowing through mantle convection, coupled with the cooling and sinking of aging ocean plates that results from their increased density.

EARTH SCIENCE

Unit 1: Organizing Principles of Earth Science

Big Idea (Core Concept):
Processes, events and features on Earth result from energy transfer and movement of matter through interconnected Earth systems.

Standard(s):
E2: Earth Systems
E3: The Solid Earth

Content Statement(s):
E2.1: Earth Systems Overview
E3.3: Plate Tectonics Theory

Content Expectations: (Content Statement Clarification)
E2.1B: Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.

Clarification: Interactions take the form of energy transfer and movement of matter.

E2.1C: Explain, using specific examples, how a change in one system affects other Earth systems.

Clarification: The biogeochemical cycles of carbon and nitrogen illustrate how systems affect each other.

E2.3A: Explain how carbon exists in different forms such as limestone (rock), carbon dioxide (gas), carbonic acid (water), and animals (life within Earth systems) and how those forms can be beneficial or harmful to humans.

Clarification: none

E2.3c: Explain how the nitrogen cycle is part of the Earth system.

Clarification: none

E2.3d: Explain how carbon moves through the Earth system (including the geosphere) and how it may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society.

Clarification: none

E3.3B: Explain why tectonic plates move using the concept of heat flowing through mantle convection, coupled with the cooling and sinking of aging ocean plates that result from their increased density.

Clarification: Heat transfer in the geosphere, from the core outward, drives plate movement. Plate tectonics is a result of the connection between processes in Earth's mantle and surface features which are in part expressions of the plates and plate boundaries.

Vocabulary:
atmosphere
biogeochemical cycles
biosphere
carbon cycle
continental plates
core
crust
Earth Systems Science
earthquakes
geosphere
hydrosphere
lithosphere
mantle
mantle convection
mid-ocean ridges
mountain belts
nitrogen cycle
oceanic plates
plate boundaries
plate movements
plate tectonics theory
subduction zones
tectonic plates
transforming matter and/or energy
upper mantle
volcanoes

Real World Context:

Earth science is an umbrella term for the scientific disciplines of geology, meteorology, climatology, hydrology, oceanography, and astronomy.

Earth systems science has given an improved, interdisciplinary perspective to researchers in fields concerned with global change, such as climate change and geologic history.

Plate tectonics is the unifying theory of geology and helps explain all features and processes in the geosphere.

Large quantities of carbon dioxide can be taken in by the Earth's plants, algae, and remain dissolved in ocean water. The carbon cycle is a biogeochemical cycle that quantifies the movement of carbon through the four major Earth systems.

Carbon dioxide is a major greenhouse gas that makes Earth warm enough to sustain life as we know it. Human industrialization has dramatically increased the percentage of carbon dioxide in the atmosphere, making the Earth warmer and altering the climate system.

Foraminifer, corals, snails, and other marine organisms take in carbon forming calcium carbonate in shells and other hard structures. Upon their death some of these structures are deposited and lithified to become limestone, a major carbon reservoir.

Acidic water running over limestone can dissolve calcium carbonate and carry it into rivers, lakes, and groundwater.

Nitrogen exists in several organic and inorganic forms throughout the Earth systems and can be depicted as one of the biogeochemical cycles known as the "Nitrogen-Cycle." It is very important for ecosystems. Human actions such as burning of trees or fossil fuels, use of nitrogen fertilizer, impact the movement and storage of nitrogen. Detrimental results include nitrogen loading in waterways and increased nitrogen based pollutants including nitrous oxide, a greenhouse gas.

At black smokers, heat energy is transferred from the interior of the Earth to the ocean. The hot water carries dissolved minerals. These minerals and heat energy are utilized by bacteria as the basis of an ecosystem which is not based on photosynthesis.

Instruments, Measurement, and Representations

Diagrams depicting the interactions of Earth's major systems
Diagrams of carbon cycle, nitrogen cycle, and water cycle
Diagrams and models of the cross section of the Earth showing layers of the
Samples of the different forms of carbon and nitrogen
Global and regional maps showing tectonic plates and plate boundaries.

Instructional Examples:

i. Inquiry
CE: E1.1A, E2.4B
Students investigate current environmental issues related to Earth science and generate research questions that would be important to pursue in their own community or region.

ii. Reflection
CE: E1.2E

Students investigate the research questions Earth scientists pursue and how they relate to career paths within the Earth sciences.

iii. Enrichment
CE: E2.3A

Students develop games which will be used by younger students to help them analyze and quantify the various ways carbon (or nitrogen) moves through the Earth systems.

iv. General
CE: E2.3A

Students carry out a series of lab explorations where they quantify, replicate or simulate a variety of conversions of carbon from one form to another (e.g., crushing shells and gluing them together like formation of limestone; pouring acid on limestone and testing the acidity or alkalinity of the liquid collected; bubble carbon dioxide through water and test the pH of the water; etc.)

v. Intervention
CE: E2.3A

Through class discussion, students build a diagram or concept map showing the various ways carbon moves the Earth system. Have students copy the diagram in their notebooks.

Units by Content Expectations

EARTH SCIENCE

Unit 2: Earthquakes & Earth's Interior

Code	Content Expectation
E2.2	*Energy in Earth Systems* Energy in Earth systems can exist in a number of forms (e.g., thermal energy as heat in the Earth, chemical energy stored as fossil fuels, mechanical energy as delivered by tides) and can be transformed from one state to another and move from one reservoir to another. Movement of matter and its component elements, through and between Earth's systems, is driven by Earth's internal (radioactive decay and gravity) and external (Sun as primary) sources of energy. Thermal energy is transferred by radiation, convection, and conduction. Fossil fuels are derived from plants and animals of the past, are nonrenewable and, therefore, are limited in availability. All sources of energy for human consumption (e.g., solar, wind, nuclear, ethanol, hydrogen, geothermal, hydroelectric) have advantages and disadvantages.
E2.2C	Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.
E3.2	*Interior of the Earth* The Earth can also be subdivided into concentric layers based on their physical characteristics: (lithosphere, asthenosphere, lower mantle, outer core, and inner core). The crust and upper mantle compose the rigid lithosphere (plates) that moves over a "softer" asthenosphere (part of the upper mantle). The magnetic field of the Earth is generated in the outer core. The interior of the Earth cannot be directly sampled and must be modeled using data from seismology.
E3.2A	Describe the interior of the Earth (in terms of crust, mantle, and inner and outer cores) and where the magnetic field of the Earth is generated.
E3.2B	Explain how scientists infer that the Earth has internal layers with discernable properties using patterns of primary (P) and secondary (S) seismic wave arrivals
E3.2C	Describe the differences between oceanic and continental crust (including density, age composition).
E3.2d	Explain the uncertainties associated with models of the interior of the Earth and how these models are validated.

E3.4	*Earthquakes and Volcanoes* Plate motions result in potentially catastrophic events (earthquakes, volcanoes, tsunamis, mass wasting) that affect humanity. The intensity of volcanic eruptions is controlled by the chemistry and properties of the magma. Earthquakes are the result of abrupt movements of the Earth. They generate energy in the form of body and surface waves.
E3.4B	Describe how the sizes of earthquakes and volcanoes are measured or characterized.
E3.4C	Describe the effects of earthquakes and volcanic eruptions on humans.
E3.4f	Explain why fences are offset after an earthquake using the elastic rebound theory.

EARTH SCIENCE

Unit 2: Earthquakes and Earth's Interior

Big Idea (Core Concept):
A model of the structure and dynamics of Earth's interior where the transfer of heat from the interior towards the surface causes slow movement of Earth's tectonic plates is based largely on recordings of seismic waves.

Standard(s):
E2: Earth Systems
E3: The Solid Earth

Content Statement(s):
E2.2: Energy in Earth Systems
E3.2: Interior of the Earth
E3.4: Earthquakes and Volcanoes

Content Expectations: (Content Statement Clarification)
E2.2C: Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.

Clarification: Convection occurs in the Earth's mantle. Several models of the geometry of convection have been constructed without a consensus in the science community. Rising heat is associated with spreading centers.

E3.2A: Describe the interior of the Earth (in terms of crust, mantle, and inner and outer cores) and where the magnetic field of the Earth is generated.

Clarification: none

E3.2B: Explain how scientists infer that the Earth has internal layers with discernable properties using patterns of primary (P) and secondary (S) seismic wave arrivals

Clarification: The travel speed of seismic waves is strongly influenced by rock density, state of matter (liquid, solid) and pressure from depth. Changing density causes seismic energy to reflect and change direction incrementally or abruptly. Mapping the travel times of P-waves allows inferences on the density and composition of layers in the Earth. Mapping of P and S wave arrival times show significant circular regions where P and/or S waves do not arrive allowing inference on size, structure and composition of Earth's core.

E3.2C: Describe the differences between oceanic and continental crust (including density, age, composition).

Clarification: In comparison to continental crust, ocean crust is on average younger, thinner, denser and compositionally more homogeneous.

E3.2d: Explain the uncertainties associated with models of the interior of the Earth and how these models are validated.

Clarification: All measures and models in science involve uncertainty. Many questions in Earth science involve qualities that cannot be directly measured. Conclusions can be supported or challenged by comparison to some separate, independent investigation. In the case of the model for Earth's interior, scientists can explore such things as the composition of meteorites, mantle rocks exposed at the surface and/or measures of gravity.

E3.4B: Describe how the sizes of earthquakes and volcanoes are measured or characterized.

Clarification: The magnitude of an earthquake is recorded using instruments that respond to wave energy that reaches the surface. Also, earthquake intensity is categorized using reports of earthquake effects into levels that can be mapped.

E3.4C: Describe the effects of earthquakes and volcanic eruptions on humans.

Clarification: Injury, death or property destruction due to earthquakes result from damage to human-made structures or the effects of earthquake induced ocean waves. Structures built on sediments are more vulnerable than those built on bedrock because earthquake shaking causes sediments to lose the internal strength necessary to provide support.

E3.4f: Explain why fences are offset after an earthquake using the elastic rebound theory.

Clarification: none

Vocabulary:
asthenosphere
body waves
concentric layers
continental crust
convection
crust
earthquakes
elastic rebound theory
gravity

inner core
intensity
internal sources of energy
lithosphere
lower mantle
magnetic field
magnitude
modeling
oceanic crust
outer core
plates
primary seismic waves
properties of waves
P-waves
radioactive decay
reflection
rigid lithosphere
secondary seismic waves
seismology
surface waves
S-waves
thermal energy
upper mantle
wave amplitude

Real World Context:

Moderate, shallow earthquakes are well characterized by the Richter scale, a logarithmic scale that measures magnitude of a seismic wave.

Larger magnitude earthquakes are better characterized by the Moment Magnitude scale that is determined from seismographs and quantifies released energy.

Modified Mercalli Scale expresses the intensity of an earthquake's effects with a scale from I to XII based on descriptions of damage. Intensity zones are mapped to show patterns of earthquake damage.

A global network of seismometers has become more dense in recent decades allowing geophysicists to model the Earth's interior with more accuracy.

Earthquake risk is quantified by considering geologic surface material, building design and material, the condition of infrastructure, and population patterns. Unconsolidated sediment is a dominant surface material in the Midwest and is vulnerable to liquefaction during seismic shaking.

