SIMOC – Scalable, Interactive Model of an Off-world Community

Grades 9-14 Next Generation Science Standards, Common Core State Standards, and 21st Century Skills Alignment Document

WHAT STUDENTS DO: Use the SIMOC model to develop a habitat to support life off-world.

Students work with a model using authentic data gathered from decades of NASA and other science research on life support systems to develop a habitat to support at least 4 researchers on Mars or other off-world environments They will actively engage in creative critical thinking and iterative innovation through collaboration and persistence.

NRC FRAMEWORK/NGSS CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES (IO)
HOW DO ENGINEERS SOLVE PROBLEMS? *NGSS Core Question: ETS1: Engineering Design* What is a design for? What are the criteria and constraints of a successful solution? *NGSS ETS1.A: Defining & Delimiting an Engineering Problem* What Is the process for developing potential design solutions? *NGSS ETS1.B: Developing Possible Solutions* How can the various proposed design solutions be compared and improved? *NGSS ETS1.C: Optimizing the Design Solution*	*Students will be able to* **IO1: Use and modify a model limited by criteria and constraints to solve a complex science and engineering problem**
How and why do organisms interact with their environment and what are the effects of these interactions? *NGSS Core Question: LS2: Ecosystems: Interactions, Energy, and Dynamics* How do organisms interact with the living and nonliving environments to obtain matter and energy? *NGSS LS2.A: Interdependent Relationships in Ecosystems* How do matter and energy move through an ecosystem?	**IO2: Plan and conduct investigations using models to understand and test the interdependence of biotic and abiotic components of an ecosystem**

NGSS LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

What happens to the ecosystems when the environment changes?

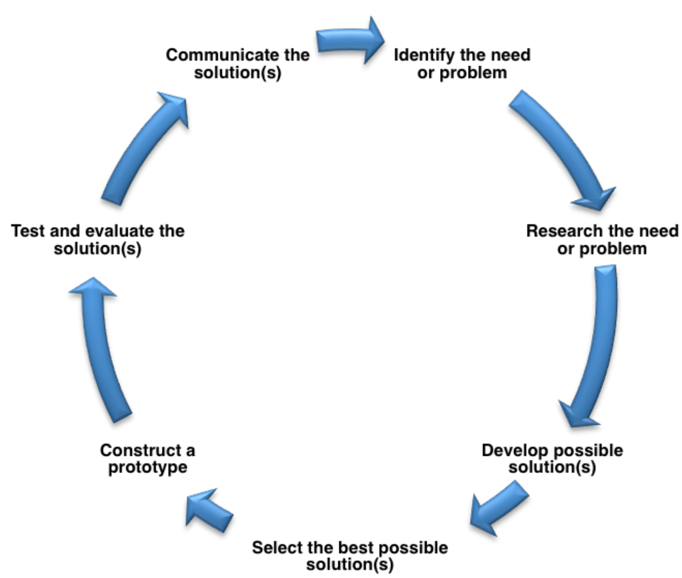
NGSS LS2.C: Ecosystem Dynamics, Functioning, and Resilience

1.0 About This Activity

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Mars instructional series. The 5E stages can be cyclical and iterative.

The format for developing a question was guided by statements made by Bybee in "Scientific and engineering practices in K-12 classrooms: Understanding a framework for K-12 science education" publish by NSTA. Here Bybee explained that the term "practices" was a much more accurate explanation of scientific inquiry. These practices "involve doing and learning in such a way that cannot be really separated." The process for reaching a scientific research question in this lesson has been discussed and vetted through planetary scientists actively involved in research.

Additionally, students engage in an engineering design activity using SIMOC. They use the engineering design process to solve problems associated with living on Mars and doing exploration and research for an extended period of time. A brief description of the engineering design process can be seen in this diagram. This design, along with the 5E Instructional Model, provides the organization for the activitities.



2.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Instructional objectives and learning outcomes are aligned with

- Achieve Inc.'s, *Next Generation Science Standards (NGSS)*
- National Research Council's, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*
- National Governors Association Center for Best Practices (NGA Center) and Council of Chief State School Officers (CCSSO)'s, *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and* Technical Subjects
- Partnership for 21st Century Skills, *A Framework for 21st Century Learning*

The following chart provides details on alignment among the core and component NGSS questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and NGSS.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO),** also aligned with NGSS Framework and NGSS.
- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics**.

