Middle School Phenomenon Model Course III – Bundle 3
Life Affects Earth

This is the third bundle of the Middle School Phenomenon Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question "How can people influence Earth?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of engineering solutions related to human effects on their environment. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health (LS2.C as in MS-LS2-5). Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on, such as water purification and recycling (LS4.D as in MS-LS2-5).

Just as changes in biodiversity can affect humans, human activities can alter the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. Changes to Earth's environments can also have different impacts (negative and positive) for different living things (ESS3.C as in MS-ESS3-3). However, 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 (ESS3.C as in MS-ESS3-3 and MS-ESS3-4).

The engineering design idea that the more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful (ETS1.A as in MS-ETS1-1) and 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-LS2-5 and MS-ETS1-2) could connect to several different science concepts, such as that changes in biodiversity can influence humans' resources (LS4.D as in MS-LS2-5), or that changes to Earth's environments can have different impacts for different living things (ESS3.C as in MS-ESS3-3). Connections could be made through engineering design tasks such as defining problems related to humans' resources or impacts on living things to determine the necessary criteria and constraints for successful solutions, and then using those criteria and constraints to evaluate proposed solutions.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (MS-ETS1-1), constructing explanations and designing solutions (MS-ESS3-3), and engaging in argumentation (MS-LS2-5, MS-ESS3-4, and MS-ETS1-2). 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 (MS-ESS3-4 and MS-ESS3-5) and Stability and Change (MS-LS2-5). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-LS2-5**. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*** [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.] 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-ESS3-4. **Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.** [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.] MS-ETS1-1. **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.** 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	My city was built on former wetlands. Some urban areas outside the flood zone now flood regularly.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. Students could *ask questions to identify evidence* [about why] ***the completeness or integrity of an ecosystem's biodiversity is used as a measure of its health***. MS-LS2-5 **Developing and Using Models** • Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. Students could *develop a model based on evidence to match what happens if* ***human activities alter the biosphere***. MS-ESS3-3 **Planning and Carrying Out Investigations** • Evaluate the accuracy of various methods for collecting data. Students could *evaluate the accuracy of various methods for collecting data* [about how] ***changes in biodiversity can influence humans' resources***. MS-LS2-5

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Use graphical displays of large data sets to identify temporal and spatial relationships. Students could *use graphical displays of large data sets to identify relationships* [between] ***per-capita consumption of natural resources*** [and] ***negative impacts on Earth***. MS-ESS3-3 and MS-ESS3-4 **Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use digital tools to analyze very large data sets for patterns and trends* [to determine if there is evidence that] ***human activities*** [might] ***cause the extinction of other species***. MS-ESS3-3 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events. Students could *apply scientific ideas, and evidence to construct an explanation* [of how] ***changes in biodiversity can influence humans'*** [access to] ***food, energy, and medicines.*** MS-LS2-5 **Engaging in Argument from Evidence** • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. Students could *compare and critique two arguments* [about the effects of] ***human activities*** [on] ***the biosphere***, *analyzing whether the arguments emphasize similar or different evidence.* MS-ESS3-3 **Obtaining, Evaluating, and Communicating Information** • Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts. Students could *evaluate data and conclusions in technical texts* [related to] ***engineered activities and technologies*** [that can help reduce] ***negative impacts on Earth*** [from] ***consumption of natural resources***. MS-ESS3-3 and MS-ESS3-4
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Patterns can be used to identify cause and effect relationships. Students could construct an argument from evidence for how *patterns can be used to identify cause and effect relationships* [between] ***increases in human populations*** [and] ***negative impacts on Earth***. MS-ESS3-3 and MS-ESS3-4 **Systems and System Models** • Models are limited in that they only represent certain aspects of the system under study. Students could describe that *models* [of] ***biodiversity influencing humans' resources*** *are limited in that they only represent certain aspects of the system under study*. MS-ESS2-6

Additional Crosscutting Concepts Building to the PEs (Continued)	**Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could analyze and interpret data on how *stability* [of] ***the biosphere*** *might be disturbed either by sudden events* or *gradual changes that accumulate over time* [due to] ***human activities***. MS-ESS3-3
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods** • Scientific values function as criteria in distinguishing between science and non-science. Students could ask questions about how *scientific values* [are used to] *distinguish between science and non-science* [in understanding how] ***changes to Earth's environment can have different impacts for different living things***. MS-ESS3-3 **Science is a Human Endeavor** • Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas. Students could construct an argument from evidence for how *scientists' habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas* [affect their understanding of how] ***changes in biodiversity can influence ecosystem services*** [such as] ***water purification***. MS-LS2-5

MS-LS2-5 Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

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

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(s).

- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

LS4.D: Biodiversity and Humans

- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.*(secondary)*

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. *(secondary)*

Crosscutting Concepts

Stability and Change

- Small changes in one part of a system might cause large changes in another part.

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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 use 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.