Instruments, Measurement, and Representations

Seismographs and seismograms

Models and diagrams showing the movement of Earth's internal convection currents.

Cross sections of Earth showing ray paths of seismic waves and inferred layers of the Earth.

Maps of earthquake distribution and their relationship to plate boundaries.

Scales of earthquake magnitude

Scales of earthquake intensity

Instructional Examples:

i. Inquiry
CE: E1.1D, E1.1f, E3.2B

Using an average speed of P-wave (11 km/s) calculate travel time of a seismic P-wave at various locations around the globe assuming a homogeneous Earth. Tabulate and compare results to seismic data sets presented by a seismic ray-path cutaway poster from IRIS (www.iris.edu), which conveys how seismic data has been used to develop a model of the interior of the earth.

ii. Reflection
CE: E1.2f, E3.4C

In a scenario where student teams are risk mitigation experts, students design and critique mitigation plans for a city at risk of earthquake damage using maps of geologic surface materials and human infrastructure. Limited by a fixed budget, students shall propose a plan to minimize risk considering building design and materials, geologic surface material and critical urban infrastructure.

iii. Enrichment
CE: E3.4B

Using historical earthquake data available online at the USGS Earthquake Center (http://neic.usgs.gov/neis/epic/epic_rect.html) for a given region, determine the reoccurrence interval for earthquakes of various magnitude ranges. Using curve fitting techniques, project the data set to hypothesize the reoccurrence interval for earthquakes of one magnitude beyond your dataset.

iv. General
CE: E3.4B

Using historical earthquake data available online at the USGS Earthquake Center (http://neic.usgs.gov/neis/epic/epic_rect.html) for a given region, determine the reoccurrence interval for earthquakes of various magnitude ranges within the dataset available.

v. Intervention
CE: E3.4B

Using magnitude M4.0-5.0 earthquake data presented in a table that shows frequency in 5-year periods back 25 years, calculate the average number of earthquakes in a 5 year period. Analyze and describe important reoccurrence patterns recognizable in the earthquake data.

Units by Content Expectation

EARTH SCIENCE

Unit 3: Plate Tectonics and Volcanism

Code	Content Expectation
E2.1	*Earth Systems Overview* The Earth is a system consisting of four major interacting components: geosphere (crust, mantle, and core), atmosphere (air), hydrosphere (water), and biosphere (the living part of Earth). Physical, chemical, and biological processes act within and among the four components on a wide range of time scales to continuously change Earth's crust, oceans, atmosphere, and living organisms. Earth elements move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of geochemical cycles.
E2.1B	Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.
E2.1C	Explain, using specific examples, how a change in one system affects other Earth systems.
E2.2	*Energy in Earth Systems* Energy in Earth systems can exist in a number of forms (e.g., thermal energy as heat in the Earth, chemical energy stored as fossil fuels, mechanical energy as delivered by tides) and can be transformed from one state to another and move from one reservoir to another. Movement of matter and its component elements, through and between Earth's systems, is driven by Earth's internal (radioactive decay and gravity) and external (Sun as primary) sources of energy. Thermal energy is transferred by radiation, convection, and conduction. Fossil fuels are derived from plants and animals of the past, are nonrenewable and, therefore, are limited in availability. All sources of energy for human consumption (e.g., solar, wind, nuclear, ethanol, hydrogen, geothermal, hydroelectric) have advantages and disadvantages.
E2.2A	Describe the Earth's principal sources of internal and external energy (e.g., radioactive decay, gravity, solar energy).
E2.2C	Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.

E3.3	*Plate Tectonics Theory* The Earth's crust and upper mantle make up the lithosphere, which is broken into large mobile pieces called tectonic plates. The plates move at velocities in units of centimeters per year as measured using the global positioning system (GPS). Motion histories are determined with calculations that relate rate, time, and distance of offset geologic features. Oceanic plates are created at mid-ocean ridges by magmatic activity and cooled until they sink back into the Earth at subduction zones. At some localities, plates slide by each other. Mountain belts are formed both by continental collision and as a result of subduction. The outward flow of heat from Earth's interior provides the driving energy for plate tectonics.
E3.3A	Explain how plate tectonics accounts for the features and processes (sea floor spreading, mid-ocean ridges, subduction zones, earthquakes and volcanoes, mountain ranges) that occur on or near the Earth's surface.
E3.3B	Explain why tectonic plates move using the concept of heat flowing through mantle convection, coupled with the cooling and sinking of aging ocean plates that results from their increased density.
E3.3C	Describe the motion history of geologic features (e.g., plates, Hawaii) using equations relating rate, time, and distance.
E3.3d	Distinguish plate boundaries by the pattern of depth and magnitude of earthquakes.
E3.4	*Earthquakes and Volcanoes* Plate motions result in potentially catastrophic events (earthquakes, volcanoes, tsunamis, mass wasting) that affect humanity. The intensity of volcanic eruptions is controlled by the chemistry and properties of the magma. Earthquakes are the result of abrupt movements of the Earth. They generate energy in the form of body and surface waves.
E3.4A	Use the distribution of earthquakes and volcanoes to locate and determine the types of plate boundaries.
E3.4B	Describe how the sizes of earthquakes and volcanoes are measured or characterized.
E3.4C	Describe the effects of earthquakes and volcanic eruptions on humans.
E3.4d	Explain how the chemical composition of magmas relates to plate tectonics and affects the geometry, structure, and explosivity of volcanoes.
E3.4e	Explain how volcanoes change the atmosphere, hydrosphere, and other Earth systems.

EARTH SCIENCE

Unit 3: Plate Tectonics and Volcanoes

Big Idea (Core Concept):
Plate tectonics is the central organizing theory of geology and is part of the explanation of every phenomena and process observable in the Geosphere. Plate tectonics influence phenomena in the atmosphere, hydrosphere and biosphere.

Standard(s):
E2: Earth Systems
E3: The Solid Earth

Content Statement(s):
E2.1: Earth Systems Overview
E2.2: Energy in Earth Systems
E3.3: Plate Tectonics Theory

Content Expectations: (Content Statement Clarification)
E2.1B: Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.

Clarification: Compounds from the geosphere move into the atmosphere and hydrosphere through volcanic eruptions.

E2.1C: Explain, using specific examples, how a change in one system affects other Earth systems.

Clarification: Volcanism can cause a temporary global cooling with secondary effects on the atmosphere, hydrosphere and biosphere.

E2.2A: Describe the Earth's principal sources of internal and external energy (e.g., radioactive decay, gravity, solar energy).

Clarification: In the earliest stage of Earth's history, internal thermal energy was generated from gravitational force, the decay of radioactive elements and extraterrestrial impacts.

E2.2C: Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.

Clarification: Convection of heat in the Earth's mantle is thought to drive the motion of plates.

E3.3A: Explain how plate tectonics accounts for the features and processes (sea floor spreading, mid-ocean ridges, subduction zones, earthquakes and volcanoes, mountain ranges) that occur on or near the Earth's surface.

Clarification: None

E3.3B: Explain why tectonic plates move using the concept of heat flowing through mantle convection, coupled with the cooling and sinking of aging ocean plates that result from their increased density.

Clarification: The main driving force of plate motion is gravity-controlled sinking of cooler, denser oceanic lithosphere (as a limb of a convection cell) into subduction zones. The subducting ocean lithosphere pulls the rest of the plate along with it.

E3.3C: Describe the motion history of geologic features (e.g., plates, Hawaii) using equations relating rate, time, and distance.

Clarification: None

E3.3d: Distinguish plate boundaries by the pattern of depth and magnitude of earthquakes.

Clarification: None

E3.4A: Use the distribution of earthquakes and volcanoes to locate and determine the types of plate boundaries.

Clarification: Volcanoes are characterized by their size and shape and classified into three types of landforms. Their form is controlled by magma chemistry and the plate tectonic context.

E3.4B: Describe how the sizes of earthquakes and volcanoes are measured or characterized.

Clarification: None

E3.4C: Describe the effects of earthquakes and volcanic eruptions on humans.

Clarification: None

E3.4d: Explain how the chemical composition of magmas relates to plate tectonics and affects the geometry, structure, and explosivity of volcanoes.

Clarification: None

E3.4e: Explain how volcanoes change the atmosphere, hydrosphere, and other Earth systems.

Clarification: Biosphere as "other Earth systems."

Vocabulary:
aging ocean plates
atmosphere
biosphere
chemical composition
continental collision
convection
core
crust
density
driving energy
driving force
earthquakes
explosivity
geologic features
geosphere
global positioning system
hydrosphere
lithosphere
magma
magmatic activity
mantle convection
mid-ocean ridges
molten rock
mountain belts
mountain ranges
oceanic plates
plate boundaries
plate collision
plate tectonics theory
pressure
radioactive decay
sea floor spreading
subduction zones
tectonic plates
thermal energy
transform faults
upper mantle
volcanoes

Real World Context:

A cooling limb of a convection cell is associated with subducting plates. Rising heat is associated with spreading centers. Aging ocean crust cools by conduction eventually causing the lithosphere to become more dense than the underlying asthenosphere.

The plate tectonic context is a necessary consideration in the interpretation of ancient and modern geologic features and materials.

Modern plate motions are determined through the use of geodetic and satellite technology. Plate motions of the past are deduced from offsets of geologic features including landforms, rock formations and magnetic signatures recorded in rocks that can be correlated to a paleomagnetic time scale.

Composite (or strata) volcanoes develop in a general line (called a volcanic arc) parallel to a convergent plate boundary, built upon the overriding plate.

Intraplate volcanoes are developed over hotspots and produce a variety of volcanic landforms. Hotspots under oceanic lithosphere produce shield volcanoes that develop a linear chain of ocean islands if the plate has moved over the hotspots (e.g., Hawaii). Hotspots under continental lithosphere may produce a plateau of layered volcanic rocks, such as the Columbia River flood basalts which emerged as fluid, low viscosity lava. In other instances they may produce highly explosive volcanic events and related landforms (e.g., Yellowstone).

Instruments, Measurement, and Representations:

Plate tectonic maps with symbols of plate boundaries and relative motion arrows.

Global positioning system

Block diagrams and two dimensional profiles illustrate the geometry, motion and components of Earth’s lithosphere within plates and at plate boundaries.

Geologic maps depict volcanic rock formations and/or offsets in geologic features.

Profile diagrams of volcanoes depict their shape, size and internal structure.

