# Middle School Topic Model Course II – Bundle 3
# Geologic Changes to the Earth

*This is the third bundle of the Middle School Topics Model Course II. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart].*

*Bundle 1 Question: This bundle is assembled to address the question "how has the Earth changed?"*

**Summary**
The bundle organizes performance expectations with a focus on helping students begin to understand geologic changes that take place on Earth. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

**Connections between bundle DCIs**
Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources that are distributed unevenly around the planet as a result of past geologic processes (ESS3.A as in MS-ESS3-1). This concept connects to the idea that Earth's plates have moved great distances, collided, and spread apart (ESS2.A as in MS-ESS2-3). All Earth processes, including the movement of plates, are the result of energy flowing and matter cycling within and among the planet's systems, shaping Earth's history (ESS2.A as in MS-ESS2-2). This idea connects to the concept that the energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms (ESS2.A as in MS-ESS2-1), and also that water's movements cause weathering and erosion, which can further change the land's surface features and create underground formations (ESS2.C as in MS-ESS2-2). Understanding the history of natural hazards and related geologic forces can help forecast the locations and likelihoods of future events (ESS3.B as in MS-ESS3-2).

The engineering design idea that the iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution (ETS1.C as in MS-ETS1-4) could connect to many science ideas, including that water's movements cause weathering and erosion (ESS2.C as in MS-ESS2-2) or that mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events (ESS3.B as in MS-ESS3-2). Connections could be made through engineering design tasks such as testing and refining a solution for minimizing the effects of water on soil erosion in a housing development, or modifying solutions for forecasting tornados.

**Bundle Science and Engineering Practices**
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-ESS2-1 and MS-ETS1-4), analyzing and interpreting data (MS-ESS2-3 and MS-ESS3-2), and constructing scientific explanations (MS-ESS2-2 and MS-ESS3-1). Many other practice elements can be used in instruction.

**Bundle Crosscutting Concepts**
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-ESS2-3 and MS-ESS3-2), Cause and Effect (MS-ESS3-1), Scale, Proportion, and Quantity (MS-ESS2-2), and Stability and Change (MS-ESS2-1). Many other crosscutting concept elements can be used in instruction.

*All instruction should be three-dimensional.*

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| **Performance Expectations** | MS-ESS2-1. **Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.** [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [Assessment Boundary: Assessment does not include the identification and naming of minerals.]<br><br>MS-ESS2-2. **Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]<br><br>MS-ESS2-3. **Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.** [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.]<br><br>MS-ESS3-1. **Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.** [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]<br><br>MS-ESS3-2. **Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.** [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado prone regions or reservoirs to mitigate droughts).]<br><br>MS-ETS1-4. **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.** |
| **Example Phenomena** | Fossils of sea creatures can be found in areas that are thousands of miles away from an ocean.<br><br>Oil wells can be found in some states but not others. |
| **Additional Practices Building to the PEs** | **Asking Questions and Defining Problems**<br>• Ask questions that require sufficient and appropriate empirical evidence to answer.<br>Students could *ask questions that require sufficient and appropriate empirical evidence* [about how] ***maps of ancient land and water patterns make clear how Earth's plates have moved great distances, collided, and spread apart***. MS-ESS2-3 |

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| **Additional Practices Building to the PEs (Continued)** | **Developing and Using Models**<br>• Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.<br>Students could *modify a model based on evidence* [about how] ***water's movements cause weathering and erosion, which change the land's surface features and create underground formations***. MS-ESS2-2<br><br>**Planning and Carrying Out Investigations**<br>• Collect data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.<br>Students could *collect data to serve as the basis for evidence* [that] ***mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events***. MS-ESS3-2<br><br>**Analyzing and Interpreting Data**<br>• Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.<br>Students could *use graphical displays of large data sets to identify temporal and spatial relationships* [between] ***the uneven distribution of resources around the planet and past geologic processes***. MS-ESS3-1<br><br>**Using Mathematical and Computational Thinking**<br>• Use digital tools to test and compare proposed solutions to an engineering design problem.<br>Students could *use digital tools to test and compare proposed solutions to a problem* [caused by] ***chemical and physical changes in Earth's materials due to the energy that flows and matter that cycles within and among the planet's systems***. MS-ESS2-1<br><br>**Constructing Explanations and Designing Solutions**<br>• Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.<br>Students could *apply scientific ideas to test a design of process* [for how] ***mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events***. MS-ESS3-2<br><br>**Engaging in Argument from Evidence**<br>• Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.<br>Students could *evaluate competing design solutions based on jointly developed and agreed-upon design criteria* [for] ***forecasting the locations and likelihoods of future events***. MS-ESS3-2 |

