High School Conceptual Progressions Model III – Bundle 4
Earth's Impact on Humans

This is the fourth bundle of the High School Conceptual Progressions Model Course III. 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 "how do Earth's systems affect me?"	
Summary The bundle organizes performance expectations with a focus on helping students build understanding of the ways Earth systems affect human societies and vice versa. 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** The availability of resources has guided the development of human society (ESS3.A as in HS-ESS3-1), and natural hazards and other geologic events have shaped the course of human history, significantly altering the sizes of human populations and driving human migrations (ESS3.B as in HS-ESS3-1). Our abilities to model, predict, and manage current and future impacts (ESS3.D as in HS-ESS3-5) from the environment have improved. However, the sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources (ESS3.C as in HS-ESS3-3). **Bundle Science and Engineering Practices** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of analyzing data (HS-ESS3-5), using mathematics and computational thinking (HS-ESS3-3), and constructing explanations (HS-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 Cause and Effect (HS-ESS3-1) and Stability and Change (HS-ESS3-3 and HS-ESS3-5). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	**HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.** [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.] **HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.** [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]

Performance Expectations (Continued)	**HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.** [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]
Example Phenomena	Most major cities are located near large bodies of water. When the temperature increases in a region, people who live at higher altitudes can get malaria.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Evaluate a question to determine if it is testable and relevant Students could *evaluate questions* [about how] ***the sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources*** *to determine if the questions are testable and relevant*. HS-ESS3-3 **Developing and Using Models** • Design a test of a model to ascertain its reliability. Students could *design a test of a model* [of] ***the magnitudes of human impacts on*** [global climate] *to ascertain its reliability*. HS-ESS3-5 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make a directional hypothesis that specifies what happens to* ***biodiversity*** *when* ***management of natural resources*** [changes]. HS-ESS3-3 **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data to make valid and reliable scientific claims* [about how] ***natural hazards and other geologic events have shaped the course of human history***. HS-ESS3-1 **Using Mathematical and Computational Thinking** • Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model 'makes sense' by comparing the outcomes with what is known about the real world. Students could *use simple limit cases to test simulations* [of] ***the management of human impacts*** [on climate]. HS-ESS3-5 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could apply scientific ideas, principles, and evidence to provide an explanation [for how] ***the sustainability of human societies requires responsible management of natural resources***. HS-ESS3-3

Additional Practices Building to the PEs (Continued)	**Engaging in Argument from Evidence** • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required. Students could *respectfully provide and receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions* [about how] ***natural hazards and other geologic events have shaped the course of human history***. HS-ESS3-1 **Obtaining, Evaluating, and Communicating Information** • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats Students could *communicate scientific information* [about how] ***the magnitudes of human impacts on*** [global climate] ***are greater than they have ever been***. HS-ESS3-5
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Changes in systems may have various causes that may not have equal effects. Students could construct an argument about how *changes in* [global climate] *may have various causes that may not have equal effects*, [including as evidence] ***the magnitude of human impacts*** [on climate]. HS-ESS3-5 **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Students could, *when describing* ***the sustainability of human societies and the biodiversity that supports them***, *define the boundaries and initial conditions of the system and analyze their inputs and outputs*. HS-ESS3-3 **Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. Students could develop a model for how *feedback can stabilize or destabilize a system*, [including a system of] ***responsible management of natural resources***. HS-ESS3-3
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific explanations can be probabilistic. Students could construct an argument about how *scientific explanations can be probabilistic*, [using as an example] ***explanations about the magnitudes of human impacts*** [on climate]. HS-ESS3-1 **Science Addresses Questions About the Natural and Material World** • Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. Students could construct an argument that many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues, [using as an example] ***human abilities to model, predict, and manage current and future impacts*** [on climate]. HS-ESS3-5

HS-ESS3-1

Students who demonstrate understanding can:

HS-ESS3-1. **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.** [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Disciplinary Core Ideas

ESS3.A: Natural Resources

- Resource availability has guided the development of human society.

ESS3.B: Natural Hazards

- Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

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Connections to Engineering, Technology, and Applications of Science

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

- Modern civilization depends on major technological systems.

Observable features of the student performance by the end of the course:			
1	Articulating the explanation of phenomena		
	a	Students construct an explanation that includes:	
		i.	Specific cause and effect relationships between environmental factors (natural hazards, changes in climate, and the availability of natural resources) and features of human societies including population size and migration patterns; and
		ii.	That technology in modern civilization has mitigated some of the effects of natural hazards, climate, and the availability of natural resources on human activity.
2	Evidence		
	a	Students identify and describe* the evidence to construct their explanation, including:	
		i.	Natural hazard occurrences that can affect human activity and have significantly altered the sizes and distributions of human populations in particular regions;
		ii.	Changes in climate that affect human activity (e.g., agriculture) and human populations, and that can drive mass migrations;
		iii.	Features of human societies that have been affected by the availability of natural resources; and
		iv.	Evidence of the dependence of human populations on technological systems to acquire natural resources and to modify physical settings.

	b	Students use a variety of valid and reliable sources for the evidence, potentially including theories, simulations, peer review, or students' own investigations.
3	Reasoning	
	a	Students use reasoning that connects the evidence, 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 describe*:
		i. The effect of natural hazards, changes in climate, and the availability of natural resources on features of human societies, including population size and migration patterns; and
		ii. How technology has changed the cause and effect relationship between the development of human society and natural hazards, climate, and natural resources.
	b	Students describe* reasoning for how the evidence allows for the distinction between causal and correlational relationships between environmental factors and human activity.