Instructional Examples:

i. Inquiry
CE: E1.1D, E3.3A, E3.3d

Student teams are given one of four global maps: 1) earthquakes keyed for magnitude and depth, 2) active volcanoes, 3) age of the ocean floor, and 4) world topography/bathymetry. After studying the Pacific Plate, the student teams present the details of observations they have made. Then students classify plate boundaries types based on patterns in data depicted by the four global maps.

ii. Reflection
CE: E1.2i, E3.3A

Create a time line that includes call out boxes with narrations and illustrations of the discoveries and personalities that led to the Plate Tectonic Theory starting with the evidence Alfred Wegener cited in his characterization of continental drift. Analyze the timeline with an emphasis on events and perspectives that characterize the nature of science.

iii. Enrichment
CE: E3.3C

Given the ages of each of the Hawaiian Islands presented on a regional map, calculate the average speed and determine the direction of the Pacific Plate relative to the Hawaiian Hotspot over the past 5.6 million years. Gather data points for each island and plot them on a distance versus time graph. Use the graph to calculate and tabulate average velocities at one million year increments from 0 to 6 million years before present.

iv. General
CE: E3.3C

Given the ages of each of the Hawaiian Islands presented on a regional map, calculate the average speed and determine the direction of the Pacific Plate relative to the Hawaiian Hotspot over the past 5.6 million years.

v. Intervention
CE: E3.3C

Using a physical model of the Hawaiian Hotspot track simulate how far the Pacific Plate has moved in the past 6 million years. To do this, use tracing paper and a white piece of paper taped to a table. The white paper has a red 1 centimeter dot roughly in the middle, representing the Hawaiian Hot Spot. The transparent tracing paper has a map of the Hawaiian Islands printed on it. According to a data table that lists the ages of each of Hawaii's islands, move the tracing paper so that each island is over the hotspot at a specific time. Equate 10 seconds of real time to 1 million years of times starting with Kauai at 5.1 million years ago.

Units by Content Expectation

EARTH SCIENCE

Unit 4: Rock Forming Processes

Code	Content Expectation
E3.1	*Advanced Rock Cycle* Igneous, metamorphic, and sedimentary rocks are indicators of geologic and environmental conditions and processes that existed in the past. These include cooling and crystallization, weathering and erosion, sedimentation and lithification, and metamorphism. In some way, all of these processes are influenced by plate tectonics, and some are influenced by climate.
E3.1A	Discriminate between igneous, metamorphic, and sedimentary rocks and describe the processes that change one kind of rock into another.
E3.1B	Explain the relationship between the rock cycle and plate tectonics theory in regard to the origins of igneous, sedimentary, and metamorphic rocks.
E3.1c	Explain how the size and shape of grains in a sedimentary rock indicate the environment of formation (including climate) and deposition.
E3.1d	Explain how the crystal sizes of igneous rocks indicate the rate of cooling and whether the rock is extrusive or intrusive.
E3.1e	Explain how the texture (foliated, nonfoliated) of metamorphic rock can indicate whether it has experienced regional or contact metamorphism.

EARTH SCIENCE

Unit 4: Rock Forming Processes

Big Idea (Core Concept):
Understanding natural processes and Earth materials allows Earth history to be discerned.

Standard(s):
E3: The Solid Earth

Content Statement(s):
E3.1: Advanced Rock Cycle

Content Expectations: (Content Statement Clarification)
E3.1A: Discriminate between igneous, metamorphic, and sedimentary rocks and describe the processes that change one kind of rock into another.

Clarification: In addition physical characteristics, discrimination can involve an understanding of the processes and environments of rock formation. Rock forming processes can be understood in a plate tectonics context.
Exclusion: Rock types other than those listed in the prerequisites.

E3.1B: Explain the relationship between the rock cycle and plate tectonics theory in regard to the origins of igneous, sedimentary, and metamorphic rocks.

Clarification: The processes and products depicted in the rock cycle can be understood in a plate tectonic context commonly with reference to conditions and activities at convergent or divergent plate boundaries.

E3.1c: Explain how the size and shape of grains in a sedimentary rock indicate the environment of formation (including climate) and deposition.

Clarification: Grain size reflects the amount of energy in the environment that sediment transport occurred. Grain shape in part reflects the duration of sediment transport.

E3.1d: Explain how the crystal sizes of igneous rocks indicate the rate of cooling and whether the rock is extrusive or intrusive.

Clarification: None

E3.1e: Explain how the texture (foliated, non-foliated) of metamorphic rock can indicate whether it has experienced regional or contact metamorphism.

Clarification: None

Vocabulary:

contact metamorphism
cooling
crystallization
deposition
erosion
extrusive
foliation
grain shape
grain size
igneous rocks
intrusive
lithification
magma
metamorphic rocks
metamorphism
molten rock
non-foliated texture
plate tectonic context
regional metamorphism
rock cycle
rock sequence
sedimentary rocks
sedimentation
weathering

Real World Context:

Rock forming processes create large-scale forms and structures that assist in the interpretation of geologic history and the plate tectonic context.

Regions of the continental crust that expose (at the surface) deep crustal igneous and metamorphic rocks are remnants of mountain ranges and must have experienced dramatic uplift due to the compression typical of a convergent plate boundary.

The percentage of silica in igneous rocks is a influential variable that relates to the origin and history of magma in a plate tectonic context. The silica content influences the viscosity of magma, temperature of crystallization of minerals, the types of intrusive and extrusive igneous bodies and the byproducts of weathering and erosion.

Basalt is the most common surface or near surface crustal rock because it is the main product of ocean spreading centers which formed all the of the ocean crust.

An ancient volcanic arc can be inferred from deposits of andesite (fine grained, with intermediate percentage of silica) and pyroclastic rocks such as tuff and understood to be a product of a composite (or strata) volcano.

The composition and sorting of sedimentary grains provides clues to the sediment source region, transport history and environment of deposition.

Sedimentary rocks that are comprised of volcanic rock fragments indicate a volcanic source region, and if sub-rounded to angular a short travel history, such as that of an ocean trench next to a volcanic arc. Well rounded, quartz rich sandstones may represent a beach environment at a passive continental margin.

Chemically precipitated rocks that have formed due to evaporation (e.g., rock salt, rock gypsum) are possibly remnants of shallow seas in warm arid climates.

Biochemical sedimentary rocks (e.g., chert, fossiliferous limestone) originate in ocean environments when the hard remains of marine organisms collect as sediment. Great ocean depth can be inferred from chert because calcium carbonate has high solubility in colder high pressure environments, typical of the deep oceans.

Metamorphic rocks can record a history of changing pressure and/or temperature that can be associated with specific plate tectonic settings. For example, blueschist represent the high pressure low temperature environment of a subduction zone. Gneiss is produced from a number of rock types exposed to extremely high pressure and temperature that occur deep in the crust where mountain building occurs. These examples all have foliation due to high pressure. Marble and quartzite are non-foliated and may have formed from contact metamorphism caused by extreme heat provided by igneous intrusions. However, because marble and quartzite are dominated by equant minerals, regional metamorphism would not produce foliation either.

Some important rock forming processes concentrate strategic minerals in economically viable deposits.

Instruments, Measurement, and Representations

The rock cycle diagram is a generalized representation of rock forming processes and products.

Microscopes and hand lenses for observations of details.

Schematic profiles and block diagrams depict rock distributions in plate tectonic contexts.

Rock classification charts emphasize useful qualities for distinguishing rock types and some aspects of rock origins.

Regional geologic maps of rock types allow interpretations of geologic history and plate tectonic contexts.

Instructional Examples:

i. Inquiry
CE: E1.1E, E3.1B, E3.1c, E3.1d, E3.1e

Study a generalized geologic map of the Appalachian Mountains in conjunction with a summary of the geologic history. Identify specific rock formations that support the conclusions presented in the summary. Write a description of the rock characteristics that are used as evidence for elements of the presented geologic history.

ii. Reflection
CE: E1.2k, E3.1A

Describe the importance of a strategic mineral along with a description of the geologic setting that produces the most important contemporary source for the United States.

iii. Enrichment
CE: E3.1B

Create a poster of a detailed block diagram that depicts a specific volcanic arc at an ocean-continent convergent plate boundary. Determine the distribution of specific rock formations using scientific journal articles and geologic maps. Adhere small hand samples of various rocks to the locations of their formation. Attach annotation cards that identify the rock samples and describe their genesis.

iv. General
CE: E3.1B

Create a poster of a detailed block diagram depicting a generalized volcanic arc at an ocean-continent convergent plate boundary. Attach small hand samples of various rocks to the locations of their formation. Attach annotation cards that identify the rock samples and describe their genesis.

v. Intervention
CE: E3.1B

Given a poster of a detailed block diagram that depicts a generalized volcanic arc at an ocean-continent convergent plate boundary, adhere small hand samples of various rocks to the locations of their formation. Attach annotation cards that identify the rock samples and describe their genesis.

Units by Content Expectation

EARTH SCIENCE

Unit 5: Discerning Earth History

Code	Content Expectation
E5.3	*Earth History and Geologic Time* The solar system formed from a nebular cloud of dust and gas 4.6 Ga (billion years ago). The Earth has changed through time and has been affected by both catastrophic (e.g., earthquakes, meteorite impacts, volcanoes) and gradual geologic events (e.g., plate movements, mountain building) as well as the effects of biological evolution (formation of an oxygen atmosphere). Geologic time can be determined through both relative and absolute dating.
E5.3B	Explain the process of radioactive decay and explain how radioactive elements are used to date the rocks that contain them.
E5.3C	Relate major events in the history of the Earth to the geologic time scale, including formation of the Earth, formation of an oxygen atmosphere, rise of life, Cretaceous-Tertiary (K-T) and Permian extinctions, and Pleistocene ice age.
E5.3D	Describe how index fossils can be used to determine time sequence.
E5.3x	*Geologic Dating* Early methods of determining geologic time, such as the use of index fossils and stratigraphic principles, allowed for the relative dating of geological events. However, absolute dating was impossible until the discovery that certain radioactive isotopes in rocks have known decay rates, making it possible to determine how many years ago a given mineral or rock formed. Different kinds of radiometric dating techniques exist. Technique selection depends on the composition of the material to be dated, the age of the material, and the type of geologic event that affected the material.
E5.3e	Determine the approximate age of a sample, when given the half-life of a radioactive substance (in graph or tabular form) along with the ratio of daughter to parent substances present in the sample.
E5.3f	Explain why C-14 can be used to date a 40,000 year old tree but U-Pb cannot.
E5.3g	Identify a sequence of geologic events using relative-age dating principles.

EARTH SCIENCE

Unit 5: Discerning Earth History

Big Idea (Core Concept):
The application of age dating techniques provides evidence for an ancient Earth and allows for the interpretation of Earth history which has been the basis of the design and refinement of the geologic time scale.

Standard(s):
E5: Earth in Space and Time

Content Statement(s):
E5.3:   Earth History and Geologic Time
E5.3x: Geologic Dating

Content Expectations: (Content Statement Clarification)
E5.3B: Describe the process of radioactive decay and explain how radioactive elements are used to date the rocks that contain them.

Clarification: None

E5.3C: Relate major events in the history of the Earth to the geologic time scale, including formation of the Earth, formation of an oxygen atmosphere, rise of life, Cretaceous-Tertiary (K-T) and Permian extinctions, and Pleistocene ice age.

Clarification: While the immensity of geologic time is presented on the geologic time scale, analogies to comprehendible dimensions are necessary in order to understand durations of time between significant events and geologic rates of change.

E5.3D: Describe how index fossils can be used to determine time sequence.

Clarification: none

E5.3e: Determine the approximate age of a sample, when given the half-life of a radioactive substance (in graph or tabular form) along with the ratio of daughter to parent substances present in the sample.

Clarification: none

E5.3f: Explain why C-14 can be used to date a 40,000 year old tree but U-Pb cannot.

Clarification: none

E5.3g: Identify a sequence of geologic events using relative-age dating principles.

Clarification: The law of superposition, the principle of original horizontality, the principle of crosscutting relationships and the implications of unconformities allows geologists to discern sequences of geologic events based on the physical relationship of geologic features.

