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
Developing and Using Models 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. • Develop and use a model to describe phenomena.	**ESS2.A: Earth's Materials and Systems** • 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** • 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:			
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.	

	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		

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:			
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-ESS2-4 Earth's Systems

Students who demonstrate understanding can:

MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.] [*Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is 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

Developing and Using Models

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.

- Develop a model to describe unobservable mechanisms.

Disciplinary Core Ideas

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

- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- Global movements of water and its changes in form are propelled by sunlight and gravity.

Crosscutting Concepts

Energy and Matter

- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a phenomenon, students develop a model in which they identify the relevant components:	
		i.	Water (liquid, solid, and in the atmosphere).
		ii.	Energy in the form of sunlight.
		iii.	Gravity.
		iv.	Atmosphere.
		v.	Landforms.
		vi.	Plants and other living things.
2	Relationships		
	a	In their model, students describe* the relevant relationships between components, including:	
		i.	Energy transfer from the sun warms water on Earth, which can evaporate into the atmosphere.
		ii.	Water vapor in the atmosphere forms clouds, which can cool and condense to produce precipitation that falls to the surface of Earth.
		iii.	Gravity causes water on land to move downhill (e.g., rivers and glaciers) and much of it eventually flows into oceans.
		iv.	Some liquid and solid water remains on land in the form of bodies of water and ice sheets.
		v.	Some water remains in the tissues of plants and other living organisms, and this water is released when the tissues decompose.
3	Connections		
	a	Students use the model to account for both energy from light and the force of gravity driving water cycling between oceans, the atmosphere, and land, including that:	
		i.	Energy from the sun drives the movement of water from the Earth (e.g., oceans, landforms, plants) into the atmosphere through transpiration and evaporation.
		ii.	Water vapor in the atmosphere can cool and condense to form rain or crystallize to form snow or ice, which returns to Earth when pulled down by gravity.
		iii.	Some rain falls back into the ocean, and some rain falls on land. Water that falls on land can:

		1. Be pulled down by gravity to form surface waters such as rivers, which join together and generally flow back into the ocean.
		2. Evaporate back into the atmosphere.
		3. Be taken up by plants, which release it through transpiration and also eventually through decomposition.
		4. Be taken up by animals, which release it through respiration and also eventually through decomposition.
		5. Freeze (crystallize) and/or collect in frozen form, in some cases forming glaciers or ice sheets.
		6. Be stored on land in bodies of water or below ground in aquifers.
	b	Students use the model to describe* that the transfer of energy between water and its environment drives the phase changes that drive water cycling through evaporation, transpiration, condensation, crystallization, and precipitation.
	c	Students use the model to describe* how gravity interacts with water in different phases and locations to drive water cycling between the Earth's surface and the atmosphere.

MS-ESS2-5 Earth's Systems

Students who demonstrate understanding can:

MS-ESS2-5. Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions. [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]

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
Planning and Carrying Out Investigations Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions. • Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. **ESS2.D: Weather and Climate** • Because these patterns are so complex, weather can only be predicted probabilistically.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:			
1	Identifying the phenomenon under investigation		
	a	From the given investigation plan, students describe* the phenomenon under investigation, which includes the relationships between air mass interactions and weather conditions.	
	b	Students identify the purpose of the investigation, which includes providing evidence to answer questions about how motions and complex interactions of air masses result in changes in weather conditions [note: expectations of students regarding mechanisms are limited to relationships between patterns of activity of air masses and changes in weather].	
2	Identifying the evidence to address the purpose of the investigation		
	a	From a given investigation plan, students describe* the data to be collected and the evidence to be derived from the data that would indicate relationships between air mass movement and changes in weather, including:	
		i.	Patterns in weather conditions in a specific area (e.g., temperature, air pressure, humidity, wind speed) over time.
		ii.	The relationship between the distribution and movement of air masses and landforms, ocean temperatures, and currents.

		iii. The relationship between observed, large-scale weather patterns and the location or movement of air masses, including patterns that develop between air masses (e.g., cold fronts may be characterized by thunderstorms).
	b	Students describe* how the evidence to be collected will be relevant to determining the relationship between patterns of activity of air masses and changes in weather conditions.
	c	Students describe* that because weather patterns are so complex and have multiple causes, weather can be predicted only probabilistically.
3	Planning the investigation	
	a	Students describe* the tools and methods used in the investigation, including how they are relevant to the purpose of the investigation.
4	Collecting the data	
	a	According to the provided investigation plan, students make observations and record data, either firsthand and/or from professional weather monitoring services.