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| **Additional Practices Building to the PEs (Continued)** | **Obtaining, Evaluating, and Communicating Information**<br>• Gather, read, synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.<br>Students could *gather, read, synthesize information from multiple sources and assess the credibility, accuracy, and possible bias of each publication* [about how] ***maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart***. MS-ESS2-3 |
| **Additional Crosscutting Concepts Building to the PEs** | **Patterns**<br>• Patterns can be used to identify cause and effect relationships.<br>Students could *use patterns to identify cause and effect relationships* [between] ***water's movements*** [and] ***erosion.*** MS-ESS2-2<br><br>**Scale, Proportion, and Quantity**<br>• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.<br>Students could evaluate the limitations of a *model* [that makes use of the fact that] *time and space can be observed at various scales* [using] ***maps of ancient land and water patterns, making clear how Earth's plates have moved great distances, collided, and spread apart***. MS-ESS2-3<br><br>**Energy and Matter**<br>• Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.<br>Students could obtain, evaluate, and communicate information about how *the transfer of energy drives the motion and/or cycling of matter* [and these] ***cycles produce chemical and physical changes in Earth's materials and living organisms***. MS-ESS2-1 |
| **Additional Connections to Nature of Science** | **Scientific Knowledge is Based on Empirical Evidence**<br>• Science knowledge is based on logical and conceptual connections between evidence and explanations.<br>Students could construct an argument about how s*cience knowledge is based on logical and conceptual connections between evidence and explanations,* [including for how] ***Earth's plates have moved great distances, collided, and spread apart***. MS-ESS2-3<br><br>**Science is a Way of Knowing**<br>• Science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge.<br>Students could obtain, evaluate, and communicate information about how *science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge* [about how] ***mineral, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes.*** MS-ESS3-1 |

## MS-ESS2-1 Earth's Systems

Students who demonstrate understanding can:

**MS-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.** [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [*Assessment Boundary: Assessment does not include the identification and naming of minerals.*]

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

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
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| **Developing and Using Models**<br>Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.<br>• Develop and use a model to describe phenomena. | **ESS2.A: Earth's Materials and Systems**<br>• All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. | **Stability and Change**<br>• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale. |

| Observable features of the student performance by the end of the course: | | | |
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| 1 | Components of the model | | |
| | a | To make sense of a given phenomenon, students develop a model in which they identify the relevant components, including: | |
| | | i. | General types of Earth materials that can be found in different locations, including: |
| | | | 1. Those located at the surface (exterior) and/or in the interior |
| | | | 2. Those that exist(ed) before and/or after chemical and/or physical changes that occur during Earth processes (e.g., melting, sedimentation, weathering). |
| | | ii. | Energy from the sun. |
| | | iii. | Energy from the Earth's hot interior. |
| | | iv. | Relevant earth processes |
| | | v. | The temporal and spatial scales for the system. |
| 2 | Relationships | | |
| | a | In the model, students describe* relationships between components, including: | |
| | | i. | Different Earth processes (e.g., melting, sedimentation, crystallization) drive matter cycling (i.e., from one type of Earth material to another) through observable chemical and physical changes. |
| | | ii. | The movement of energy that originates from the Earth's hot interior and causes the cycling of matter through the Earth processes of melting, crystallization, and deformation. |
| | | iii. | Energy flows from the sun cause matter cycling via processes that produce weathering, erosion, and sedimentation (e.g., wind, rain). |
| | | iv. | The temporal and spatial scales over which the relevant Earth processes operate. |
| 3 | Connections | | |
| | a | Students use the model to describe* (based on evidence for changes over time and processes at different scales) that energy from the Earth's interior and the sun drive Earth processes that together cause matter cycling through different forms of Earth materials. | |