Important Note: This lesson is color-coded to help teachers identify each of the three dimensions of NGSS. The following identifying colors are used: Practices are blue, Cross-Cutting Concepts are green, and Disciplinary Core Ideas are orange.

This color-coding is consistent with the NGSS Performance Expectations and Foundation Boxes.

Quick View of Standards Alignment:

This alignment document provides full details of standards alignment, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were integrated to ensure maximal learning. For convenience, a quick view follows:

The following are the Disciplinary Core Ideas most associated with these lessons.

HOW DO ENGINEERS SOLVE PROBLEMS?

NGSS Core Question: ETS1: Engineering Design

What is a design for? What are the criteria and constraints of a successful solution?

NGSS ETS1.A: Defining & Delimiting an Engineering Problem

What Is the process for developing potential design solutions?

NGSS ETS1.B: Developing Possible Solutions

How can the various proposed design solutions be compared and improved?

NGSS ETS1.C: Optimizing the Design Solution

How and why do organisms interact with their environment and what are the effects of these interactions?

NGSS Core Question: LS2: Ecosystems: Interactions, Energy, and Dynamics

How do organisms interact with the living and nonliving environments to obtain matter and energy?

NGSS LS2.A: Interdependent Relationships in Ecosystems

How do matter and energy move through an ecosystem?

NGSS LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

What happens to the ecosystems when the environment changes?

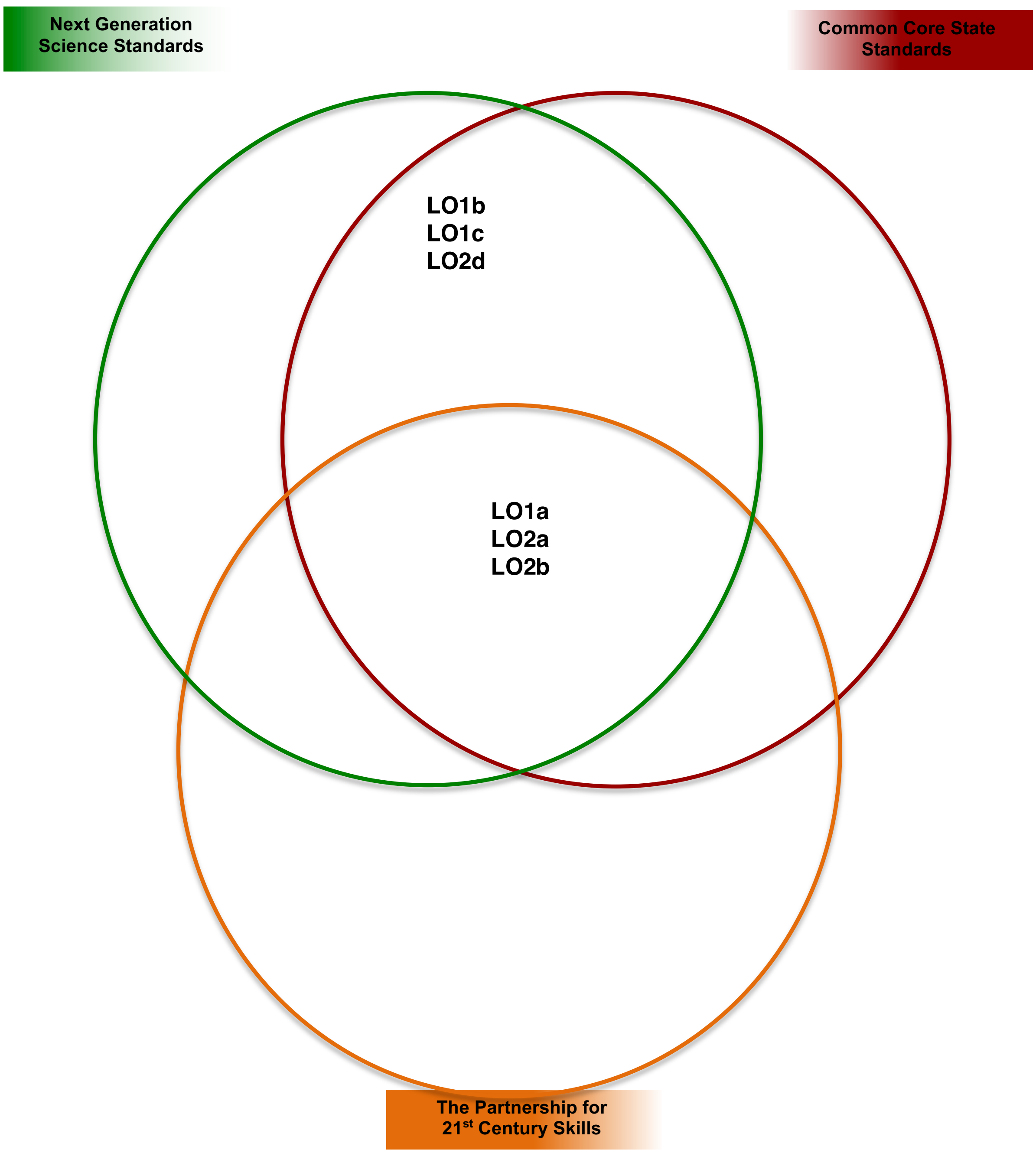
NGSS LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Instructional Objective *Students will be able to*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO1: **Use and modify a model limited by criteria and constraints to solve a complex science and engineering problem**	**LO1a:** to **analyze criteria and constraints** in an **engineering design task** and **collect data to generate and refine** an **appropriate solution using tools (instruments) to achieve the mission goal** **LO1b:** **to identify and explain** the **specific components** of the **engineering design cycle for the designed model** **LO1c:** to **identify and explain** the **complex relationship between science and engineering design**	**DISCIPLINARY CORE IDEA:** **EST1.A: Defining and Delimiting Engineering Problems** **EST1.B: Developing Possible Solutions** **EST1.C: Optimizing the Design Solution** **PS4.C: Information Technologies and Instrumentation** **PRACTICES:** 1. **Asking Questions and Defining Problems** 2. **Developing and Using Models** 3. **Planning and Carrying Out Investigations** 4. **Analyzing and Interpreting Data** 5. **Using mathematics and computational thinking** 6. **Constructing Explanations and Designing Solutions** 7. **Engaging in Argument from Evidence** **CROSSCUTTING CONCEPTS:** 1. **Cause and Effect** 2. **Systems and System Models** 3. **Energy and Matter** 4. **Structure and Function** 5. **Stability and Change** **Science is a Human Endeavor**	***Rubrics in SIMOC Lesson***

Instructional Objective *Students will be able to*	Learning Outcomes *Students will demonstrate the measurable abilities*	Standards *Students will address*	
IO2: **Plan and conduct investigations using models to understand and test the interdependence of biotic and abiotic components of an ecosystem**	**LO2a:** **to ask questions that can be investigated and that define a design problem to identify how humans are dependent on environmental interactions with other living things and nonliving factors in a system** **LO2b:** **to plan and conduct an investigation into maintaining a healthy ecosystem in a closed system by tracking the flow of matter and energy** **LO2c:** **to use and modify a model using evidence to establish stability over time in a dynamic engineered ecosystem** **LO2d:** **to construct an explanation that includes qualitative and quantitative relationships using models of systems** showing that organisms survive by obtaining necessary resources through interdependent relationships with other organisms and the physical environment.	**DISCIPLINARY CORE IDEA:** **LS2.A: Interdependent Relationships in Ecosystems** **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** **PRACTICES:** **1. Asking Questions and Defining Problems** **2. Developing and Using Models** **3. Planning and Carrying Out Investigations** **4. Analyzing and Interpreting Data** **5. Using mathematics and computational thinking** **6. Constructing Explanations and Designing Solutions** **7. Engaging in Argument from Evidence** **8. Obtaining, Evaluating, and Communicating Information** **CROSSCUTTING CONCEPTS:** **1. Cause and Effect** **2. Systems and System Models** **3. Energy and Matter** **4. Structure and Function** **5. Stability and Change** **Science is a Human Endeavor**	***Rubrics in SIMOC Lesson***

3.0 Learning Outcomes, NGSS, Common Core, & 21st Century Skills Connections

The connections diagram is used to organize the learning outcomes addressed in the lesson to establish where each will meet the Next Generation Science Standards, ELA Common Core Standards, and the 21st Century Skills and visually determine where there are overlaps in these documents.



4.0 Evaluation/Assessment

Use the *(N) Design Rubrics* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. There are several different rubrics that you can use depending on the focus of your class and your goals.

5.0 References

Achieve, Inc. (2013). *Next generation science standards*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications.* Colorado Springs: BSCS.

Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom.* Washington, DC: The National Academies Press.

