Middle School Topics Model Course 1-Bundle 4
Understanding the Rise in Global Temperature

This is the fourth bundle of the Middle School Topics Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 4 Question: This bundle is assembled to address the question of "What is contributing to the rise in global temperature?"

Summary

The bundle organizes performance expectations around the theme of understanding the rise in global temperature, with a focus on the water cycle, regional climates, and the relationship of humans to the environment. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Human activities have significantly altered the biosphere. But changes to Earth's environments can have different impacts (negative and positive) for different living things (ESS3.C as in MS-ESS3-3). These concepts of the impact of human activities connect to the idea that human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (ESS3.D as in MS-ESS3-5).

The rise in Earth's mean surface temperature (ESS3.D as in MS-ESS3-5) connects to the idea that 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.C as in MS-ESS2-5). Movements of water in the atmosphere connect to the idea that global movements of water and its changes in form are propelled by sunlight and gravity (ESS2.C as in MS-ESS2-4). Finally, ideas about movements of water in the atmosphere and oceans also connect to the idea that 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 (ESS2.D as in MS-ESS2-6).

The idea that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-2) could connect to the idea that human activities have significantly altered the biosphere. But changes to Earth's environments can have different impacts (negative and positive) for different living things (ESS3.C as in MS-ESS3-3). This connection could be shown through a task such as a report that reviewed two possible solutions that could mitigate global warming, analyzing those solutions through criteria and constraints.

Alternatively, idea that 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.C as in MS-ESS2-5) could connect to the idea that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-2). Students could demonstrate this by proposing a process for monitoring changes in wind and corresponding changes to ocean temperatures, and then evaluating each other's proposed processes using criteria and constraints developed by the class.

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 a model (MS-ESS2-4), carrying out investigations (MS-ESS2-5), developing and using a model (MS-ESS2-6), designing solutions (MS-ESS3-3), and asking questions (MS-ESS3-5). 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 Energy and Matter (MS-ESS2-4), Cause and Effect (MS-ESS2-5 and MS-ESS3-3), Systems and System Models (MS-ESS2-6), and Stability and Change (MS-ESS3-5). Many other crosscutting concepts elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	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.*] 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.*] 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.*] MS-ESS3-3 **Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.*** [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).] MS-ESS3-5 **Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.** [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.] MS-ETS1-2 **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**

Example Phenomena	Sometimes there are strong winds. Rain can start or stop suddenly. There are distinctly different climates around the country and around the world. Industrial, transportation, and other human activities can produce air pollution. Many waterways near population centers are cleaner than they were just decades ago.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. Students could *ask questions about* **the complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents,** [to determine how they affect] **major determinants of local weather patterns**. MS-ESS2-5 • Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. Students could *define a design problem to create a process to monitor [how]* **human activities can alter the biosphere.** MS-ESS3-3 **Developing and Using Models** • Develop and/or use a model to predict and/or describe phenomena. Students could *develop a model to describe* [local] **weather**. MS-ESS2-5 **Planning and Carrying Out Investigations** • Collect data about the performance of a proposed object, tool, process or system under a range of conditions. Students could *collect data about* [the effectiveness of] *a method for* [monitoring] **a human impact on the environment**. MS-ESS3-3 **Analyzing and Interpreting Data:** • Analyze and interpret data to determine similarities and differences in findings. Students could *analyze data from different* [studies that show how] **human activities affect current rise in Earth's mean surface temperature**. MS-ESS3-5

Additional Practices Building to the PEs (Continued)	**Using Mathematics and Computational Thinking:** • Use mathematical representations to describe and/or support scientific conclusions and design solutions. Students could *use a mathematical model to describe how* **human activities can alter the biosphere**. MS-ESS3-3 **Constructing Explanations and Designing Solutions:** • Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process, or system. Students could apply *scientific principles to test a process* [for altering the effects of] **human activities on natural habitats.** MS-ESS3-3 **Engaging in Argument from Evidence:** • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. Students could *evaluate design solutions* [that use] **probabilistic methods of predicting weather** based on how well they meet design criteria and constraints. MS-ESS2-6 **Obtaining, Evaluating, and Communicating Information:** • Gather, read, and synthesize information from multiple appropriate sources and asses the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. Students could *gather, read, and synthesize information from multiple appropriate sources about the way that* **the release of greenhouse gases from burning fossil fuels affect Earth's mean surface temperature,** *and asses the credibility and accuracy of each publication*. HS-ESS3-5
Additional Crosscutting Concepts Leading to PE	**Energy and Matter: Flows, Cycles, and Conservation** • The transfer of energy can be tracked as energy flows through a designed or natural system. Students could describe *how the transfer of energy can be tracked as energy flows through the ocean,* **exerting a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents**. MS-ESS2-6 **Stability and Change** • Small changes in one part of a system might cause large changes in another part. Students could identify how *small changes in one part of a system might cause large changes in another part* [by gathering information about how] **changes in sunlight affect global movements of water and its changes in form**. MS-ESS2-4