Exclusions: The principle of inclusions
Specific types of unconformities

Vocabulary:

absolute age dating
C-14
Cretaceous-Tertiary (K-T)
cross cutting relationships
decay rates
evolution of life
geologic dating
geologic events
geologic time
geologic time scale
half-life
index fossils
law of superposition
Permian extinctions
physical relationship of geologic features
Pleistocene ice age
principle of original horizontality
radioactive decay
radioactive elements
radioactive isotopes
radioactive substance
radiometric dating
ratio of daughter to parent substance
relative age dating
unconformities
U-Pb

Real World Context:

Determining sequences of events in geologic time couples what is known about index fossils with insights on rock origin, rock layers and the evolution of life.

A relative geologic time scale was constructed in the 18th and 19th century using index fossils in conjunction with relative age dating principles such as the law of superposition, the principle of original horizontality, crosscutting relationships, inclusions and unconformities.

Uniformitarianism is the fundamental principle of geology that relates to the interpretation of Earth History. It says that geologic processes occurring today are generally the same as those that shaped Earth in the past, and can be used to interpret Earth history. A short hand phrase is "the present is the key to the past."

Early scientific research on the nature and behavior of the atom led to an understanding of how radiometric decay could be used for age dating of geologic materials. Radiometric dating techniques put absolute ages on geologic and paleontologic events some of which are the basis of divisions in the geologic time scale.

The techniques of radioactive dating are valid and understandable. Misrepresentation of the processes and level of validity has occurred in the non-scientific publications.

Instruments, Measurement, and Representations

Geologic time scale
Diagrams that show time ranges of key index fossils
Diagrams that show composite geologic sections used for the correlation of rock units
Profiles of geologic sections that show spatial relationships of geologic features for relative age dating
Table of half life values for radioactive elements
Measures of stable daughter product from parent isotope
Graphs of radioactive decay curves for specific elements to relate percents of remaining parent isotopes to their half life value.

Instructional Examples:

i. Inquiry
CE: E1.1i, E5.3C

Compare a current geologic time scale to one published several decades ago. Note the differences and similarities. Research the discoveries that required notable changes in the geologic time scale such as the age of the beginnings of the Cambrian or Cenozoic Periods.

ii. Reflection
CE: E1.2i, E5.3B, E5.3D, E5.3g

Create a time line that includes call out boxes with narrations and illustrations of the discoveries from the 18th century on that developed the modern geologic time scale. Analyze the timeline with an emphasis on events and perspectives that characterize the nature of science.

iii. Enrichment
CE: E5.3D, E5.3e, E5.3g

Using a geologic cross section, discern an age bracketed sequence of geologic events that requires the application of relative age dating principles in conjunction with time brackets provided from index fossils and parent-daughter isotope ratios of a specific radioactive element.

iv. General
CE: E5.3D, E5.3g

Using a geologic cross section, discern an age bracketed sequence of geologic events that requires the application of relative age dating principles in conjunction with time brackets provided from index fossils.

v. Intervention
CE: E5.3g

Using a geologic cross section, list a sequence of geologic events that requires the application of relative age dating principles.

Units by Content Expectation

EARTH SCIENCE

Unit 6: Severe Weather

Code	Content Expectation
E2.2	*Energy in Earth Systems* Energy in Earth systems can exist in a number of forms (e.g., thermal energy as heat in the Earth, chemical energy stored as fossil fuels, mechanical energy as delivered by tides) and can be transformed from one state to another and move from one reservoir to another. Movement of matter and its component elements, through and between Earth's systems, is driven by Earth's internal (radioactive decay and gravity) and external (Sun as primary) sources of energy. Thermal energy is transferred by radiation, convection, and conduction. Fossil fuels are derived from plants and animals of the past, are nonrenewable and, therefore, are limited in availability. All sources of energy for human consumption (e.g., solar, wind, nuclear, ethanol, hydrogen, geothermal, hydroelectric) have advantages and disadvantages.
E2.2A	Describe the Earth's principal sources of internal and external energy (e.g., radioactive decay, gravity, solar energy).
E2.2C	Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.
E2.2D	Identify the main sources of energy to the climate system.
E4.3	*Severe Weather* Tornadoes, hurricanes, blizzards, and thunderstorms are severe weather phenomena that impact society and ecosystems. Hazards include downbursts (wind shear), strong winds, hail, lightning, heavy rain, and flooding. The movement of air in the atmosphere is due to differences in air density resulting from variations in temperature. Many weather conditions can be explained by fronts that occur when air masses meet.
E4.3A	Describe the various conditions of formation associated with severe weather (thunderstorms, hurricanes, floods, waves, and drought).
E4.3B	Describe the damage resulting from and the social impact of thunderstorms, tornadoes, hurricanes, and floods.
E4.3C	Describe severe weather and flood safety and mitigation.
E4.3D	Describe the seasonal variations in severe weather.
E4.3E	Describe conditions associated with frontal boundaries that result in severe weather (thunderstorms, tornadoes, and hurricanes).
E4.3F	Describe how mountains, frontal wedging (including dry lines), convection, and convergence form clouds and precipitation.
E4.3g	Explain the process of adiabatic cooling and adiabatic temperature changes to the formation of clouds.

EARTH SCIENCE

Unit 6: Severe Weather

<u>Big Idea</u> (Core Concept):
Protecting the human interests of health, safety and resource management depends upon an understanding of natural hazards and human impact on Earth systems.

<u>Standard(s)</u>:
E2: Earth Systems
E4: The Fluid Earth

<u>Content Statement(s):</u>
E2.2: Energy in Earth Systems
E4.3: Severe Weather

<u>Content Expectations</u>: (Content Statement Clarification)
E2.2A: Describe the Earth's principal sources of internal and external energy (e.g., radioactive decay, gravity, solar energy).

Clarification: Radiation from the sun heats the Earth's surface. The surface in turn heats the atmosphere creating temperature differences in water, land, and the atmosphere which drive local, regional, and global patterns of atmospheric circulation.

E2.2C: Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.

Clarification: Radiation from the Sun heats the land and water of Earth which in turn heats the atmosphere. Thermal energy produces movement of matter (convection) observed as wind.

E2.2D: Identify the main sources of energy to the climate system.

Clarification: Radiation from the Sun creates temperature differences in water, land, and the atmosphere, which drive local, regional, and global patterns of atmospheric circulation.

E4.3A: Describe the various conditions of formation associated with severe weather (thunderstorms, tornadoes, hurricanes, floods, waves, and drought).

Clarification: None

E4.3B: Describe the damage resulting from and the social impact of thunderstorms, tornadoes, hurricanes, and floods.

Clarification: none

E4.3C: Describe severe weather and flood safety and mitigation.

Clarification: Loss of property, personal injury, and loss of life can be reduced through the application of forecasting technology and informed decisions on land use and individual behavior.

E4.3D: Describe the seasonal variations in severe weather.

Clarification: none

E4.3E: Describe conditions associated with frontal boundaries that result in severe weather (thunderstorms, tornadoes, and hurricanes).

Clarification: none

E4.3F: Describe how mountains, frontal wedging (including dry lines), convection, and convergence form clouds and precipitation.

Clarification: none

E4.3g: Explain the process of adiabatic cooling and adiabatic temperature changes to the formation of clouds.

Clarification: none

Vocabulary:
adiabatic cooling
advection
air density
air masses
blizzards
clouds
conduction
convection
convergence
downbursts
drought
dry lines
external energy sources
flooding
frontal boundaries
frontal wedging
fronts
hail
heavy rain
hurricanes
lightning
mitigation
precipitation

radiation
seasonal variations
severe weather
thermal energy
thunderstorms
tornadoes
ultraviolet radiation
waves
wind shear

Real World Context:
Mid-latitude cyclones form between 30° and 60° North Latitude. Because of the location of the United States mid-latitude cyclones have a tremendous impact on our weather.

Hurricane risk in the United States is both seasonal and regional.

Where and when hurricanes form is due to the temperature of ocean water. What direction they move is mostly a function of the direction of prevailing winds and the Coriolis Effect.

Much of the energy that empowers hurricanes comes from the latent heat as water evaporates from the ocean and later condenses into rain.

The United States Gulf Coast is among the world's most at-risk regions in terms of human mortality and economic loss due to hurricanes.

Improved ability to predict severe weather has led to reduced risk of injury and death.

Some lifting mechanisms include frontal boundaries such as cold fronts or warm fronts, upper level disturbances, orographic lifting (upslope flow associated with higher elevations), low level warm air or moisture advection (the transport of warmer temperature or higher amounts of moisture by the wind), and low pressure systems.

Tornado formation is possible when significant directional wind shear exists in the atmosphere ahead of a cold front in the presence of a strong upper level jet stream. Thunderstorms and tornadoes can develop anytime during the year in North America, however there is some times that are more conducive to their formation.

Storm prediction uses measurements of air pressure, wind speed, wind direction, temperature, cloudiness and precipitation.
Exclusions: Details of wind speeds, storm surge, associated with Saffir-Simpson and Fujita scales

Instruments, Measurement, and Representations

Meteorological instruments such as barometers, psychrometers, thermometer, rain gauge, anemometer, wind vane used to measure weather variables

Weather maps for interpretation and forecasting showing pressure gradients, wind direction, temperature, precipitation

Graphs showing meteorological variables such as temperature versus elevation, pressure versus time

Topographic maps that show flood plains

Instructional Examples:

i. Inquiry
CE: E1.1D, E4.3E

Collect weather data such as temperature, relative humidity and wind speed. Plot the data over time and correlate to observations of precipitation and cloud cover patterns that occurs.

ii. Reflection
CE: E1.2C, E4.3C

Compare the weather forecasts produced by a variety of sources (e.g., NOAA, University of Michigan's Weather Underground, network television, regional newspapers). Compare the level of detail the organizations provide and the accuracy of their prediction.

iii. Enrichment
CE: E4.3E

Download a series of infrared satellite images showing a week of stormy weather in North America. Locate and identify frontal boundaries. Assemble the images into a written report with a narrative that describes the conditions that formed the storm and governed its travel.

iv. General
CE: E4.3E

Using a series of weather maps, that show the development and movement of a cold front in the central United States, assemble the images into a written report with a narrative description that describes the conditions that formed the storm and governed its travel.

v. Intervention
CE: E4.3A

Using a series of weather maps and a list of concepts, produce a narrative that describes the conditions that formed the storm and governed its travel.

Units by Content Expectation

EARTH SCIENCE

Unit 7: Oceans and Climate

Code	Content Expectation
E2.1	*Earth Systems Overview* The Earth is a system consisting of four major interacting components: geosphere (crust, mantle, and core), atmosphere (air), hydrosphere (water), and biosphere (the living part of Earth). Physical, chemical, and biological processes act within and among the four components on a wide range of time scales to continuously change Earth's crust, oceans, atmosphere, and living organisms. Earth elements move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of geochemical cycles.
E2.1B	Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.
E2.1C	Explain, using specific examples, how a change in one system affects other Earth systems.
E2.2	*Energy in Earth Systems* Energy in Earth systems can exist in a number of forms (e.g., thermal energy as heat in the Earth, chemical energy stored as fossil fuels, mechanical energy as delivered by tides) and can be transformed from one state to another and move from one reservoir to another. Movement of matter and its component elements, through and between Earth's systems, is driven by Earth's internal (radioactive decay and gravity) and external (Sun as primary) sources of energy. Thermal energy is transferred by radiation, convection, and conduction. Fossil fuels are derived from plants and animals of the past, are nonrenewable and, therefore, are limited in availability. All sources of energy for human consumption (e.g., solar, wind, nuclear, ethanol, hydrogen, geothermal, hydroelectric) have advantages and disadvantages.
E2.2C	Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.
E2.2e	Explain how energy changes form through Earth systems.

