SIMOC-B2: A Computer Simulation of Biosphere 2

Grades 5-8 Next Generation Science Standards, Common Core Standards, and 21st Century Skills Alignment Document

WHAT STUDENTS DO: Use the SIMOC model to study and conduct experiments on the Biosphere 2 internal ecosystem.

Students use a free online simulation model to investigate the food, carbon, and water cycles inside Biosphere 2 and design and test ways to optimize them. They will actively engage in data analysis, computational thinking, and iterative innovation through collaboration and persistence.

NGSS CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES
How (and why) do organisms interact with their environment and what are the effects of these interactions? *LS2: Ecosystems: Interactions, Energy and Dynamics.* How do organisms interact with the living and nonliving environments to obtain matter and energy? *LS2.A: Interdependent Relationships in Ecosystems* How do matter and energy move through an ecosystem? *LS2.B: Cycles of Matter and Energy Transfer in Ecosystems* What happens to ecosystems when the environment changes? *LS2.C: Ecosystem Dynamics, Functions and Resilience*	***Students will be able to:*** IO1: **Explore and interpret data using computer models to describe and predict the interdependence of biotic and abiotic components of an ecosystem.**
How do engineers solve problems? *ETS1: Engineering Design* What is a design for? What are the criteria and constraints of a successful solution? *ETS1.A: Defining and Delimiting the Engineering Problem* What is the process for developing potential design solutions? *ETS1.B: Developing Possible Solutions* How can various design solutions be compared and improved? *ETS1.C: Optimizing the Design Solution*	***Students will be able to:*** IO2: **Use and modify a model limited by criteria and constraints to solve a complex science and engineering problem**

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 SIMOC-B2 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" published 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 scientists, researchers and administrators working on Biosphere 2.

Additionally, students engage in an engineering design activity using SIMOC. They use the engineering design process to carry out an investigation into an O_2 deficit in Biosphere 2, essentially recreating the landmark scientific study *Oxygen Loss in Biosphere 2* from 1993. A brief description of the engineering design process can be seen in this diagram. This diagram, along with the 5E Instructional Model, provides the organization for the activities.

Activity	5E Instructional Model	Engineering Design Process
(A) Designing a Biosphere	Engage	
(B) Identify the Problem	Explore	Identify the need or problem
(C) Research the Problem	Explain	Research the need or problem
(D) Develop Solutions	Elaborate	Develop possible solution(s)
		Select the best possible solution(s)
(E) Evaluate Solutions	Evaluate	Construct a Prototype
		Test and evaluate the solution(s)
(F) Communicate the Solution		Communicate the solution(s)
(G) Reflection		

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 & Interact 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 components 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 (and why) do organisms interact with their environment and what are the effects of these interactions? *LS2: Ecosystems: Interactions, Energy and Dynamics.*

How do organisms interact with the living and nonliving environments to obtain matter and energy? *LS2.A: Interdependent Relationships in Ecosystems*

How do matter and energy move through an ecosystem? *LS2.B: Cycles of Matter and Energy Transfer in Ecosystems*

What happens to ecosystems when the environment changes? *LS2.C: Ecosystem Dynamics, Functions and Resilience*

How do engineers solve problems? *ETS1: Engineering Design*

What is a design for? What are the criteria and constraints of a successful solution? *ETS1.A: Defining and Delimiting the Engineering Problem*

What is the process for developing potential design solutions? *ETS1.B: Developing Possible Solutions*