HS-ESS3-3

Students who demonstrate understanding can:

HS-ESS3-3. **Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.** [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [*Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.*]

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

Science and Engineering Practices

Using Mathematics and Computational Thinking

Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Create a computational model or simulation of a phenomenon, designed device, process, or system.

Disciplinary Core Ideas

ESS3.C: Human Impacts on Earth Systems

- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

Crosscutting Concepts

Stability and Change

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

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Connections to Engineering, Technology, and Applications of Science

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

- Modern civilization depends on major technological systems.
- New technologies can have deep impacts on society and the environment, including some that were not anticipated.

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Connections to Nature of Science

Science is a Human Endeavor

- Science is a result of human endeavors, imagination, and creativity.

Observable features of the student performance by the end of the course:			
1	Representation		
	a	Students create a computational simulation (using a spreadsheet or a provided multi-parameter program) that contains representations of the relevant components, including:	
		i.	A natural resource in a given ecosystem;
		ii.	The sustainability of human populations in a given ecosystem;
		iii.	Biodiversity in a given ecosystem; and

		iv. The effect of a technology on a given ecosystem.
2	Computational modeling	
	a	Students describe* simplified realistic (corresponding to real-world data) relationships between simulation variables to indicate an understanding of the factors (e.g., costs, availability of technologies) that affect the management of natural resources, human sustainability, and biodiversity. *(For example, a relationship could be described that the amount of a natural resource does not affect the sustainability of human populations in a given ecosystem without appropriate technology that makes use of the resource; or a relationship could be described that if a given ecosystem is not able to sustain biodiversity, its ability to sustain a human population is also small.)*
	b	Students create a simulation using a spreadsheet or provided multi-parameter program that models each component and its simplified mathematical relationship to other components. Examples could include:
		i. S=C*B*R*T, where S is sustainability of human populations, C is a constant, B is biodiversity, R is the natural resource, and T is a technology used to extract the resource so that if there is zero natural resource, zero technology to extract the resource, or zero biodiversity, the sustainability of human populations is also zero; and
		ii. B=B1+C*T, where B is biodiversity, B1 is a constant baseline biodiversity, C is a constant that expresses the effect of technology, and T is a given technology, so that a given technology could either increase or decrease biodiversity depending on the value chosen for C.
	c	The simulation contains user-controlled variables that can illustrate relationships among the components (e.g., technology having either a positive or negative effect on biodiversity).
3	Analysis	
	a	Students use the results of the simulation to:
		i. Illustrate the effect on one component by altering other components in the system or the relationships between components;
		ii. Identify the effects of technology on the interactions between human populations, natural resources, and biodiversity; and
		iii. Identify feedbacks between the components and whether or not the feedback stabilizes or destabilizes the system.
	b	Students compare the simulation results to a real world example(s) and determine if the simulation can be viewed as realistic.
	c	Students identify the simulation’s limitations relative to the phenomenon at hand.

HS-ESS3-5

Students who demonstrate understanding can:

HS-ESS3-5. **Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.** [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [*Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using computational models in order to make valid and reliable scientific claims. - ***Connections to Nature of Science*** **Scientific Investigations Use a Variety of Methods** • Science investigations use diverse methods and do not always use the same set of procedures to obtain data. • New technologies advance scientific knowledge. **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based on empirical evidence. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation.	**ESS3.D: Global Climate Change** • Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.	**Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Observable features of the student performance by the end of the course:			
1	Organizing data		
	a	Students organize data (e.g., with graphs) from global climate models (e.g., computational simulations) and climate observations over time that relate to the effect of climate change on the physical parameters or chemical composition of the atmosphere, geosphere, hydrosphere, or cryosphere.	
	b	Students describe* what each data set represents.	
2	Identifying relationships		
	a	Students analyze the data and identify and describe* relationships within the datasets, including:	
		i.	Changes over time on multiple scales; and
		ii.	Relationships between quantities in the given data.
3	Interpreting data		

	a	Students use their analysis of the data to describe* a selected aspect of present or past climate and the associated physical parameters (e.g., temperature, precipitation, sea level) or chemical composition (e.g., ocean pH) of the atmosphere, geosphere, hydrosphere or cryosphere.
	b	Students use their analysis of the data to predict the future effect of a selected aspect of climate change on the physical parameters (e.g., temperature, precipitation, sea level) or chemical composition (e.g., ocean pH) of the atmosphere, geosphere, hydrosphere or cryosphere.
	c	Students describe* whether the predicted effect on the system is reversible or irreversible.
	d	Students identify one source of uncertainty in the prediction of the effect in the future of a selected aspect of climate change.
	e	In their interpretation of the data, students:
		i. Make a statement regarding how variation or uncertainty in the data (e.g., limitations, accuracy, any bias in the data resulting from choice of sample, scale, instrumentation, etc.) may affect the interpretation of the data; and
		ii. Identify the limitations of the models that provided the simulation data and ranges for their predictions.