E4.2	*Oceans and Climate* Energy from the Sun and the rotation of the Earth control global atmospheric circulation. Oceans redistribute matter and energy around the Earth through currents, waves, and interaction with other Earth systems. Ocean currents are controlled by prevailing winds, changes in water density, ocean topography, and the shape and location of landmasses. Oceans and large lakes (e.g., Great Lakes) have a major effect on climate and weather because they are a source of moisture and a large reservoir of heat. Interactions between oceanic circulation and the atmosphere can affect regional climates throughout the world.
E4.2A	Describe the major causes for the ocean's surface and deep water currents, including the prevailing winds, the Coriolis effect, unequal heating of the Earth, changes in water temperature and salinity in high latitudes, and basin shape.
E4.2B	Explain how the interactions between the oceans and the atmosphere influence global and regional climate. Include the major concepts of heat transfer by ocean currents, thermohaline circulation, boundary currents, evaporation, precipitation, climatic zones, and the ocean as a major CO_2 reservoir.
E4.2c	Explain the dynamics (including ocean-atmosphere interactions) of the El Nino-Southern Oscillation (ENSO) and its effect on continental climates.
E4.2d	Identify factors affecting seawater density and salinity and describe how density affects oceanic layering and currents.
E4.2e	Explain the differences between maritime and continental climates with regard to oceanic currents.
E4.2f	Explain how the Coriolis effect controls oceanic circulation.

EARTH SCIENCE

Unit 7: Oceans and Climate

Big Idea (Core Concept):
Local, regional, and global climates are patterns of atmospheric circulation driven by temperature differences in water, land and the atmosphere which involves the exchange of matter and energy between the ocean and atmosphere.

Standard(s):
E2: Earth Systems
E4: Fluid Earth

Content Statement(s):
E2.1: Earth Systems Overview
E2.2: Energy in Earth Systems
E4.2: Oceans and Climate

Content Expectations: (Content Statement Clarification)
E2.1B: Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.

Clarification: The oceans affect atmospheric temperature and humidity, while atmospheric winds drive and direct ocean surface currents.

E2.1C: Explain, using specific examples, how a change in one system affects other Earth systems.

Clarification: The oceans affect atmospheric temperature and humidity, while atmospheric winds drive and direct ocean surface currents. Heat in the atmosphere and ocean is in part absorbed and releases due to the evaporation and condensation of water.

E2.2C: Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.

Clarification: Heat energy is transferred between the ocean and the atmosphere by conduction and within the atmosphere by convection.

E2.2e: Explain how energy changes form through Earth system

Clarification: Radiation from the Sun heats the land and water of Earth which in turn heats the atmosphere. Thermal energy produces movement of matter (convection) observed in wind and ocean currents. Thermal energy also moves between the ocean and the atmosphere when water evaporates and condenses.

E4.2A: Describe the major causes for the ocean's surface and deep water currents, including the prevailing winds, the Coriolis effect, unequal heating of the Earth, changes in water temperature and salinity in high latitudes, and basin shape.

Clarification: none

E4.2B: Explain how the interactions between the oceans and the atmosphere influence global and regional climate. Include the major concepts of heat transfer by ocean currents, thermohaline circulation, boundary currents, evaporation, precipitation, climate zones, and the ocean as a major carbon dioxide reservoir.

Clarification: none

E4.2c: Explain the dynamics (including ocean- atmosphere interactions) of the El Nino Southern Oscillation (ENSO) and its effect on continental climate.

Clarification: none

E4.2d: Identify factors affecting seawater density and salinity and describe how density affects oceanic layering and currents.

Clarification: Seawater density is affected by freezing or melting of water, evaporation, precipitation and runoff.

E4.2e: Explain the differences between maritime and continental climates with regard to oceanic currents.

Clarification: Variability in climate is influenced by the temperature of ocean currents and direction of prevailing winds.

E4.2f: Explain how the Coriolis Effect controls oceanic circulation.

Clarification: none

Vocabulary:
atmosphere
basin shape
boundary currents
carbon dioxide reservoir
climatic zones
conduction
continental climates
convection
Coriolis effect
deep ocean currents
El Nino-Southern Oscillation (ENSO)

evaporation
global atmospheric circulation
heat reservoir (oceans, large lakes)
heat transfer of ocean currents
interactions of Earth's systems
maritime climates
ocean-atmospheric interactions
oceanic layering
ocean currents
precipitation
prevailing winds
water density
radiation
regional climates
salinity
seawater density
thermal energy
thermohaline circulation
unequal heating

Real World Context:

Warm ocean water heats air above it to produce strong convection currents and high annual rain fall.

The Ekman Spiral describes how the Coriolis Effect causes ocean currents to spiral in one direction with greater depth.

Ocean gyres result from the interaction of wind driven surface currents, Coriolis Effect, and the location of continents.

The warm Gulf Stream current causes Great Britain and northwestern Europe to be much warmer than would be predicted based on their latitude. The Labrador Current in a similar way cools the east coast of Canada.

Distinct layers in the Atlantic Ocean can be identified as to where they originated (e.g., North Atlantic, Mediterranian Sea, etc.). Their unique characteristics (and the order of their position in the water column) is due to their temperatures and salt concentrations.

El Nino events increase the frequency of drought and fires in northern Australia and Indonesia, and flooding in Ecuador and Peru. Our increased ability to predict El Nino events allow farmers to change what crops they plant for the upcoming season.

Argo floats are used to measure temperature, salinity and currents in the ocean at depth which allows the construction of vertical profiles of these variables.

Instruments, Measurements, and Representations:
Graphs that characterizing the climate of a region by plotting average monthly temperature and precipitation.
Ocean maps depict characteristics of ocean surface water and the variables of the atmosphere such as temperature and wind direction.
Vertical profiles depict variations by depth of ocean temperature, salinity and currents.

Instructional Examples:
i. Inquiry
CE: E1.1D, E4.2e

Using a global elevation map determine the most appropriate pair of cities to compare the effects of latitude on average monthly temperature. The most appropriate pair would minimize the effect of other climatic variables. Do this for other climatic variables such as temperature versus elevation, lake effect snow, rain shadow, proximity to marine influence.

ii. Reflection
CE: E1.2k, E4.2e

Investigate the social and economic impact of El Nino on societies in the equatorial Pacific region. Evaluate the mitigating actions occurring with increasing El Nino prediction capabilities.

iii. Enrichment
CE: E4.2B

Gather and map data from NOAA data buoys and/or floating instrument packages (available on the Internet) along a variety of coastlines. From the data, determine likely climate conditions along those coasts.

iv. General
CE: E4.2B

Compare maps of ocean surface temperature data near the coasts of the Carolinas and California. Use the comparisons to generalize about the local climate experienced by coastal communities.

v. Intervention
CE: E4.2B

Using newsreels or images of beach goers in a variety of coastal regions taken in the same season, compare the clothing and activities (e.g., swimming) of the people. Associate the movies and images to various coastal regions with the aid of sea surface temperature and current maps.

Units by Content Expectation

EARTH SCIENCE

Unit 8: Climate Change

Code	Content Expectation
E2.1	*Earth Systems Overview* The Earth is a system consisting of four major interacting components: geosphere (crust, mantle, and core), atmosphere (air), hydrosphere (water), and biosphere (the living part of Earth). Physical, chemical, and biological processes act within and among the four components on a wide range of time scales to continuously change Earth's crust, oceans, atmosphere, and living organisms. Earth elements move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of geochemical cycles.
E2.1A	Explain why the Earth is essentially a closed system in terms of matter.
E2.1B	Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.
E2.1C	Explain, using specific examples, how a change in one system affects other Earth systems.
E2.2	*Energy in Earth Systems* Energy in Earth systems can exist in a number of forms (e.g., thermal energy as heat in the Earth, chemical energy stored as fossil fuels, mechanical energy as delivered by tides) and can be transformed from one state to another and move from one reservoir to another. Movement of matter and its component elements, through and between Earth's systems, is driven by Earth's internal (radioactive decay and gravity) and external (Sun as primary) sources of energy. Thermal energy is transferred by radiation, convection, and conduction. Fossil fuels are derived from plants and animals of the past, are nonrenewable and, therefore, are limited in availability. All sources of energy for human consumption (e.g., solar, wind, nuclear, ethanol, hydrogen, geothermal, hydroelectric) have advantages and disadvantages.
E2.2e	Explain how energy changes form through Earth systems.
E2.2f	Explain how elements exist in different compounds and states as they move from one reservoir to another.
E2.3	*Biogeochemical Cycles* The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Most elements can exist in several different states and chemical forms; they move within and between the geosphere, atmosphere, hydrosphere, and biosphere as part of the Earth system. The movements can be slow or rapid. Elements and compounds have significant impacts on the biosphere and have important impacts on human health.

E2.3A	Explain how carbon exists in different forms such as limestone (rock), carbon dioxide (gas), carbonic acid (water), and animals (life within Earth systems and how those forms can be beneficial or harmful to humans.
E2.3d	Explain how carbon moves through the Earth system (including the geosphere) and how it may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society.
E5.4	*Climate Change* Atmospheric gases trap solar energy that has been reradiated from the Earth's surface (the greenhouse effect). The Earth's climate has changed both gradually and catastrophically over geological and historical time frames due to complex interactions between many natural variables and events. The concentration of greenhouse gases (especially carbon dioxide) has increased due to human industrialization which has contributed to a rise in average global atmospheric temperatures and changes in the biosphere, atmosphere, and hydrosphere. Climates of the past are researched, usually using indirect indicators, to better understand and predict climate change.
E5.4A	Explain the natural mechanism of the greenhouse effect including comparisons of the major greenhouse gases (water vapor, carbon dioxide, methane, nitrous oxide, and ozone).
E5.4B	Describe natural mechanisms that could result in significant changes in climate (e.g., major volcanic eruptions, changes in sunlight received by the Earth, meteorite impacts).
E5.4C	Analyze the empirical relationship between the emission of carbon dioxide, atmospheric carbon dioxide levels and the average global temperature over the past 150 years.
E5.4D	Based on evidence of observable changes in recent history and climate change models, explain the consequences of warmer oceans (including the results of increased evaporation, shoreline and estuarine impacts, oceanic algae growth, and coral bleaching) and changing climatic zones (including the adaptive capacity of the biosphere).
E5.4e	Based on evidence from historical climate research (e.g., fossils, varves, ice core data) and climate change models, explain how the current melting of polar ice caps can impact the climate system.
E5.4f	Describe geological evidence that implies climates were significantly colder at times in the geologic record (e.g., geomorphology, striations, and fossils).
E5.4g	Compare and contrast the heat trapping mechanisms of the major greenhouse gases resulting from emissions (carbon dioxide, methane, nitrous oxide, fluorocarbons) as well as their abundance and heat trapping capacity.