Additional Crosscutting Concepts Leading to PE (Continued)	**Scale, Proportion, and Quantity** • Phenomena that can be observed at one scale may not be observable at another scale. Students could describe how *phenomena that can be observed at one scale may not be observable at another scale* [by investigating evidence for the idea that] **the release of greenhouse gases from burning fossil fuels affect Earth's mean surface temperature** [and observing the scale of data points that are necessary for observing phenomena related to this concept]. HS-ESS3-5
Additional Connections to Nature of Science	**Scientific knowledge is Based on Empirical Evidence** • Science disciplines share common rules of obtaining and evaluating empirical evidence. Students could [look back to previous life sciences instruction to compare the] *rules of obtaining and evaluating empirical evidence* [with those used in the Earth sciences in this unit of instruction]. **Science Addresses questions about the Natural and Material World** • Science knowledge can describe consequences of actions but is not responsible for society's decisions. Students could describe how *science knowledge can describe consequences of actions but is not responsible for society's decisions* [related to] **understanding human behavior and human vulnerability to climate changes**. MS-ESS3-5

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.

MS-ESS3-3 Earth and Human Activity

Students who demonstrate understanding can:

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.*[Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

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.

- Apply scientific principles to design an object, tool, process or system.

Disciplinary Core Ideas

ESS3.C: Human Impacts on Earth Systems

- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Crosscutting Concepts

Cause and Effect

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.

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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	Using scientific knowledge to generate design solutions		
	a	Given a problem related to human impact on the environment, students use scientific information and principles to generate a design solution that:	
		i.	Addresses the results of the particular human activity.
		ii.	Incorporates technologies that can be used to monitor and minimize negative effects that human activities have on the environment.
	b	Students identify relationships between the human activity and the negative environmental impact based on scientific principles, and distinguish between causal and correlational relationships to facilitate the design of the solution.	
2	Describing* criteria and constraints, including quantification when appropriate		
	a	Students define and quantify, when appropriate, criteria and constraints for the solution, including:	
		i.	Individual or societal needs and desires.
		ii.	Constraints imposed by economic conditions (e.g., costs of building and maintaining the solution).
3	Evaluating potential solutions		
	a	Students describe* how well the solution meets the criteria and constraints, including monitoring or minimizing a human impact based on the causal relationships between relevant scientific principles	

		about the processes that occur in, as well as among, Earth systems and the human impact on the environment.
	b	Students identify limitations of the use of technologies employed by the solution.

MS-ESS3-5 Earth and Human Activity

Students who demonstrate understanding can:

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]

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
Asking Questions and Defining Problems Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. • Ask questions to identify and clarify evidence of an argument.	**ESS3.D: Global Climate Change** • Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.	**Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Observable features of the student performance by the end of the course:			
1	Addressing phenomena of the natural world		
	a	Students examine a given claim and the given supporting evidence as a basis for formulating questions. Students ask questions that would identify and clarify the evidence, including:	
		i.	The relevant ways in which natural processes and/or human activities may have affected the patterns of change in global temperatures over the past century.
		ii.	The influence of natural processes and/or human activities on a gradual or sudden change in global temperatures in natural systems (e.g., glaciers and arctic ice, and plant and animal seasonal movements and life cycle activities).
		iii.	The influence of natural processes and/or human activities on changes in the concentration of carbon dioxide and other greenhouse gases in the atmosphere over the past century.
2	Identifying the scientific nature of the question		
	a	Students questions can be answered by examining evidence for:	
		i.	Patterns in data that connect natural processes and human activities to changes in global temperatures over the past century.
		ii.	Patterns in data that connect the changes in natural processes and/or human activities related to greenhouse gas production to changes in the concentrations of carbon dioxide and other greenhouse gases in the atmosphere.

MS-ETS1-2 Engineering Design

Students who demonstrate understanding can:

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

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
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	**ETS1.B: Developing Possible Solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	

Observable features of the student performance by the end of the course:		
1	Identifying the given design solution and associated claims and evidence	
	a	Students identify the given supported design solution.
	b	Students identify scientific knowledge related to the problem and each proposed solution.
	c	Students identify how each solution would solve the problem.
2	Identifying additional evidence	
	a	Students identify and describe* additional evidence necessary for their evaluation, including:
		i. Knowledge of how similar problems have been solved in the past.
		ii. Evidence of possible societal and environmental impacts of each proposed solution.
	b	Students collaboratively define and describe* criteria and constraints for the evaluation of the design solution.
3	Evaluating and critiquing evidence	
	a	Students use a systematic method (e.g., a decision matrix) to identify the strengths and weaknesses of each solution. In their evaluation, students:
		i. Evaluate each solution against each criterion and constraint.
		ii. Compare solutions based on the results of their performance against the defined criteria and constraints.
	b	Students use the evidence and reasoning to make a claim about the relative effectiveness of each proposed solution based on the strengths and weaknesses of each.