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Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Observable features of the student performance by the end of the course:			
1	Identifying the given design solution and supporting evidence		
	a	Students identify and describe*:	
		i.	The given competing design solutions for maintaining biodiversity and ecosystem services.
		ii.	The given problem involving biodiversity and/or ecosystem services that is being solved by the given design solutions, including information about why biodiversity and/or ecosystem services are necessary to maintaining a healthy ecosystem.
		iii.	The given evidence about performance of the given design solutions.
2	Identifying any potential additional evidence that is relevant to the evaluation		
	a	Students identify and describe* the additional evidence (in the form of data, information, or other appropriate forms) that is relevant to the problem, design solutions, and evaluation of the solutions, including:	
		i.	The variety of species (biodiversity) found in the given ecosystem.
		ii.	Factors that affect the stability of the biodiversity of the given ecosystem.

		iii.	Ecosystem services (e.g., water purification, nutrient recycling, prevention of soil erosion) that affect the stability of the system.
	b	Students collaboratively define and describe* criteria and constraints for the evaluation of the design solution.	
3	Evaluating and critiquing the design solution		
	a	In their evaluations, students use scientific evidence to:	
		i.	Compare the ability of each of the competing design solutions to maintain ecosystem stability and biodiversity.
		ii.	Clarify the strengths and weaknesses of the competing designs with respect to each criterion and constraint (e.g., scientific, social, and economic considerations).
		iii.	Assess possible side effects of the given design solutions on other aspects of the ecosystem, including the possibility that a small change in one component of an ecosystem can produce a large change in another component of the ecosystem.

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-ESS3-4 Earth and Human Activity

Students who demonstrate understanding can:

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

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

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(s).

- Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

Disciplinary Core Ideas

ESS3.C: Human Impacts on Earth Systems

- 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

- 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.

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Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Observable features of the student performance by the end of the course:		
1	Supported claims	
	a	Students make a claim, to be supported by evidence, to support or refute an explanation or model for a given phenomenon. Students include the following idea in their claim: that increases in the size of the human population and per-capita consumption of natural resources affect Earth systems.
2	Identifying scientific evidence	
	a	Students identify evidence to support the claim from the given materials, including:
		i. Changes in the size of human population(s) in a given region or ecosystem over a given timespan.

		ii.	Per-capita consumption of resources by humans in a given region or ecosystem over a given timespan.
		iii.	Changes in Earth systems in a given region or ecosystem over a given timespan.
		iv.	The ways engineered solutions have altered the effects of human activities on Earth's systems.
3	Evaluating and critiquing evidence		
	a	Students evaluate the evidence for its necessity and sufficiency for supporting the claim.	
	b	Students determine whether the evidence is sufficient to determine causal relationships between consumption of natural resources and the impact on Earth systems.	
	c	Students consider alternative interpretations of the evidence and describe* why the evidence supports the claim they are making, as opposed to any alternative claims.	
4	Reasoning and synthesis		
	a	Students use reasoning to connect the evidence and evaluation to the claim. In their arguments, students describe* a chain of reasoning that includes:	
		i.	Increases in the size of the human population or in the per-capita consumption of a given population cause increases in the consumption of natural resources.
		ii.	Natural resource consumption causes changes in Earth systems.
		iii.	Because human population growth affects natural resource consumption and natural resource consumption has an effect on Earth systems, changes in human populations have a causal role in changing Earth systems.
		iv.	Engineered solutions alter the effects of human populations on Earth systems by changing the rate of natural resource consumption or mitigating the effects of changes in Earth systems.

MS-ETS1-1 Engineering Design

Students who demonstrate understanding can:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

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

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.

- 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.

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

Crosscutting Concepts

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.
- The uses of technologies and 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.

Observable features of the student performance by the end of the course:			
1	Identifying the problem to be solved		
	a	Students describe* a problem that can be solved through the development of an object, tool, process, or system.	
2	Defining the process or system boundaries and the components of the process or system		
	a	Students identify the system in which the problem is embedded, including the major components and relationships in the system and its boundaries, to clarify what is and is not part of the problem. In their definition of the system, students include:	
		i.	Which individuals or groups need this problem to be solved.
		ii.	The needs that must be met by solving the problem.
		iii.	Scientific issues that are relevant to the problem.
		iv.	Potential societal and environmental impacts of solutions.
		v.	The relative importance of the various issues and components of the process or system.
3	Defining criteria and constraints		
	a	Students define criteria that must be taken into account in the solution that:	
		i.	Meet the needs of the individuals or groups who may be affected by the problem (including defining who will be the target of the solution).
		ii.	Enable comparisons among different solutions, including quantitative considerations when appropriate.
	b	Students define constraints that must be taken into account in the solution, including:	
		i.	Time, materials, and costs.
		ii.	Scientific or other issues that are relevant to the problem.
		iii.	Needs and desires of the individuals or groups involved that may limit acceptable solutions.
		iv.	Safety considerations.
		v.	Potential effect(s) on other individuals or groups.
		vi.	Potential negative environmental effects of possible solutions or failure to solve the problem.

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.	