EARTH SCIENCE

Unit 8: Climate Change

<u>Big Idea</u> (Core Concept):
Predicting and mitigating the potential impact of global climate change requires an understanding of the mechanisms of Earth's climate, involving studies of past climates, measurements of current interactions of Earth's systems and the construction of climate change models.

<u>Standard(s):</u>
E2: Earth Systems
E5: Earth in Space and Time

<u>Content Statement(s):</u>
E2.1: Earth Systems Overview
E2.2: Energy in Earth Systems
E2.3: Biogeochemical Cycles
E5.4: Climate Change

<u>Content Expectations</u>: (Content Statement Clarification)
E2.1A: Explain why the Earth is essentially a closed system in terms of matter.

Clarification: The abundance of elements that make up greenhouse gases are essentially constant in the Earth system, but move between the four major systems.

E2.1B: Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.

Clarification: The systems interact through exchanges and transformation of matter and energy such as the storage and release of carbon in different environments.

E2.1C: Explain, using specific examples, how a change in one system affects other Earth systems.

Clarification: There are countless examples of how a change in one system impacts others, including the specifics of how changes in the biosphere effect the amount of carbon dioxide available to operate as a greenhouse gas.

E2.2e: Explain how energy changes form through Earth systems.

Clarification: none

E2.2f: Explain how elements exist in different compounds and states as they move from one reservoir to another.

Clarification: Reservoirs are the settings where the elements exists, such as the components of the carbon or nitrogen cycle.

E2.3A: Explain how carbon exists in different forms such as limestone (rock), carbon dioxide (gas), carbonic acid (water), and animals (life) within Earth systems and how those forms can be beneficial or harmful to humans.

Clarification: none

E2.3d: Explain how carbon moves through the Earth system (including the geosphere) and how it may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society.

Clarification: none

E5.4A: Explain the natural mechanism of the greenhouse effect including comparisons of the major greenhouse gases (water vapor, carbon dioxide, methane, nitrous oxide, and ozone).

Clarification: none

E5.4B: Describe natural mechanisms that could result in significant changes in climate (e.g., major volcanic eruptions, changes in sunlight received by the Earth, and meteorite impacts).

Clarification: none

E5.4C: Analyze the empirical relationship between the emissions of carbon dioxide, atmospheric carbon dioxide levels, and the average global temperature over the past 150 years.

Clarification: none

E5.4D: Based on evidence of observable changes in recent history and climate change models, explain the consequences of warmer oceans (including the results of increased evaporation, shoreline and estuarine impacts, oceanic algae growth, and coral bleaching) and changing climatic zones (including the adaptive capacity of the biosphere).

Clarification: none

E5.4e: Based on evidence from historical climate research (e.g., fossils, varves, ice core data) and climate change models, explain how the current melting of polar ice caps can impact the climate system.

Clarification: none

E5.4f: Describe geologic evidence that implies climates were significantly colder at times in the geologic record (e.g., geomorphology, striations, and fossils).

Clarification: none

E5.4g: Compare and contrast the heat trapping mechanisms of the major greenhouse gases resulting from emissions (carbon dioxide, methane, nitrous oxide, fluorocarbons) as well as their abundance and heat trapping capacity.

Clarification: none

Vocabulary:
adaptive capacity
atmosphere
atmospheric change
biogeochemical cycles
biosphere
carbon
carbon cycle
carbon dioxide
climatic zones
climate change
climate change models
climate system
conduction
convection
coral bleaching
emissions
estuarine impacts
evaporation
external energy sources
fossil fuels
fossils
geologic record
geomorphology
greenhouse effect
greenhouse gases
human industrialization
hydrosphere
ice core
limestone
methane
natural mechanisms
nitrous oxide
organic matter

ozone
polar ice caps
radiation
shoreline impacts
striations
thermal energy
trapping mechanisms
varves
volcanic eruptions
water vapor

Real World Context:

The Intergovernmental Panel on Climate Change (IPCC) assesses scientific, technical and socio-economic information related to climate change and produces comprehensive reports on the potential impacts and options for adaptation and mitigation.

The endeavor to predict the consequences of global warming depends greatly on the Earth system science perspective. Researchers interpret observations in light of the connections of systems and subsystems.

Burning of fossil fuels releases carbon once stored in ancient biomass. This carbon can exist in several main forms and reside in different reservoirs of the Earth system. Releases of carbon dioxide into the atmosphere promotes greater plant growth, moving carbon from the atmosphere into plants. More carbon dioxide in the atmosphere also results in more of it dissolving in water of the oceans, lakes, and rain.

The burning of biomass both releases more carbon dioxide into the air and reduces the biosphere's capacity to remove carbon dioxide through photosynthesis.

The current warming trend is resulting in the melting of glacial ice. Other possible effects include the melting of permafrost (releasing methane) and also warming oceans which melts methane hydrates of the ocean floor.

Melting of glacial ice effects Earth systems in many ways. The effects of sea level rise are most profound when ice is land based. Increasing water density drives the thermohaline current (initiating the North Atlantic Deep Water) and plays a major role distributing Earth's heat. Increased fresh water in the North Atlantic Ocean due to melting ice decreases sea water salinity and therefore water density. Resulting changes in global heat distribution would impact climate on land regionally, a hypothesis supported by studies of ancient climates. The melting of ice reduces Earth's average albedo (the reflectivity of Earth surface materials) and therefore increases the amount of energy absorbed by the Earth.

Volcanic eruptions can release more greenhouse gases (carbon dioxide and water vapor) into the air. It also releases sulfur dioxide which combines with rain to form acid rain, which increases the weathering of limestone and puts more carbon dioxide from the limestone into the air.

Aerosols in the upper atmosphere that form by the interaction of the sulfur dioxide and water act to cause a temporary cooling of global temperatures when there is a major eruption

The ratio of oxygen 16 to oxygen 18 in the calcium carbonate of fossils varies in accordance with water temperature and is therefore used to research past climates.

Multiple lines of evidence (including foram fossils, dust deposits in ocean sediments, pollen deposits, tree ring measurements, and ice core testing) all lead to very similar conclusions about the historical patterns of temperature changes in the Earth system. Data derived from ice cores strongly suggests a relationship between atmospheric carbon dioxide levels and temperature.

Instruments, Measurement, and Representations:

Graphs of atmospheric carbon dioxide over time
Graphs of inferred atmospheric temperature and carbon dioxide levels derived from studies of ice cores
Diagrams of energy flow through the Earth system
Diagrams of the carbon cycle
Satellite images and photographs of glaciers at different times, documenting melting of glacial ice.

Instructional Examples:

i. Inquiry
CE: E1.1B, E2.2e

Students design a method for determining Earth's average temperature. Their plan will discuss the challenges and limitations of their method and consider how this is done by researchers.

ii. Reflection
CE: E1.2C, E5.4C

Students collect a variety of statements made about the connection between human carbon dioxide emission, the level of carbon dioxide in the atmosphere, and the average global temperature. They will identify the evidence sited for each statement, evaluate the validity and logic of the supporting arguments, and determine to what degree the statements are consistent with the standards of scientific empiricism.

iii. Enrichment
CE:E5.4C

Present students with graphs for the last 150 years which show (a) estimated carbon dioxide emissions from humans, (b) measured changes in the carbon dioxide levels in Hawaii and elsewhere, and (c) estimates of the average global temperature. Have them also obtain information about alternative ideas about what currently or historically causes changes either in carbon dioxide levels in the atmosphere or Earth's temperature (volcanic eruptions, changes in the tilt of the Earth, or wobble in Earth's orbit). Determine whether the changes are better explained by natural or human induced changes in carbon dioxide levels.

iv. General
CE: E5.4C

Present students with graphs for the last 150 years which show (a) estimated carbon dioxide emissions from humans and other sources, (b) measured changes in the carbon dioxide levels, and (c) estimates of the average global temperature. Have students segment each graph into sections suggested by changes in the general slope of the graph. Determine whether the changes are better explained by natural or human induced changes in carbon dioxide levels.

v. Intervention
CE: E5.4C

Present students with three graphs for the last 150 years which show (a) estimated carbon dioxide emissions from humans, (b) measured changes in the carbon dioxide levels in Hawaii, and (c) estimates of the average global temperature. Have them decide if the trends in each graph seem to be the same or different.

Units by Content Expectation

EARTH SCIENCE

Unit 9: Hydrogeology

Code	Content Expectation
E2.1	*Earth Systems Overview* The Earth is a system consisting of four major interacting components: geosphere (crust, mantle, and core), atmosphere (air), hydrosphere (water), and biosphere (the living part of Earth). Physical, chemical, and biological processes act within and among the four components on a wide range of time scales to continuously change Earth's crust, oceans, atmosphere, and living organisms. Earth elements move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of geochemical cycles.
E2.1C	Explain, using specific examples, how a change in one system affects other Earth systems.
E2.3	*Biogeochemical Cycles* The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Most elements can exist in several different states and chemical forms; they move within and between the geosphere, atmosphere, hydrosphere, and biosphere as part of the Earth system. The movements can be slow or rapid. Elements and compounds have significant impacts on the biosphere and have important impacts on human health.
E2.3b	Explain why small amounts of some chemical forms may be beneficial for life but are poisonous in large quantities (e.g., dead zone in the Gulf of Mexico, Lake Nyos in Africa, fluoride in drinking water).
E2.3c	Explain how the nitrogen cycle is part of the Earth system.
E4.1	*Hydrogeology* Fresh water moves over time between the atmosphere, hydrosphere (surface water, wetlands, rivers, and glaciers), and geosphere (groundwater). Water resources are both critical to and greatly impacted by humans. Changes in water systems will impact quality, quantity, and movement of water. Natural surface water processes shape the landscape everywhere and are affected by human land use decisions.
E4.1A	Compare and contrast surface water systems (lakes, rivers, streams, wetlands) and groundwater in regard to their relative size as Earth's freshwater reservoirs and the dynamics of water movement (inputs and outputs, residence times, sustainability).

E4.1B	Explain the features and processes of groundwater systems and how the sustainability of North American aquifers has changed in recent history (e.g., the past 100 years) qualitatively using the concepts of recharge, residence time, inputs and outputs.
E4.1C	Explain how water quality in both groundwater and surface systems is impacted by land use decisions.

EARTH SCIENCE

Unit 9: Hydrogeology

<u>Big Idea</u> (Core Concept):
Finding solutions to problems related to water resources requires an understanding of the dynamics and interconnectedness of the components of the hydrosphere and the impact created by human activity.

<u>Standard(s):</u>
E2: Earth Systems
E4: The Fluid Earth

<u>Content Statement(s):</u>
E2.1: Earth Systems
E2.3: Biogeochemical Cycles
E4.1: Hydrogeology

<u>Content Expectations</u>: (Content Statement Clarification)
E2.1C: Explain, using specific examples, how a change in one system affects other Earth systems.

Clarification: The shape of land within a watershed and the sediment load of rivers results from the interaction between the geosphere (rock type), the atmosphere (climate) and hydrosphere (surface runoff).

E2.3b: Explain why small amounts of some chemical forms may be beneficial for life but are poisonous in large quantities (e.g., dead zone in the Gulf of Mexico, Lake Nyos in Africa, fluoride in drinking water).