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| | b | Students use the model to account for interactions between different Earth processes, including: |
| | | i. The Earth's internal heat energy drives processes such as melting, crystallization, and deformation that change the atomic arrangement of elements in rocks and that move and push rock material to the Earth's surface where it is subject to surface processes like weathering and erosion. |
| | | ii. Energy from the sun drives the movement of wind and water that causes the erosion, movement, and sedimentation of weathered Earth materials. |
| | | iii. Given the right setting, any rock on Earth can be changed into a new type of rock by processes driven by the Earth's internal energy or by energy from the sun. |
| | c | Students describe* that these changes are consistently occurring but that landforms appear stable to humans because they are changing on time scales much longer than human lifetimes. |

## MS-ESS2-2 Earth's Systems

Students who demonstrate understanding can:

**MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]

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

### Science and Engineering Practices

**Constructing Explanations and Designing Solutions**

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.

### Disciplinary Core Ideas

**ESS2.A: Earth's Materials and Systems**

- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

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

- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

### Crosscutting Concepts

**Scale Proportion and Quantity**

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

| Observable features of the student performance by the end of the course: | | | |
|---|---|---|---|
| 1 | Articulating the explanation of phenomena | | |
| | a | Students articulate a statement that relates a given phenomenon to a scientific idea, including that geoscience processes have changed the Earth's surface at varying time and spatial scales. | |
| | b | Students use evidence and reasoning to construct an explanation for the given phenomenon, which involves changes at Earth's surface. | |
| 2 | Evidence | | |
| | a | Students identify and describe* the evidence necessary for constructing an explanation, including: | |
| | | i. | The slow and large-scale motion of the Earth's plates and the results of that motion. |
| | | ii. | Surface weathering, erosion, movement, and the deposition of sediment ranging from large to microscopic scales (e.g., sediment consisting of boulders and microscopic grains of sand, raindrops dissolving microscopic amounts of minerals). |
| | | iii. | Rapid catastrophic events (e.g., earthquakes, volcanoes, meteor impacts). |
| | b | Students identify the corresponding timescales for each identified geoscience process. | |
| | c | Students use multiple valid and reliable sources, which may include students' own investigations, evidence from data, and observations from conceptual models used to represent changes that occur on very large or small spatial and/or temporal scales (e.g., stream tables to illustrate erosion and deposition, maps and models to show the motion of tectonic plates). | |
| | Reasoning | | |

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| 3 | a | Students use reasoning, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to connect the evidence and support an explanation for how geoscience processes have changed the Earth's surface at a variety of temporal and spatial scales. Students describe* the following chain of reasoning for their explanation: | |
| | | i. | The motion of the Earth's plates produces changes on a planetary scale over a range of time periods from millions to billions of years. Evidence for the motion of plates can explain large-scale features of the Earth's surface (e.g., mountains, distribution of continents) and how they change. |
| | | ii. | Surface processes such as erosion, movement, weathering, and the deposition of sediment can modify surface features, such as mountains, or create new features, such as canyons. These processes can occur at spatial scales ranging from large to microscopic over time periods ranging from years to hundreds of millions of years. |
| | | iii. | Catastrophic changes can modify or create surface features over a very short period of time compared to other geoscience processes, and the results of those catastrophic changes are subject to further changes over time by processes that act on longer time scales (e.g., erosion of a meteor crater). |
| | | iv. | A given surface feature is the result of a broad range of geoscience processes occurring at different temporal and spatial scales. |
| | | v. | Surface features will continue to change in the future as geoscience processes continue to occur. |

## MS-ESS2-3 Earth's Systems

Students who demonstrate understanding can:

**MS-ESS2-3. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.** [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [*Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.*]

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

### Science and Engineering Practices

**Analyzing and Interpreting Data**
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze and interpret data to provide evidence for phenomena.

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***Connections to Nature of Science***

**Scientific Knowledge is Open to Revision in Light of New Evidence**

- Science findings are frequently revised and/or reinterpreted based on new evidence.