Miller, Linn, & Gronlund. (2009). *Measurement and assessment in teaching*. Upper Saddle River, NJ: Pearson.

National Academies Press. (1996, January 1). *National science education standards*. Retrieved February 7, 2011 from http://www.nap.edu/catalog.php?record_id=4962

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards*. Washington, DC: Authors.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

The Partnership for 21st Century Skills (2011). *A framework for 21st century learning.* Retrieved March 15, 2012 from http://www.p21.o

(M) Teacher Resource. SIMOC NGSS Alignment (1 of 5)

Related Standard(s)

This lesson supports the preparation of students toward achieving Performance Expectations using the Practices, Cross-Cutting Concepts and Disciplinary Core Ideas defined below:

(HS-ETS1-1), (HS-ETS1-2), (HS-ETS1-4);
(HS-LS2-1), (HS-LS2-2), (HS-LS2-3), (HS-LS2-4), (HS-LS2-6);

Next Generation Science Standards Alignment (NGSS)

Instructional Objective	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
IO1: **Use and modify a model limited by criteria and constraints to solve a complex science and engineering problem**	**Asking Question and Defining Problems:** Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. **Developing and Using Models:** Develop a complex model that allows for manipulation and testing of a proposed process or system. Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict	**ETS1.A: Defining and Delimiting Engineering Problems:** Humanity faces major global challenges today, such as the need for sup- plies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** Both physical models and computers can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. Computers are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; 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. (HS-ETS1-4) **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 (trade-offs) may be needed. (HS-ETS1-2)	**Cause and Effect: S**tudents understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They recognize changes in systems may have various causes that may not have equal effects. **Systems and System Models:** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer

	phenomena, analyze systems, and/or solve problems. **Planning and Carrying Out Investigations:** Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. **Analyzing and Interpreting Data:** Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. **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. **Constructing Explanations and Designing Solutions:** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Engaging in Argument from Evidence:** Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant		models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models. **Energy and Matter: S**tudents learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. . **Structure and Function: S**tudents investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem. **Stability and Change: S**tudents understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback

	factors (e.g. economic, societal, environmental, ethical considerations). **Obtaining, Evaluating, and Communicating Information** Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.		can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.

(M) Teacher Resource. SIMOC NGSS Alignment (2 of 5)

Next Generation Science Standards Alignment (NGSS)

Instructional Objective	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
IO2: **Plan and conduct investigations using models to understand and test the interdependence of biotic and**	**Asking Question and Defining Problems:** Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. **Developing and Using Models:** Develop and/or use a	**LS2.A: Interdependent Relationships in Ecosystems:** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1, HS-LS2-2) **LS2.B: Cycles of Matter and Energy in Ecosystems:** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy	**Cause and Effect:** **S**tudents understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They recognize changes in systems may have various causes that may not have equal effects.

abiotic components of an ecosystem	model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Planning and Carrying Out Investigations:** Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. **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. Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. **Using Mathematical and Computational Thinking:** Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.	for life processes. Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. (HS-LS2-3, HS-LS2-4) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience:** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. 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. (HS-LS2-6)	**Systems and System Models** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models. **Energy and Matter:** **S**tudents learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. **Structure and Function:** **S**tudents investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem.

	Constructing Explanations and Designing Solutions: Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Engaging in Argument from Evidence:** Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. **Obtaining, Evaluating, and Communicating Information** Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.		**Stability and Change: S**tudents understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.

(M) Teacher Resource. SIMOC NGSS Alignment (3 of 5)

Next Generation Science Standards Alignment (NGSS)

Learning Outcomes	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
LO1a: to analyze criteria and constraints in an engineering design task and collect data to generate and refine an appropriate solution using tools (instruments) to achieve the mission goal	**Asking Question and Defining Problems:** Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. **Developing and Using Models:** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Planning and Carrying Out Investigations:** Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's	**ETS1.A: Defining and Delimiting Engineering Problems:** Humanity faces major global challenges today, such as the need for sup- plies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** Both physical models and computers can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. Computers are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; 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. (HS-ETS1-4) **LS2.A: Interdependent Relationships in Ecosystems:** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1, HS-LS2-2) **LS2.B: Cycles of Matter and Energy in Ecosystems:** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred	**Systems and System Models:** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models. **Energy and Matter: S**tudents learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems.

	design to ensure variables are controlled. **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. **Obtaining, Evaluating, and Communicating Information** Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.	upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. (HS-LS2-3, HS-LS2-4) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience:** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. 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. (HS-LS2-6)	Energy drives the cycling of matter within and between systems. . **Structure and Function:** **S**tudents investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem. **Stability and Change: S**tudents understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.
LO1b: to identify and explain the specific components of the engineering design cycle for the designed model	**Constructing Explanations and Designing Solutions:** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Engaging in Argument from Evidence:** Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.	**ETS1.A: Defining and Delimiting Engineering Problems:** Humanity faces major global challenges today, such as the need for sup- plies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** Both physical models and computers can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. Computers are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; 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. (HS-ETS1-4) **ETS1.C: Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions	**Cause and Effect:** **S**tudents understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They recognize changes in systems may have various causes that may not have equal effects. **Systems and System Models** Students can investigate or analyze a system by defining its boundaries and initial conditions,

		about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models.
LO1c: to identify and explain the complex relationship between science and engineering design	**Developing and Using Models:** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Planning and Carrying Out Investigations:** Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. **Engaging in Argument from Evidence:** Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience:** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. 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. (HS-LS2-6) **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 (trade-offs) may be needed. (HS-ETS1-2)	**Cause and Effect:** Students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They recognize changes in systems may have various causes that may not have equal effects. **Systems and System Models** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the

	that reflects scientific knowledge and student-generated evidence.		reliability due to the assumptions and approximations inherent in the models. **Stability and Change: S**tudents understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.

(M) Teacher Resource. SIMOC NGSS Alignment (4 of 5)

Next Generation Science Standards Alignment (NGSS)			
Learning Outcomes	**Science and Engineering Practices**	**Disciplinary Core Idea**	**Crosscutting Concepts**
LO2a: to ask questions that can be investigated and that define a design problem to identify how humans are dependent on environmental interactions with other living things and nonliving factors in a system	**Asking Question and Defining Problems:** Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.	**LS2.A: Interdependent Relationships in Ecosystems:** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1, HS-LS2-2) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience:** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. 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. (HS-LS2-6)	**Systems and System Models** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models.

LO2b: to plan and conduct an investigation into maintaining a healthy ecosystem in a closed system by tracking the flow of matter and energy	**Planning and Carrying Out Investigations:** Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. **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. **Using Mathematical and Computational Thinking:** Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.	**LS2.B: Cycles of Matter and Energy in Ecosystems:** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. (HS-LS2-3, HS-LS2-4) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience:** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. 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. (HS-LS2-6)	**Energy and Matter:** **S**tudents learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. **Stability and Change:** **S**tudents understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.
LO2c: to use and modify a model using evidence to establish stability over time in a dynamic engineered ecosystem	**Developing and Using Models:** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Planning and Carrying Out Investigations:** Plan an investigation or test a design individually and collaboratively to produce data to serve as the	**LS2.A: Interdependent Relationships in Ecosystems:** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1, HS-LS2-2) **LS2.B: Cycles of Matter and Energy in Ecosystems:** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. Plants or algae form the lowest level of the food web. At each	**Stability and Change:** **S**tudents understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.

	basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. **Engaging in Argument from Evidence:** Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. (HS-LS2-3, HS-LS2-4) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience:** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. 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. (HS-LS2-6)	
LO2d: to construct an explanation that includes qualitative and quantitative relationships using models of systems showing that organisms survive by obtaining necessary resources through interdependent relationships with other organisms and the physical environment.	**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. **Using Mathematical and Computational Thinking:** Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. **Constructing Explanations and Designing Solutions:** Design, evaluate, and/or refine a solution	**LS2.A: Interdependent Relationships in Ecosystems:** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1, HS-LS2-2) **LS2.B: Cycles of Matter and Energy in Ecosystems:** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain.	**Cause and Effect:** **S**tudents understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They recognize changes in systems may have various causes that may not have equal effects. **Structure and Function:** **S**tudents investigate systems by examining the properties of different materials, the structures of different components, and their

	to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Engaging in Argument from Evidence:** Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. (HS-LS2-3, HS-LS2-4) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience:** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. 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. (HS-LS2-6)	interconnections to reveal the system's function and/or solve a problem.