Clarification: The "dead zone" in the Gulf of Mexico results from Mississippi watershed runoff with excessive nutrients that lead to a profound depletion of dissolved oxygen.

E2.3c: Explain how the nitrogen cycle is part of the Earth system.

Clarification: Nitrogen is part of nutrients that effect water quality.

E4.1A: Compare and contrast surface water systems (lakes, rivers, streams, wetlands) and groundwater in regard to their relative sizes as Earth's freshwater reservoirs and the dynamics of water movement (inputs and outputs, residence times, sustainability).

Clarification: none

E4.1B: Explain the features and processes of groundwater systems and how the sustainability of North American aquifers has changed in recent history (e.g., the past 100 years) qualitatively using the concepts of recharge, residence time, inputs and outputs.

Clarification: none

E4.1C: Explain how water quality in both groundwater and surface systems is impacted by land use decisions.

Clarification: Agricultural practices, urbanization and industrialization impact water quality.

Vocabulary:
aquifers
biogeochemical
biosphere
freshwater reservoirs
glaciers
groundwater
hydrogeology
hydrosphere
inputs
land use
outputs
recharge
residence times
rivers
streams
surface water lakes
sustainability
water quality
wetlands

Real World Context
Watersheds are the main organizing concept for elements and process of surface hydrology, ground water and land use.

Depletion of ground water can impact streams and biological viability. Landscapes can establish equilibrium inconsistent with emerging climatic patterns. Changes in climatic patterns or human diversions of water will shift equilibrium and produce changes in the characteristics of streams, ground water and landscapes.

Wetlands store water and recharge rivers during dry spells. They also absorb water during large storm events. A reduction of wetlands due to development or urbanization make flooding more likely as well as low stream discharge during drier months.

While water quality can be reduced by land use in many ways, the effects of agricultural practices are perhaps most profound.

Loss of soil not only diminishes the agricultural viability of land, but may greatly increase stream water turbidity which increases absorption of thermal energy and therefore water temperature. Dissolved oxygen levels drop as water temperature rises.

Organic and synthetic fertilizer from surface run off adds nitrates to stream water which can cause algal blooms. Algae are eventually broken down by aerobic bacteria that consume great quantities of dissolved oxygen. Such occurrences can be infered from a high biochemical oxygen demand (B.O.D.) and lower percent saturation of dissolved oxygen.

The "dead zone" in the Gulf of Mexico is one of many off shore areas on Earth where coastal ecosystems suffer from extremely low amounts of dissolved oxygen. The depletion of oxygen begins in the spring, swells to a maximum size in summer and disappears in the fall. A major cause is excessive nutrients from agriculture in the Mississippi watershed.

Ground water systems are sustainable when input is equal to or exceeds out put. Major sections of the Midwest are practicing unsustainable agriculture due to excessive down draw of the Ogallala aquifer. Some areas experience topographic subsidence due to excessive and continuous ground water withdrawal.

Ground water quality suffers from industrial chemicals and saline infiltration. The United States superfund sites are prioritized locations suffering from dangerous levels of ground water pollution.

Urbanization increases the proportion of impermeable surfaces that accelerate water runoff, reduce infiltration and recharge of wetlands and aquifers.

Water quality measured by physical, chemical and biological parameters reflect land use practices.

Instruments, Measurement, and Representations

Use of U. S. Geological Survey topographic maps for identification and interpretation of watershed boundaries, topographic gradients, stream patterns and features and land use.

Bar graphs of water quality data for interpretation of trends over time, natural seasonal variation and impact of land use.

Groundwater flow maps and profiles

Data from rain gauges

Stream gauging stations provide that that shows changes in stream discharge

Instructional Examples:

i. Inquiry:
CE: E1.1D, E4.1C

Study the natural and human land use features of a watershed and hypothesize the character of water quality based on those features in terms of dissolved oxygen, fecal coliform, turbidity, and temperature. Gather water quality data to test the hypothesis.

ii. Reflection:
CE: E1.2B

Examine the scientific analysis required to be conducted by state regulators in light of the U. S. Supreme Court's 2006 supreme court decision that clarifies the interpretation of the Clean Water Act in regards to wetlands.

iii. Enrichment:
CEs: E2.4B, E4.1A

Use depths to water table data of several wells to draw contour lines and interpret flow direction of ground water in a scenario where a pollutant is moving within a ground water system. Research the technology used to solve ground water pollution problems.

iv. General:
CE: E4.1A

Use depths to water table data of several wells to draw contour lines and interpret flow direction of ground water in a scenario where a pollutant is moving within a ground water system.

v. Intervention:
CE: E4.1A

Using a clay model produced from depths to water table data of several wells, interpret flow direction of ground water in a scenario where a pollutant is moving within a ground water system.

Units by Content Expectation

EARTH SCIENCE

Unit 10: Resources and Environment Challenges

Code	Content Expectation
E2.2	*Energy in Earth Systems* Energy in Earth systems can exist in a number of forms (e.g., thermal energy as heat in the Earth, chemical energy stored as fossil fuels, mechanical energy as delivered by tides) and can be transformed from one state to another and move from one reservoir to another. Movement of matter and its component elements, through and between Earth's systems, is driven by Earth's internal (radioactive decay and gravity) and external (Sun as primary) sources of energy. Thermal energy is transferred by radiation, convection, and conduction. Fossil fuels are derived from plants and animals of the past, are nonrenewable and, therefore, are limited in availability. All sources of energy for human consumption (e.g., solar, wind, nuclear, ethanol, hydrogen, geothermal, hydroelectric) have advantages and disadvantages.
E2.2B	Identify differences in the origin and use of renewable (e.g., solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy.
E2.2C	Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.
E2.2D	Identify the main sources of energy to the climate system.
E2.2e	Explain how energy changes form through Earth systems.
E2.2f	Explain how elements exist in different compounds and states as they move from one reservoir to another.
E2.4	*Resources and Human Impacts on Earth Systems* The Earth provides resources (including minerals) that are used to sustain human affairs. The supply of non-renewable natural resources is limited and their extraction and use can release elements and compounds into Earth systems. They affect air and water quality, ecosystems, landscapes, and may have effects on long-term climate. Plans for land use and long-term development must include an understanding of the interactions between Earth systems and human activities.
E2.4A	Describe renewable and nonrenewable sources of energy for human consumption (electricity, fuels), compare their effects on the environment, and include overall costs and benefits.

E2.4B	Explain how the impact of human activities on the environment (e.g., deforestation, air pollution, coral reef destruction) can be understood through the analysis of interactions between the four Earth systems.
E2.4c	Explain ozone depletion in the stratosphere and methods to slow human activities to reduce ozone depletion.
E2.4d	Describe the life cycle of a product, including the resources, production, packaging, transportation, disposal, and pollution.

EARTH SCIENCE

Unit 10: Resources and Environment Challenges

Big Idea (Core Concept):
Protecting the human interests of health, safety and resource management depends upon an understanding of natural hazards and human impact on earth systems.

Standard(s):
E2: Earth Systems

Content Statement(s):
E2.2: Energy in Earth Systems
E2.4: Resources and Human Impacts on Earth Systems

Content Expectations: (Content Statement Clarification)
E2.2B: Identify differences in the origin and use of renewable (e.g., solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy.

Clarification: none

E2.2C: Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.

Clarification: none

E2.2D: Identify the main sources of energy to the climate system.

Clarification: none

E2.2e: Explain how energy changes form through Earth systems.

Clarification: Extracting and using natural resources causes energy to change form and/or become distributed in a way that can cause environmental impacts.

E2.2f: Explain how elements exist in different compounds and states as they move from one reservoir to another.

Clarification: Extracting and using natural resources causes elements to be released from reservoirs and can cause environmental impacts.

E2.4A: Describe renewable and nonrenewable sources of energy for human consumption (electricity, fuels), compare their effects on the environment, and include overall costs and benefits.

Clarification: All sources of energy used for human consumption have benefits, costs and environmental impact. Detailed and quantified comparisons allow for more informed decisions about the tradeoffs involved.

E2.4B: Explain how the impact of human activities on the environment (e.g., deforestation, air pollution, coral reef destruction) can be understood through the analysis of interactions between the four Earth systems.

Clarification: Human impact on the environment can be analyzed through an Earth system science perspective that focuses on how matter and energy is transferred within and between Earth's systems.

E2.4c: Explain ozone depletion in the stratosphere and methods to slow human activities to reduce ozone depletion.

Clarification: none

E2.4d: Describe the life cycle of a product, including the resources, production, packaging, transportation, disposal, and pollution.

Clarification: none

Vocabulary:
biomass
chemical energy
conduction
convection
coral reef
deforestation
ethanol
external energy sources
fossil fuels
geothermal energy
hydroelectric energy
mechanical energy
nonrenewable energy
nuclear energy
ozone
pollution
radiation
renewable energy
resources
solar energy
stratosphere
thermal energy
tides
waves
wind energy

Real World Context:

Decisions on policy and investment in energy systems for human consumption take into account many factors such as cost and access of natural resources, carbon emissions, technology, impact on society and the challenges of pollution.

Convection currents in the Earth's atmosphere produces winds which drive the surface currents of the oceans. Both can be utilized as alternative sources of energy.

The development of automobiles that run on alternative fuels (hydrogen, electricity) will reduce carbon dioxide emissions but involve other environmental trade offs.

Coral reefs are threatened around the world due to long term stresses resulting from a variety of sources. Changing ocean chemistry and temperature has an impact as well as the composition of runoff from land.

Deforestation can result in less humidity in the air, more carbon dioxide in the air, greater soil erosion, which in turn can change the chemical and physical conditions of streams, lakes, and groundwater.

The choice of paper or plastic bag in the grocery store is not simple if all the steps in making and disposing of it are considered. Paper has often been touted as the better choice environmentally, but understanding the trade-offs should require one to consider a number of issues such as how well the paper manufacturing plant is operated and what bleaching agents are used in making the paper.

Instruments, Measurement, and Representations

Diagrams of the life cycle of a product

Satellite images, which can show extent of problems as well as progress on solutions (such as improvements in the stratospheric ozone layer)
Diagrams of public energy systems (e.g., power plants) showing quantities and qualities of energy flow.

Energy diagrams depict production and consumption of natural resources or consumable products.

Instructional Examples:

i. Inquiry
CE:E1.1D, E1.1E, E1.1g, E2.4c

Analyze data and images of stratospheric ozone levels over several decades and record observations of noted patterns. Generate and pursue questions from the patterns that explain changes over time.

ii. Reflection
CE: E1.2B, E1.2g, E2.2B, E2.4A

Design the future energy system for the local community that utilizes natural resources. Provide a cost-benefit analysis as well as an environmental impact assessment.

iii. Enrichment
CE:E2.2B, E2.4A

After researching the various natural and human induced causes, create a quantified, keyed and color coded schematic diagram showing the components of the Earth systems as they relate to coral reef degradation.

iv. General
CE:E2.2B, E2.4A

After researching the various natural and human induced causes, create a keyed and color coded schematic diagram showing the components of the Earth systems as they relate to coral reef degradation.

v. Intervention
CE:E2.2B, E2.4A

After researching the various natural and human induced causes, assemble (using provided elements on cards) a keyed and color coded schematic diagram showing the components of the Earth systems as they relate to coral reef degradation.