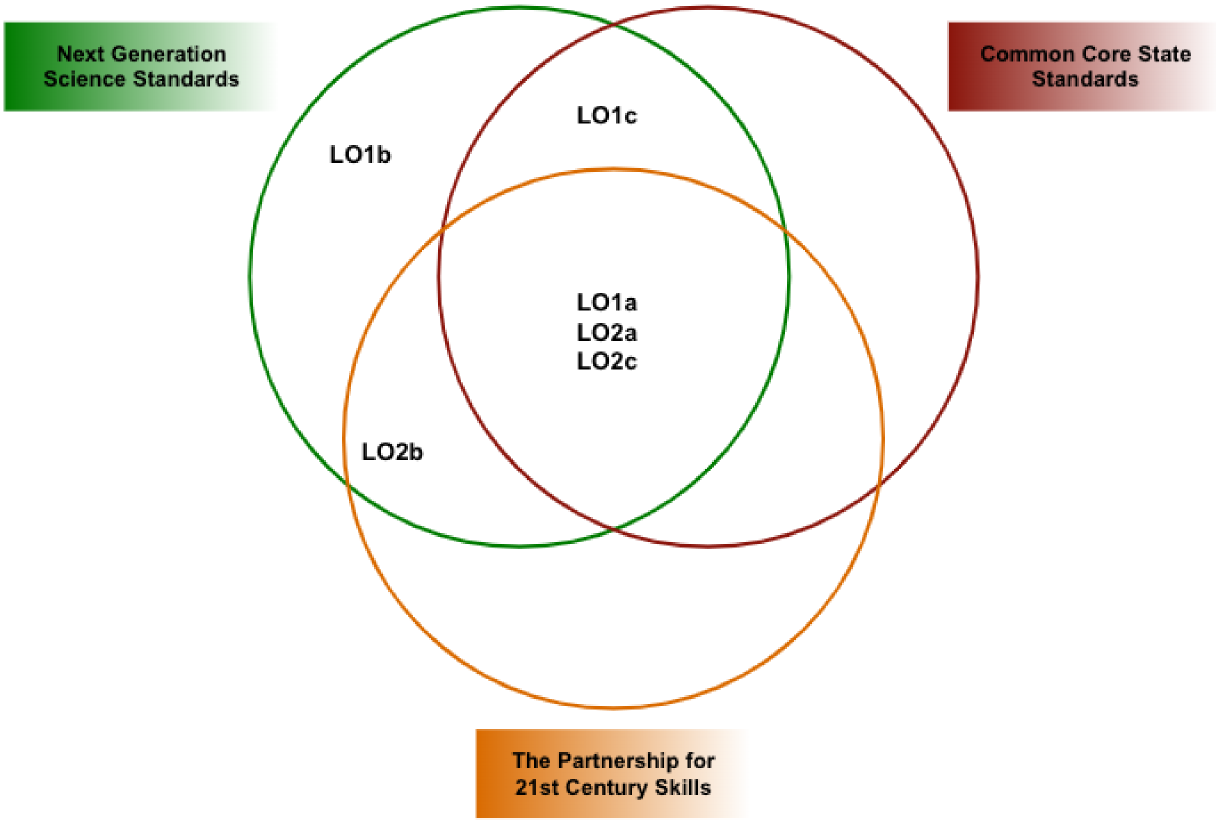
How can various design solutions be compared and improved? *ETS1.C: Optimizing the Design Solution*

Instructional Objective *Students will be able to*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	**Rubrics in SIMOC Lesson**
IO1: **Explore and interpret data using computer models to describe and predict the interdependence of biotic and abiotic components of an ecosystem.**	**LO1a: to enumerate criteria and constraints for an engineering problem with an awareness of cause and effect and interdependence.** **LO1b: to use a computer model to collect and analyze data in order to identify patterns and imbalances in an ecosystem.** **LO1c: to use mathematics and computational thinking to analyze and describe the structure, function and relative impact of individual sub-systems in an ecosystem.**	**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** **2. Developing and Using Models** **3. Analyzing and Interpreting Data** **4. Using Mathematics and Computational Thinking** **5. Obtaining, Evaluating, and Communicating Information** **CROSSCUTTING CONCEPTS:** **1. Patterns** **2. Cause and Effect** **3. Scale, Proportion, and Quantity** **4. Systems and System Models** **5. Structure and Function** **6. Stability and Change**	

Instructional Objective *Students will be able to*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO2: **Use and modify a model limited by criteria and constraints to solve a complex science and engineering problem**	**LO2a: to develop possible solutions to maintaining a healthy ecosystem in a closed system by understanding cause and effect, adjusting scale and quantities, and reasoning about interdependence.** **LO2b: to use and modify a model using evidence to establish stability over time in a dynamic engineered ecosystem.** **LO2c: 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:** **ETS1.A: Defining and Delimiting the Engineering Problem** **ETS1.B: Developing Possible Solutions** **ETS1.C: Optimizing the Design Solution** **PRACTICES:** **1. Developing and Using Models** **2. Planning and Carrying Out Investigations** **3. Analyzing and Interpreting Data** **4. Using Mathematics and Computational Thinking** **5. Constructing Explanations** **6. Engaging in Argument from Evidence** **7. Obtaining, Evaluating, and Communicating Information** **CROSSCUTTING CONCEPTS:** **1. Patterns** **2. Cause and Effect** **3. Scale, Proportion, and Quantity** **4. Systems and System Models** **5. Structure and Function** **6. Stability and Change**	**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.

SIMOC-B2 NGSS Alignment (1/5) **Teacher Guide**

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:

(MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3);
(MS-LS2-1), (MS-LS2-3), (MS-LS2-4);

Next Generation Science Standards Alignment (NGSS)

Instructional Objective	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
IO1: Explore and interpret data using computer models to describe and predict the interdependence of biotic and abiotic components of an ecosystem.	**Asking Questions** Ask questions that can be investigated and predict reasonable outcomes based on patterns ... Use prior knowledge to describe problems that can be solved. **Developing and Using Models** Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. **Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	**LS2.A: Interdependent Relationships in Ecosystems** Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1) **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example,	**Patterns** Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Graphs, charts and images can be used to identify patterns in data. **Cause and Effect** They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. **Systems and System Models** Students can understand that systems may interact with other systems; they may have sub- systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can

	Using Mathematics and Computational Thinking Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. **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.	when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations. (MS-LS2-4)	also learn that models are limited in that they only represent certain aspects of the system under study. **Structure and Function** Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its parts. They analyze many complex natural and designed structures and systems to determine how they function. **Stability and Change** Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time