(M) Teacher Resource. SIMOC NGSS Individual Activity Alignment (5 of 5)

Next Generation Science Standards Activity Alignments (NGSS)

Activity	Phases of 5E Instructional Model	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
Designing the Habitat	**Engage**	**Asking Question and Defining Problems:** Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.	**LS2.A: Interdependent Relationships in Ecosystems:** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1, HS-LS2-2)	**Systems and System Models** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models.
Researching the Problem	**Explore**	**Asking Question and Defining Problems:** Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. **Obtaining, Evaluating, and Communicating Information** Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods	**LS2.B: Cycles of Matter and Energy in Ecosystems:** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain.	**Systems and System Models** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the

		used, and describe how they are supported or not supported by evidence.	The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. (HS-LS2-3, HS-LS2-4)	assumptions and approximations inherent in the models.
Developing Possible Solutions and Selecting the Best Solution	**Explore** **Explain**	**Developing and Using Models:** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Planning and Carrying Out Investigations:** Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. **Engaging in Argument from Evidence:** Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	**ETS1.A: Defining and Delimiting Engineering Problems:** Humanity faces major global challenges today, such as the need for sup- plies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** Both physical models and computers can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. Computers are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; 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. (HS-ETS1-4)	**Systems and System Models** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models. **Energy and Matter: S**tudents learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems.

Constructing a Prototype Design, Part 1	**Explore** **Explain**	**Developing and Using Models:** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.	**ETS1.A: Defining and Delimiting Engineering Problems:** Humanity faces major global challenges today, such as the need for sup- plies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** Both physical models and computers can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. Computers are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; 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. (HS-ETS1-4)	**Structure and Function: S**tudents investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem.
Evaluating the Solution, Part 1	**Evaluate**	**Constructing Explanations and Designing Solutions:** Design, evaluate, and/or refine 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 (trade-offs) may be needed. (HS-ETS1-2)	**Cause and Effect:** **S**tudents understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They recognize changes in systems may have various causes that may not have equal effects.
Communicating the Solution, Part 1	**Explain**	**Constructing Explanations and Designing Solutions:** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources	**ETS1.A: Defining and Delimiting Engineering Problems:** Humanity faces major global challenges today, such as the need for sup- plies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global	**Systems and System Models** Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical,

		of evidence, prioritized criteria, and tradeoff considerations.	challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** Both physical models and computers can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. Computers are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; 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. (HS-ETS1-4) **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 (trade-offs) may be needed. (HS-ETS1-2)	computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models.
Evaluating the Solution, Part 2	**Evaluate**	**Constructing Explanations and Designing Solutions:** Design, evaluate, and/or refine 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 (trade-offs) may be needed. (HS-ETS1-2)	**Cause and Effect:** **S**tudents understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They recognize changes in systems may have various causes that may not have equal effects.

Constructing a Prototype Design, Part 2	**Elaborate/Extend**	**Developing and Using Models:** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.	**ETS1.A: Defining and Delimiting Engineering Problems:** Humanity faces major global challenges today, such as the need for sup- plies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** Both physical models and computers can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. Computers are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; 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. (HS-ETS1-4)	**Structure and Function: S**tudents investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem.
Evaluating the Solution, Part 3: Running the SIMOC Simulation	**Elaborate** **Explore** **Evaluate**	**Developing and Using Models:** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Planning and Carrying Out Investigations:** Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and	**ETS1.A: Defining and Delimiting Engineering Problems:** Humanity faces major global challenges today, such as the need for sup- plies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** Both physical models and computers can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. Computers are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and	**Structure and Function: S**tudents investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem.

		evaluate the investigation's design to ensure variables are controlled. **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. **Using Mathematical and Computational Thinking:** Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.	describe a design problem; 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. (HS-ETS1-4) **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 (trade-offs) may be needed. (HS-ETS1-2) **LS2.A: Interdependent Relationships in Ecosystems:** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1, HS-LS2-2)	
Understanding the Science and Engineering Practices and the Crosscutting Concepts				

(M) Teacher Resource. SIMOC CCSS Alignment

Instructional Objective	Reading Standards for Literacy in Science and Technical Subjects (9-12)	Writing Standards for Literacy in Science and Technical Subjects (9-12)
LO1b: to identify and explain the specific components of the engineering design cycle for the designed model **LO1c: to identify and explain the complex relationship between science and engineering design** **LO2d: to construct an explanation that includes qualitative and quantitative relationships using models of systems** showing that organisms survive by obtaining necessary resources through interdependent relationships with other organisms and the physical environment.	**Key Ideas and Details:** **Grade 9-10:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. **Grades 11-12:** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **Integration of Knowledge and Ideas:** **Grade 9-10:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **Grade 11-12:** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **Grade 9-10:** Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. **Grade 11-12:** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.	**Text Types and Purposes:** **Grade 9-10:** Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence. **Grade 11-12:** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. **Grade 9-10:** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns. **Grade 11-12:** Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases. **Research to Build and Present Knowledge:** **Grade 9-10:** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation. **Grade 11-12:** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

(M) Teacher Resource. SIMOC Partnerships for 21st Century Skill Alignment

21st Century Skills		
Learning Outcomes	**21st Century Skill**	**Outcomes**
LO1a: to analyze criteria and constraints in an engineering design task and collect data to generate and refine an appropriate solution using tools (instruments) to achieve the mission goal	**Collaboration**	Collaborate with others
	Critical Thinking and Problem Solving	Reason effectively and solve problems
	Flexibility and Adaptability	Adapt to change
LO2a: to ask questions that can be investigated and that define a design problem to identify how humans are dependent on environmental interactions with other living things and nonliving factors in a system	**Collaboration**	Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal.
	Critical Thinking and Problem solving	Reason effectively and solve problems
	Flexibility and Adaptability	Adapt to change
LO2b: : to plan and conduct an investigation into maintaining a healthy ecosystem in a closed system by tracking the	**Media literacy**	Analyze media

flow of matter and energy		
	Creativity and innovation	Think creatively, work creatively with others, and implement solutions.
	Critical Thinking and problem solving	Reason effectively and solve problems

(N) Teacher Resource. SIMOC NGSS Rubrics

Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

Next Generation Science Standards Alignment (NGSS)

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a: to analyze criteria and constraints in an engineering design task and collect data to generate and refine an appropriate solution using tools (instruments) to achieve the mission goal	Design criteria and constraints take into account the complexity of interacting systems. Modifies design as data is collected and analyzed.	Design criteria and constraints identify the correct subsystems and interactions. Moderately modifies design using data collected.	Design is one system. Modifications to design are random..	Design reflects personal interest.
LO1b: to identify and explain the specific components of the engineering design cycle for the designed model	Concise and thorough explanation takes into account the complex interaction between sub-systems and the complexity of the design process as data input refined design.	Explanation describes the subsystems and the iteration within design modifications	Explanation describes the overall system and the steps of the design process.	Explanation describes the impact on them as they proceeded through the design cycle.
LO1c: to identify and explain the complex relationship between science and engineering design	Concisely and thoroughly explains the complex relationship between the requirements of living things and design of the model to supply the requirements in subsystems.	Explanation includes the relationship between the science and the engineering design.	Explanation focuses on the design model.	Describes how the resulting model would take care of their personal needs.
LO2a: to ask questions that can be investigated and that define a design problem to identify how humans are dependent on environmental interactions with other living things and nonliving factors in a system	Develops researchable questions that guide investigations into the dependence of humans on complex ecosystems.	Asks questions about the interdependence of living and non-living systems.	Asks questions about the needs of humans.	Asks questions that are centered on their interests.

SIMOC

LO2b: to plan and conduct an investigation into maintaining a healthy ecosystem in a closed system by tracking the flow of matter and energy	Investigations accurately control variables of matter, energy and elements of subsystem for creating healthy, self-sustaining ecosystems.	Investigations measures the matter and energy of ecosystems.	Investigations monitor the survival of elements of the ecosystem.	Investigations observe ecosystems.
LO2c: to use and modify a model using evidence to establish stability over time in a dynamic engineered ecosystem	Uses and modifies the model from evidence to achieve stability in a dynamic engineered ecosystem.	Uses and modifies the SIMOC model to generate data. Attempts to have stability.	Uses and modifies the SIMOC model to generate data.	Makes random choices in the SIMOC environment.
LO2d: to construct an explanation that includes qualitative and quantitative relationships using models of systems showing that organisms survive by obtaining necessary resources through interdependent relationships with other organisms and the physical environment.	Constructs a complete and coherent explanation of the modifications to the SIMOC model that are qualitative and quantitative that demonstrates how a stable ecosystem could be developed by taking into account the interdependencies of the organisms in the systems.	Constructs an explanation of how modifications to the SIMOC model resulted in different outcomes. Explanation is mostly qualitative with some quantitative analysis to describe interdependency of humans on the subsystems.	Describes the modifications to the SIMOC model and describes the outcomes. Suggests a possible ideal configuration.	Describes what happened during the SIMOC trials and the team reacted to the outcomes.