MS-ESS2-6 Earth's Systems

Students who demonstrate understanding can:

MS-ESS2-6. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*]

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

Developing and Using Models
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.

- Develop and use a model to describe phenomena.

Disciplinary Core Ideas

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

- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a phenomenon, students develop a model in which they identify the relevant components of the system, with inputs and outputs, including:	
		i.	The rotating Earth.
		ii.	The atmosphere.
		iii.	The ocean, including the relative rate of thermal energy transfer of water compared to land or air.
		iv.	Continents and the distribution of landforms on the surface of Earth.
		v.	Global distribution of ice.
		vi.	Distribution of living things.
		vii.	Energy.
			1. Radiation from the sun as an input.
			2. Thermal energy that exists in the atmosphere, water, land, and ice (as represented by temperature).

2	Relationships			
	a	In the model, students identify and describe* the relationships between components of the system, including:		
		i.	Differences in the distribution of solar energy and temperature changes, including:	
			1.	Higher latitudes receive less solar energy per unit of area than do lower latitudes, resulting in temperature differences based on latitude.
			2.	Smaller temperature changes tend to occur in oceans than on land in the same amount of time.
			3.	In general, areas at higher elevations have lower average temperatures than do areas at lower elevations.
			4.	Features on the Earth's surface, such as the amount of solar energy reflected back into the atmosphere or the absorption of solar energy by living things, affect the amount of solar energy transferred into heat energy.
		ii.	Motion of ocean waters and air masses (matter):	
			1.	Fluid matter (i.e., air, water) flows from areas of higher density to areas of lower density (due to temperature or salinity). The density of a fluid can vary for several different reasons (e.g., changes in salinity and temperature of water can each cause changes in density). Differences in salinity and temperature can, therefore, cause fluids to move vertically and, as a result of vertical movement, also horizontally because of density differences.
		iii.	Factors affecting the motion of wind and currents:	
			1.	The Earth's rotation causes oceanic and atmospheric flows to curve when viewed from the rotating surface of Earth (Coriolis force).
			2.	The geographical distribution of land limits where ocean currents can flow.
			3.	Landforms affect atmospheric flows (e.g., mountains deflect wind and/or force it to higher elevation).
		iv.	Thermal energy transfer:	
			1.	Thermal energy moves from areas of high temperature to areas of lower temperature either through the movement of matter, via radiation, or via conduction of heat from warmer objects to cooler objects.
			2.	Absorbing or releasing thermal energy produces a more rapid change in temperature on land compared to in water.
			3.	Absorbing or releasing thermal energy produces a more rapid change in temperature in the atmosphere compared to either on land or in water so the atmosphere is warmed or cooled by being in contact with land or the ocean.
3	Connections			
	a	Students use the model to describe*:		
		i.	The general latitudinal pattern in climate (higher average annual temperatures near the equator and lower average annual temperatures at higher latitudes) caused by more direct light (greater energy per unit of area) at the equator (more solar energy) and less direct light at the poles (less solar energy).	
		ii.	The general latitudinal pattern of drier and wetter climates caused by the shift in the amount of air moisture during precipitation from rising moisture-rich air and the sinking of dry air.	
		iii.	The pattern of differing climates in continental areas as compared to the oceans. Because water can absorb more solar energy for every degree change in temperature compared to land, there is a greater and more rapid temperature change on land than in the ocean. At the centers of landmasses, this leads to conditions typical of continental climate patterns.	
		iv.	The pattern that climates near large water bodies, such as marine coasts, have comparatively smaller changes in temperature relative to the center of the landmass. Land near the oceans can exchange thermal energy through the air, resulting in smaller changes in temperature. At the edges of landmasses, this leads to marine climates.	
		v.	The pattern that climates at higher altitudes have lower temperatures than climates at lower altitudes. Because of the direct relationship between temperature and pressure, given the same amount of thermal energy, air at lower pressures (higher altitudes) will have lower temperatures than air at higher pressures (lower altitudes).	

		vi. Regional patterns of climate (e.g., temperature or moisture) related to a specific pattern of water or air circulation, including the role of the following in contributing to the climate pattern:
		1. Air or water moving from areas of high temperature, density, and/or salinity to areas of low temperature, density, and/or salinity.
		2. The Earth's rotation, which affects atmospheric and oceanic circulation.
		3. The transfer of thermal energy with the movement of matter.
		4. The presence of landforms (e.g., the rain shadow effect).
	b	Students use the model to describe* the role of each of its components in producing a given regional climate.