Units by Content Expectation

EARTH SCIENCE

Unit 11: Cosmology and Earth's Place in Space

Code	Content Expectation
E5.1	*The Earth in Space* Scientific evidence indicates the universe is orderly in structure, finite, and contains all matter and energy. Information from the entire light spectrum tells us about the composition and motion of objects in the universe. Early in the history of the universe, matter clumped together by gravitational attraction to form stars and galaxies. According to the Big Bang theory, the universe has been continually expanding at an increasing rate since its formation about 13.7 billion years ago.
E5.1A	Describe the position and motion of our solar system in our galaxy and the overall scale, structure, and age of the universe.
E5.1b	Describe how the Big Bang theory accounts for the formation of the universe.
E5.1c	Explain how observations of the cosmic background radiation have helped determine the age of the universe.
E5.1d	Differentiate between the cosmological and Doppler red shift.
E5.3	*Earth History and Geologic Time* The solar system formed from a nebular cloud of dust and gas 4.6 Ga (billion years ago). The Earth has changed through time and has been affected by both catastrophic (e.g., earthquakes, meteorite impacts, volcanoes) and gradual geologic events (e.g., plate movements, mountain building) as well as the effects of biological evolution (formation of an oxygen atmosphere). Geologic time can be determined through both relative and absolute dating.
E5.3A	Explain how the solar system formed from a nebula of dust and gas in a spiral arm of the Milky Way Galaxy about 4.6 Ga (billion years ago).

EARTH SCIENCE

Unit 11: Cosmology and Earth's Place in the Universe

Big Idea (Core Concept):
Exterritorial energy and materials influence Earth's systems and the position and motion of the Earth within an evolving solar system, galaxy, and universe.

Standard(s):
E5: Earth in Space and Time

Content Statement(s):
E5.1: The Earth in Space
E5.3: Earth History and Geologic Time

Content Expectations: (Content Statement Clarification)
E5.1A: Describe the position and motion of our solar system in our galaxy and the overall scale, structure, and age of the universe.

Clarification: none

E5.1b: Describe how the Big Bang theory accounts for the formation of the universe.

Clarification: none

E5.1c: Explain how observations of the cosmic background radiation have helped determine the age of the universe.

Clarification: none

E5.1d: Differentiate between the cosmological and Doppler red shift.

Clarification: none

E5.3A: Explain how the solar system formed from a nebula of dust and gas in a spiral arm of the Milky Way Galaxy about 4.6 Ga (billion years ago).

Clarification: none

Vocabulary:
age of universe
big bang theory
cosmic background radiation
cosmological red shift
doppler red shift

expanding universe
light spectrum
Milky Way Galaxy
motion of solar system
nebular cloud
scale of universe
spiral arm
structure of universe

Real World Context:
Evolution of universe: major feature of "big bang" theory.

The Doppler Redshift results from the relative motion of the light emitting object and an observer. If the source of light is moving away from an observer the wavelength of the light is shifted towards the red due to an apparent increase in wavelength from that perspective. If the source of light is moving toward an observer, the wavelength of the light is shifted toward the blue due to an apparent shortening of wavelength. These effects, called the redshift and the blueshift, respectively are together known as doppler shifts.

The Cosmological Redshift (or Hubble Redshift) is a redshift caused by the expansion of space. The wavelength of light increases as it traverses the expanding universe between its point of emission and its point of detection proportional to the expansion of space during the crossing time.

Cosmic background radiation is considered a remnant of the big bang.

Structure of universe: Location of our galaxy among others and role of gravitation in galaxy formation.

Exclusions:

The details of "inflation" or "decoupling" as part of the big bang theory
How galaxies are organized into larger structures

Instruments, Measurement, and Representations
Telescopes and binoculars to see stars, nebulae, and galaxies

Computer simulations depicting processes in stars, the formation of galaxies and the Big Bang.

Images taken by large or space-based telescopes and spectra of stars and galaxies.

Graphs that depict the relationships of stellar variables such as brightness versus temperature, distance to galaxies versus redshift.

Exclusions:

How to operate spectroscopes or calculate redshift
Naming laws represented by graphs (e.g., Hubble's Law, HR Diagram)

Instructional Examples:

i. Inquiry
CE: E1.1E, E5.1b

Create a concept map that illustrates the experimental methods, evidence and logic that forms the basis of the Big Bang theory.

ii. Reflection
CE: E1.2k

Teams will research and present an overview of the early scientists (e.g. Kepler, Brahe, Newton, Galileo) that contributed to major discoveries in astronomy with an emphasis on historical context and the impact scientific discoveries had on social and political structures in Europe.

iii. Enrichment
CE: E5.1A

Compare and contrast the scale and structure of our galaxy to that of other galaxies.

iv. General
CE: E5.1A

Using a scale of 1 cm= 3,300 light-years, build a scale model of our galaxy and identify its major components. Using the model to calculate scale distances of our galaxy and compare the enormous differences between the distance to neighboring galaxies as compared to neighboring stars.

v. Intervention
CE: E5.1A

Using a scale of 1 cm= 3,300 light-years, build a scale model of our galaxy and identify its major components.

Units by Content Expectation

EARTH SCIENCE

Unit 12: The Sun and Other Stars

Code	Content Expectation
E5.2	*The Sun Stars*, including the Sun, transform matter into energy in nuclear reactions. When hydrogen nuclei fuse to form helium, a small amount of matter is converted to energy. Solar energy is responsible for life processes and weather as well as phenomena on Earth. These and other processes in stars have led to the formation of all the other chemical elements.
E5.2A	Identify patterns in solar activities (sunspot cycle, solar flares, solar wind).
E5.2B	Relate events on the Sun to phenomena such as auroras, disruption of radio and satellite communications, and power disturbances.
E5.2C	Describe how nuclear fusion produces energy in the Sun.
E5.2D	Describe how nuclear fusion and other processes in stars have led to the formation of all the other chemical elements.
E5.2x	*Stellar Evolution* Stars, including the Sun, transform matter into energy in nuclear reactions. When hydrogen nuclei fuse to form helium, a small amount of matter is converted to energy. These and other processes in stars have led to the formation of all the other chemical elements. There is a wide range of stellar objects of different sizes and temperatures. Stars have varying life histories based on these parameters.
E5.2e	Explain how the Hertzsprung-Russell (H-R) diagram can be used to deduce other parameters (distance).
E5.2f	Explain how you can infer the temperature, life span, and mass of a star from its color. Use the H-R diagram to explain the life cycle of stars.
E5.2g	Explain how the balance between fusion and gravity controls the evolution of a star (equilibrium).
E5.2h	Compare the evolution paths of low, moderate and high mass stars using the H-R diagram.

EARTH SCIENCE

Unit 12: The Sun and Other Stars

<u>Big Idea</u> (Core Concept):
Exterritorial energy and materials influence Earth's systems and the position and motion Earth within an evolving solar system, galaxy, and universe.

<u>Standard(s)</u>:
E5: Earth in Space and Time

<u>Content Statement(s)</u>:
E5.2:   The Sun
E5.2x: Stellar Evolution

<u>Content Expectations</u>: (Content Statement Clarification)
E5.2A: Identify patterns in solar activities (sunspot cycle, solar flares, solar wind).

Clarification: The solar wind moves outward from the sun in a pinwheel shaped spiral pattern in a more or less steady flow. The number of sunspots increases and decreases in cycles that last from 6-17 years (averaging 11 years). Solar flares accompany increases in sunspot activity.

E5.2B: Relate events on the Sun to phenomena such as auroras, disruption of radio and satellite communications, and power grid disturbances.

Clarification: As emissions from the sun encounter Earth, they can ignite geomagnetic storms. These geomagnetic storms can cause electrical power outages, damage communication satellites, and affect radio communications. Increased solar emissions can also lead to a higher frequency of auroras.

E5.2C: Describe how nuclear fusion produces energy in the Sun.

Clarification: none

E5.2D: Describe how nuclear fusion and other processes in stars have led to the formation of all the other chemical elements.

Clarification: none

E5.2e: Explain how the Hertzsprung-Russell (H-R) diagram can be used to deduce other parameters (distance).

Clarification: Brightness and color can be determined given the location of a star on the H-R diagram.

E5.2f: Explain how you can infer the temperature, life span, and mass of a star from its color. Use the H-R diagram to explain the life cycles of stars.

Clarification: The Hertzsprung-Russell diagram illustrates the relationship between the absolute magnitude and the surface temperature of stars. As stars evolve, their position on the Hertzsprung-Russell diagram moves. The temperature of a star is directly related to the color of a star.

E5.2g: Explain how the balance between fusion and gravity controls the evolution of a star (equilibrium).

Clarification: none

E5.2h: Compare the evolution paths of low, moderate and high mass stars using the H-R diagram.

Clarification: none

<u>Vocabulary:</u>
auroras
Hertzsprung-Russell (H-R) diagram
life cycle of stars
nuclear fusion
nuclear reactions
power disturbances
radio and satellite communication
release of energy
solar energy
solar flares
solar wind
source of chemical elements
spontaneous nuclear reaction
star composition
star destruction
star equilibrium
star formation
star size
star system
star temperature
star types
stellar energy
stellar evolution
sunspot cycle

Real World Context:
There is evidence that Earth's climate is effected by the solar activity cycle.

Three dimensional images of the sun by space crafts such as the STEREO, have greatly enhanced our ability to follow solar storms and forecast arrival time to Earth.

The origin of elements involves the formation of Hydrogen and Helium in the early universe followed by the formation of heavier elements.

Exclusions
Details of nuclear fusion
Reaction rates in stars

Instruments, Measurement, and Representations
Telescopes and binoculars to see stars, nebulae, and galaxies

Computer simulations of processes in stars

Images taken by large or space based telescopes

Spectra of stars and galaxies

Graphs that depict the relationships of astronomic variables (e.g., brightness versus temperature, distance to galaxies versus redshift)

Diagrams and Models showing a cross-section of the Sun and the evolution of stars

Instructional Examples:
i. Inquiry
CE: E1.1D, E5.2A

Describe how analyses of sun spots helps us answer questions about the sun and develop a model for how it functions.

ii. Reflection
CE: E1.2C, E5.2B

Investigate the risk of radiation exposure during air travel after a solar storm emission.

iii. Enrichment
CE: E5.2A

Analyze the solar activity from the past 100 years and predict the impact over the next 50 years if the pattern were to proceed at the same rate. Explore the data for patterns in several ways such as segmenting time frames and averaging the number of peaks.

iv. General
CE: E5.2A

Construct a table of sunspot activity and plot the points in order to make predictions about the solar cycle and possibility of disturbances to Earth's system. Look for patterns in the data to determine how predictable sun spot activity is.

v. Intervention
CE: E5.2A

Using records of sunspot activity calculate the average solar cycle length and use that data to predict future solar maximums. Calculate and graph the number of years between the peaks and valleys.

NOTES

NOTES

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Michigan Science Leadership Academy

Michigan Biology Teachers Association
Michigan Chapter of the American Chemical Society
Michigan Earth Science Teachers Association
Michigan Chapter of the American Association of Physics Teachers
Michigan Science Education Leadership Association

Michigan Science Teachers Association

Michigan Mathematics and Science Center Network

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09/07

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