### Disciplinary Core Ideas

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

- Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. *(HS.ESS1.C GBE),(secondary)*

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

- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.

### Crosscutting Concepts

**Patterns**

- Patterns in rates of change and other numerical relationships can provide information about natural systems.

| Observable features of the student performance by the end of the course: | | | |
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| 1 | Organizing data | | |
| | a | Students organize given data that represent the distribution and ages of fossils and rocks, continental shapes, seafloor structures, and/or age of oceanic crust. | |
| | b | Students describe* what each dataset represents. | |
| | c | Students organize the given data in a way that facilitates analysis and interpretation. | |
| 2 | Identifying relationships | | |
| | a | Students analyze the data to identify relationships (including relationships that can be used to infer numerical rates of change, such as patterns of age of seafloor) in the datasets about Earth features. | |
| 3 | Interpreting data | | |
| | a | Students use the analyzed data to provide evidence for past plate motion. Students describe*: | |
| | | i. | Regions of different continents that share similar fossils and similar rocks suggest that, in the geologic past, those sections of continent were once attached and have since separated. |
| | | ii. | The shapes of continents, which roughly fit together (like pieces in a jigsaw puzzle) suggest that those land masses were once joined and have since separated. |
| | | iii. | The separation of continents by the sequential formation of new seafloor at the center of the ocean is inferred by age patterns in oceanic crust that increase in age from the center of the ocean to the edges of the ocean. |
| | | iv. | The distribution of seafloor structures (e.g., volcanic ridges at the centers of oceans, trenches at the edges of continents) combined with the patterns of ages of rocks of the seafloor (youngest ages at the ridge, oldest ages at the trenches) supports the interpretation that new crust forms at the ridges and then moves away from the ridges as new crust continues to form and that the oldest crust is being destroyed at seafloor trenches. |

## MS-ESS3-1 Earth and Human Activity

Students who demonstrate understanding can:

**MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.** [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]

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

### Science and Engineering Practices

**Constructing Explanations and Designing Solutions**

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

### Disciplinary Core Ideas

**ESS3.A: Natural Resources**

- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

### Crosscutting Concepts

**Cause and Effect**

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

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

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

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

| Observable features of the student performance by the end of the course: | | | |
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| 1 | Articulating the explanation of phenomena | | |
| | a | Students articulate a statement relating a given phenomenon to scientific ideas, including that past and current geoscience processes have caused the uneven distribution of the Earth's resources, including: | |
| | | i. | That the uneven distributions of the Earth's mineral, energy, and groundwater resources are the results of past and current geologic processes. |
| | | ii. | That resources are typically limited and nonrenewable due to factors such as the long amounts of time required for some resources to form or the environment in which resources were created forming once or only rarely in the Earth's history. |
| | b | Students use evidence and reasoning to construct a scientific explanation of the phenomenon. | |
| 2 | Identifying the scientific evidence to construct the explanation | | |
| | a | Students identify and describe* the evidence necessary for constructing the explanation, including: | |
| | | i. | Type and distribution of an example of each type of Earth resource: mineral, energy, and groundwater. |
| | | ii. | Evidence for the past and current geologic processes (e.g., volcanic activity, sedimentary processes) that have resulted in the formation of each of the given resources. |
| | | iii. | The ways in which the extraction of each type of resource by humans changes how much and where more of that resource can be found. |

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| | b | Students use multiple valid and reliable sources of evidence. | |
| 3 | Reasoning | | |
| | a | Students use reasoning to connect the evidence and support an explanation. Students describe* a chain of reasoning that includes: | |
| | | i. | The Earth's resources are formed as a result of past and current geologic processes. |
| | | ii. | The environment or conditions that formed the resources are specific to certain areas and/or times on Earth, thus identifying why those resources are found only in those specific places/periods. |
| | | iii. | As resources as used, they are depleted from the sources until they can be replenished, mainly through geologic processes. |
| | | iv. | Because many resources continue to be formed in the same ways that they were in the past, and because the amount of time required to form most of these resources (e.g., minerals, fossil fuels) is much longer than timescales of human lifetimes, these resources are limited to current and near-future generations. Some resources (e.g., groundwater) can be replenished on human timescales and are limited based on distribution. |
| | | v. | The extraction and use of resources by humans decreases the amounts of these resources available in some locations and changes the overall distribution of these resources on Earth. |

## MS-ESS3-2 Earth and Human Activity

Students who demonstrate understanding can:

**MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.** [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]

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

### Science and Engineering Practices

**Analyzing and Interpreting Data**
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze and interpret data to determine similarities and differences in findings.