Next Generation Science Standards Alignment (NGSS)			
Instructional Objective	**Science and Engineering Practices**	**Disciplinary Core Idea**	**Crosscutting Concepts**
IO2: Use and modify a model limited by criteria and constraints to solve a complex science and engineering problem	**Asking Questions** Ask questions that can be investigated and predict reasonable outcomes based on patterns ... Use prior knowledge to describe problems that can be solved. **Developing and Using Models** Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. **Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. **Using Mathematics and Computational Thinking** Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. **Obtaining, Evaluating, and Communicating Information**	**ETS1.A: Defining and Delimiting Engineering Problems** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (MS-ETS1-1) **ETS1.B: Developing Possible Solutions** A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. In any case, it is important to be able to communicate and explain solutions to others. (MS-ETS1-2) **ETS1.C: Optimizing the Design Solution** Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	**Patterns** Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Graphs, charts and images can be used to identify patterns in data. **Cause and Effect** They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. **Systems and System Models** Students can understand that systems may interact with other systems; they may have sub- systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study. **Structure and Function** Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its

	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.	Once such a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful. (MS-ETS1-3)	parts. They analyze many complex natural and designed structures and systems to determine how they function. **Stability and Change** Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time

Next Generation Science Standards Alignment (NGSS)

Instructional Objective	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
LO1a: to enumerate criteria and constraints for an engineering problem with an awareness of cause and effect and interdependence.	**Asking Questions** Ask questions that can be investigated and predict reasonable outcomes based on patterns ... Use prior knowledge to describe problems that can be solved. **Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. **Using Mathematics and Computational Thinking** Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.	**LS2.A: Interdependent Relationships in Ecosystems** Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations. (MS-LS2-4)	**Cause and Effect** They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. **Systems and System Models** Students can understand that systems may interact with other systems; they may have sub- systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study. **Stability and Change** Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time

LO1b: to use a computer model to collect and analyze data in order to identify patterns and imbalances in an ecosystem.	**Developing and Using Models** Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. **Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. **Using Mathematics and Computational Thinking** Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.	**LS2.A: Interdependent Relationships in Ecosystems** Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations. (MS-LS2-4)	**Systems and System Models** Students can understand that systems may interact with other systems; they may have sub- systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study. **Structure and Function** Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its parts. They analyze many complex natural and designed structures and systems to determine how they function. **Stability and Change** Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time
LO1c: to use mathematics and computational thinking to analyze and describe the structure, function and relative impact of individual sub-systems in an ecosystem.	**Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. **Using Mathematics and Computational Thinking** Use digital tools (e.g., computers) to analyze very large data sets for	**LS2.A: Interdependent Relationships in Ecosystems** Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-	**Patterns** Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Graphs, charts and images can be used to identify patterns in data. **Cause and Effect** They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect

	patterns and trends. **Constructing Explanations and Designing Solutions** Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. **Engaging in Argument from Evidence** Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.	LS2-1) **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)	relationships in systems can only be described using probability. **Structure and Function** Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its parts. They analyze many complex natural and designed structures and systems to determine how they function.

Next Generation Science Standards Alignment (NGSS)

Instructional Objective	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
LO2a: to develop possible solutions to maintaining a healthy ecosystem in a closed system by understanding cause and effect, adjusting scale and quantities, and reasoning about interdependence.	**Developing and Using Models** Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. **Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	**ETS1.A: Defining and Delimiting Engineering Problems** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (MS-ETS1-1) **ETS1.B: Developing Possible Solutions** A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. In any case, it is important to be able to communicate and explain solutions to others. (MS-ETS1-2)	**Cause and Effect** They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. **Structure and Function** Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its parts. They analyze many complex natural and designed structures and systems to determine how they function.
LO2b: 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 to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. **Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena.	**ETS1.C: Optimizing the Design Solution** Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	**Systems and System Models** Students can understand that systems may interact with other systems; they may have sub- systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the

	Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. **Using Mathematics and Computational Thinking** Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.	Once such a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful. (MS-ETS1-3)	system under study. **Stability and Change** Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time
LO2c: 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 and interpret data to provide evidence for phenomena. Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. **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.	**ETS1.A: Defining and Delimiting Engineering Problems** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (MS-ETS1-1) **ETS1.C: Optimizing the Design Solution** Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. Once such a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful. (MS-ETS1-3)	**Scale, Proportion and Quantity** Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. **Stability and Change** Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time

Next Generation Science Standards Alignment (NGSS)

Activity	Phases of 5E Instructional Model	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
Designing a Biosphere	**Engage**	**Asking Questions** Ask questions that can be investigated and predict reasonable outcomes based on patterns ... Use prior knowledge to describe problems that can be solved.	**ETS1.A: Defining and Delimiting Engineering Problems** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (MS-ETS1-1)	**Structure and Function** Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its parts. They analyze many complex natural and designed structures and systems to determine how they function.
Identify the Problem	**Explore**	**Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. **Using Mathematics and Computational Thinking** Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.	**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact— primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)	**Patterns** Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Graphs, charts and images can be used to identify patterns in data. **Stability and Change** Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time

Research the Problem	**Explain**	**Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. **Developing and Using Models** Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.	**LS2.A: Interdependent Relationships in Ecosystems** