High School Modified Domains Model Course III – Life Sciences
Bundle 6: Humans Affect the Lives of Other Organisms

This is the sixth bundle of the High School Domains Model Course III – Life Sciences. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 6 Question: This bundle is assembled to address the question "how can we make a positive impact on Earth and organisms?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how to sustain human populations while increasing the positive effects of human activities on the environment and biodiversity. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Humans depend on the living world (LS4.D as in HS-LS4-6), creating a need for responsible management of natural resources to sustain human societies and the biodiversity that supports them (ESS3.C as in HS-ESS3-3). Resource availability 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 (ESS3.B as in HS-ESS3-1). Conversely, human activity can disrupt an ecosystem and threaten the survival of some species (LS2.C as in HS-LS2-) through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change (LS4.D as in HS-LS4-6).Changes in the physical environment have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline or extinction of some species (LS4.C as in HS-LS4-6).

Three engineering design core ideas are integrated in this bundle. The first two are 1) that it is important to take into account a range of constraints, including cost safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts when evaluating solutions (ETS1.B as in HS-ETS1-3) and 2) that criteria can be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed (ETS1.C as in HS-ETS1-2). These core ideas could connect to several different science concepts, including the importance of responsibly managing natural resources to sustain human societies and biodiversity (ESS3.C as in HS-ESS3-3). Connections could be made through engineering design tasks, such as designing methods of producing more food with fewer resources or designing housing subdivisions to minimize negative effects on biodiversity (ESS3.C as in HS-ESS3-3).

The third engineering core idea integrated in this bundle is that both physical models and computers can be used in running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs (ETS1.B as in HS-ETS1-4). This core idea could connect to many different science ideas, including that scientists and engineers can develop technologies that produce less pollution and waste and that preclude ecosystem degradation (ESS3.C as in HS-ESS3-4) or that anthropogenic changes can disrupt an ecosystem and threaten the survival of some species (LS2.C as in HS-LS2-7). Connections could be made by developing presentations for community members about new systems for minimizing disruption of local habitats or minimizing the introduction of invasive species.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of using mathematics and computational thinking (HS-LS4-6, HS-ESS3-3, and HS-ETS1-4) and constructing explanations and designing solutions (HS-LS2-7, HS-ESS3-1, HS-ESS3-4, HS-ETS1-2, and HS-ETS1-3). 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-LS4-6 and HS-ESS3-1), Systems and System Models (HS-ETS1-4), and Stability and Change (HS-LS2-7, HS-ESS3-3, and HS-ESS3-4). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	HS-LS2-7. **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*** [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.] HS-LS4-6. **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*** [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.] 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.] HS-ESS3-4. **Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).] HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.** HS-ETS1-4. **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**
Example Phenomenon	When we travel out of state to go camping, we are not allowed to bring our own firewood. There are “ghost towns” in the west part of the country.

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] ***management of natural resources*** [affects] ***the sustainability of human societies*** *to determine if the questions are testable and relevant.* HS-ESS3-3 **Developing and Using Models** • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Students could *use a model based on evidence to predict the relationships between* ***anthropogenic changes in the environment and the survival of some species***. HS-LS2-7 **Planning and Carrying Out Investigations** • Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. Students could *plan a safe and ethical test* [of] ***a technology that produces less pollution and waste***. HS-ESS3-4 **Analyzing and Interpreting Data** • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. Students could *evaluate the impact of new data on a model of a proposed* ***technology that produces less pollution and waste and that preclude ecosystem degradation***. HS-ESS3-4 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could *use mathematical representations of phenomena to support claims* [that] ***natural hazards have significantly altered the sizes of human populations***. HS-ESS3-1 **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 solve design problems* [related to] ***responsible management of natural resources***. HS-ESS3-3 **Engaging in Argument from Evidence** • Respectfully provide critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, and responding thoughtfully to diverse perspectives. Students could *respectfully provide 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

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Students could *compare, integrate, and evaluate sources of information presented in different media or formats to solve a problem* [related to how] ***anthropogenic changes in the environment can disrupt an ecosystem and threaten the survival of some species, and*** [in doing so,] ***consider social, cultural, and environmental impacts*** [of the solution]. HS-LS2-7 and HS-ETS1-3
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Students could *predict cause and effect relationships for* [for how] ***anthropogenic changes in the environment can disrupt an ecosystem*** *by examining what is known about smaller scale mechanisms within the system*. HS-LS2-7 **Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Students could construct an argument from evidence for how *the significance of* ***an ecosystem disruption*** *is dependent on the scale, proportion, and quantity at which it occurs*. HS-LS2-7 **Systems and System Models** • Models can be used predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. Students could evaluate the merits and limitations of using two different models of how ***resource availability has driven human migrations*** *to predict* [future human migrations, describing that] *these predictions have limited precision and reliability*. HS-ESS3-1
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. Students could obtain, evaluate, and communicate how a scientific theory is a substantiated explanation based on a body that facts that has been repeatedly confirmed and has been validated by the scientific community, [using as an example the body of facts supporting the idea that] anthropogenic changes in the environment can disrupt an ecosystem and threaten the survival of some species. HS-LS2-7 **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 solve issues. Students could obtain, evaluate, and communicate information [about how] ***scientists and engineers can make contributions by developing technologies that produce less pollution and waste*** [while also] *relying on social and cultural contexts to solve issues* [by] ***considering social, cultural, and environmental impacts*** [of the technologies]. HS-ESS3-4 and HS-ETS1-3

HS-LS2-7

Students who demonstrate understanding can:

HS-LS2-7. **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*** [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

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 ideas, principles, and theories.

- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Moreover, anthropogenic changes (induced by human activity) in the environment — including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change — can disrupt an ecosystem and threaten the survival of some species.

LS4.D: Biodiversity and Humans

- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). *(secondary)*
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. *(secondary) (Note: This Disciplinary Core Idea is also addressed by HS-LS4-6.)*

ETS1.B: Developing Possible Solutions

- When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. *(secondary)*

Crosscutting Concepts

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable.

Observable features of the student performance by the end of the course:		
1	Using scientific knowledge to generate the design solution	
	a	Students design a solution that involves reducing the negative effects of human activities on the environment and biodiversity, and that relies on scientific knowledge of the factors affecting changes and stability in biodiversity. Examples of factors include but are not limited to:
		i. Overpopulation;
		ii. Overexploitation;
		iii. Habitat destruction;
		iv. Pollution;
		v. Introduction of invasive species; and
		vi. Changes in climate.
	b	Students describe* the ways the proposed solution decreases the negative effects of human activity on the environment and biodiversity.
2	Describing criteria and constraints, including quantification when appropriate	
	a	Students describe* and quantify (when appropriate) the criteria (amount of reduction of impacts and human activities to be mitigated) and constraints (for example, cost, human needs, and environmental impacts) for the solution to the problem, along with the tradeoffs in the solution.
3	Evaluating potential solutions	
	a	Students evaluate the proposed solution for its impact on overall environmental stability and changes.
	b	Students evaluate the cost, safety, and reliability, as well as social, cultural, and environmental impacts, of the proposed solution for a select human activity that is harmful to an ecosystem.
4	Refining and/or optimizing the design solution	
	a	Students refine the proposed solution by prioritizing the criteria and making tradeoffs as necessary to further reduce environmental impact and loss of biodiversity while addressing human needs.

HS-LS4-6

Students who demonstrate understanding can:

HS-LS4-6. **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*** [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]

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
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 or revise a simulation of a phenomenon, designed device, process, or system.	**LS4.C: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species. **LS4.D: Biodiversity and Humans** • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. *(Note: This Disciplinary Core Idea is also addressed by HS-LS2-7.)* **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *(secondary)* • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. *(secondary)*	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Observable features of the student performance by the end of the course:		
1	Representation	
	a	Students create or revise a simulation that:
		i. Models effects of human activity (e.g., overpopulation, overexploitation, adverse habitat alterations, pollution, invasive species, changes in climate) on a threatened or endangered species or to the genetic variation within a species; and
		ii. Provides quantitative information about the effect of the solutions on threatened or endangered species.
	b	Students describe* the components that are modeled by the computational simulation, including human activity (e.g., overpopulation, overexploitation, adverse habitat alterations, pollution, invasive species, changes in climate) and the factors that affect biodiversity.
	c	Students describe* the variables that can be changed by the user to evaluate the proposed solutions, tradeoffs, or other decisions.
2	Computational modeling	
	a	Students use logical and realistic inputs for the simulation that show an understanding of the reliance of ecosystem function and productivity on biodiversity, and that take into account the constraints of cost, safety, and reliability as well as cultural, and environmental impacts.
	b	Students use the simulation to identify possible negative consequences of solutions that would outweigh their benefits.
3	Analysis	
	a	Students compare the simulation results to expected results.
	b	Students analyze the simulation results to determine whether the simulation provides sufficient information to evaluate the solution.
	c	Students identify the simulation's limitations.
	d	Students interpret the simulation results, and predict the effects of the specific design solutions on biodiversity based on the interpretation.
4	Revision	
	a	Students revise the simulation as needed to provide sufficient information to evaluate the solution.

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-ESS3-4

Students who demonstrate understanding can:

HS-ESS3-4. **Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

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.

- Design or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Disciplinary Core Ideas

ESS3.C: Human Impacts on Earth Systems

- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *(secondary)*

Crosscutting Concepts

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system.

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Connections to Engineering, Technology, and Applications of Science

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

- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Observable features of the student performance by the end of the course:			
1	Using scientific knowledge to generate the design solution		
	a	Students use scientific information to generate a number of possible refinements to a given technological solution. Students:	
		i.	Describe* the system being impacted and how the human activity is affecting that system;
		ii.	Identify the scientific knowledge and reasoning on which the solution is based;
		iii.	Describe* how the technological solution functions and may be stabilizing or destabilizing the natural system;
		iv.	Refine a given technological solution that reduces human impacts on natural systems; and
		v.	Describe* that the solution being refined comes from scientists and engineers in the real world who develop technologies to solve problems of environmental degradation.
2	Describing criteria and constraints, including quantification when appropriate		
	a	Students describe* and quantify (when appropriate):	
		i.	Criteria and constraints for the solution to the problem; and
		ii.	The tradeoffs in the solution, considering priorities and other kinds of research-driven tradeoffs in explaining why this particular solution is or is not needed.
3	Evaluating potential refinements		

	a	In their evaluation, students describe* how the refinement will improve the solution to increase benefits and/or decrease costs or risks to people and the environment.
	b	Students evaluate the proposed refinements for:
		i. Their effects on the overall stability of and changes in natural systems; and
		ii. Cost, safety, aesthetics, and reliability, as well as cultural and environmental impacts.

HS-ETS1-2

Students who demonstrate understanding can:

HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**

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
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 ideas, principles and theories. • Design a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.	

Observable features of the student performance by the end of the course:		
1	Using scientific knowledge to generate the design solution	
	a	Students restate the original complex problem into a finite set of two or more sub-problems (in writing or as a diagram or flow chart).
	b	For at least one of the sub-problems, students propose two or more solutions that are based on student-generated data and/or scientific information from other sources.
	c	Students describe* how solutions to the sub-problems are interconnected to solve all or part of the larger problem.
2	Describing criteria and constraints, including quantification when appropriate	
	a	Students describe* criteria and constraints for the selected sub-problem.
	b	Students describe* the rationale for the sequence of how sub-problems are to be solved, and which criteria should be given highest priority if tradeoffs must be made.

HS-ETS1-3

Students who demonstrate understanding can:

HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental 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
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 ideas, principles and theories. • Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	- ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Observable features of the student performance by the end of the course:			
1	Evaluating potential solutions		
	a	In their evaluation of a complex real-world problem, students:	
		i.	Generate a list of three or more realistic criteria and two or more constraints, including such relevant factors as cost, safety, reliability, and aesthetics that specifies an acceptable solution to a complex real-world problem;
		ii.	Assign priorities for each criterion and constraint that allows for a logical and systematic evaluation of alternative solution proposals;
		iii.	Analyze (quantitatively where appropriate) and describe* the strengths and weaknesses of the solution with respect to each criterion and constraint, as well as social and cultural acceptability and environmental impacts;
		iv.	Describe* possible barriers to implementing each solution, such as cultural, economic, or other sources of resistance to potential solutions; and
		v.	Provide an evidence-based decision of which solution is optimum, based on prioritized criteria, analysis of the strengths and weaknesses (costs and benefits) of each solution, and barriers to be overcome.
2	Refining and/or optimizing the design solution		
	a	In their evaluation, students describe* which parts of the complex real-world problem may remain even if the proposed solution is implemented.	

HS-ETS1-4

Students who demonstrate understanding can:

HS-ETS1-4. **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**

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
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. • Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.	**ETS1.B: Developing Possible Solutions** • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.

Observable features of the student performance by the end of the course:			
1	Representation		
	a	Students identify the following components from a given computer simulation:	
		i.	The complex real-world problem with numerous criteria and constraints;
		ii.	The system that is being modeled by the computational simulation, including the boundaries of the systems;
		iii.	What variables can be changed by the user to evaluate the proposed solutions, tradeoffs, or other decisions; and
		iv.	The scientific principle(s) and/or relationship(s) being used by the model.
2	Computational Modeling		
	a	Students use the given computer simulation to model the proposed solutions by:	
		i.	Selecting logical and realistic inputs; and
		ii.	Using the model to simulate the effects of different solutions, tradeoffs, or other decisions.
3	Analysis		
	a	Students compare the simulated results to the expected results.	
	b	Students interpret the results of the simulation and predict the effects of the proposed solutions within and between systems relevant to the problem based on the interpretation.	
	c	Students identify the possible negative consequences of solutions that outweigh their benefits.	
	d	Students identify the simulation's limitations.	