### Disciplinary Core Ideas

**ESS3.B: Natural Hazards**

- Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

### Crosscutting Concepts

**Patterns**

- Graphs, charts, and images can be used to identify patterns in data.

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

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

- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

| Observable features of the student performance by the end of the course: | | |
|---|---|---|
| 1 | Organizing data | |
| | a | Students organize given data that represent the type of natural hazard event and features associated with that type of event, including the location, magnitude, frequency, and any associated precursor event or geologic forces. |
| | b | Students organize data in a way that facilitates analysis and interpretation. |
| | c | Students describe* what each dataset represents. |
| 2 | Identifying relationships | |
| | a | Students analyze data to identify and describe* patterns in the datasets, including: |
| | | i. The location of natural hazard events relative to geographic and/or geologic features. |
| | | ii. Frequency of natural hazard events. |
| | | iii. Severity of natural hazard events. |
| | | iv. Types of damage caused by natural hazard events. |

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| | | v. Location or timing of features and phenomena (e.g., aftershocks, flash floods) associated with natural hazard events. |
| | b | Students describe* similarities and differences among identified patterns. |
| 3 | Interpreting data | |
| | a | Students use the analyzed data to describe*: |
| | | i. Areas that are susceptible to the natural hazard events, including areas designated as at the greatest and least risk for severe events. |
| | | ii. How frequently areas, including areas experiencing the highest and lowest frequency of events, are at risk. |
| | | iii. What type of damage each area is at risk of during a given natural hazard event. |
| | | iv. What features, if any, occur before a given natural hazard event that can be used to predict the occurrence of the natural hazard event and when and where they can be observed. |
| | b | Using patterns in the data, students make a forecast for the potential of a natural hazard event to affect an area in the future, including information on frequency and/or probability of event occurrence; how severe the event is likely to be; where the event is most likely to cause the most damage; and what events, if any, are likely to precede the event. |
| | c | Students give at least three examples of the technologies that engineers have developed to mitigate the effects of natural hazards (e.g., the design of buildings and bridges to resist earthquakes, warning sirens for tsunamis, storm shelters for tornados, levees along rivers to prevent flooding). |

## MS-ETS1-4 Engineering Design

Students who demonstrate understanding can:

**MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.**

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

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.<br>• Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. | **ETS1.B: Developing Possible Solutions**<br>• A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.<br>• Models of all kinds are important for testing solutions.<br>**ETS1.C: Optimizing the Design Solution**<br>• The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. | |

| Observable features of the student performance by the end of the course: | | | |
|---|---|---|---|
| 1 | Components of the model | | |
| | a | Students develop a model in which they identify the components relevant to testing ideas about the designed system, including: | |
| | | i. | The given problem being solved, including criteria and constraints. |
| | | ii. | The components of the given proposed solution (e.g., object, tools, or process), including inputs and outputs of the designed system. |
| 2 | Relationships | | |
| | a | Students identify and describe* the relationships between components, including: | |
| | | i. | The relationships between each component of the proposed solution and the functionality of the solution. |
| | | ii. | The relationship between the problem being solved and the proposed solution. |
| | | iii. | The relationship between each of the components of the given proposed solution and the problem being solved. |
| | | iv. | The relationship between the data generated by the model and the functioning of the proposed solution. |
| 3 | Connections | | |
| | a | Students use the model to generate data representing the functioning of the given proposed solution and each of its iterations as components of the model are modified. | |
| | b | Students identify the limitations of the model with regards to representing the proposed solution. | |
| | c | Students describe* how the data generated by the model, along with criteria and constraints that the proposed solution must meet, can be used to optimize the design solution through iterative testing and modification. | |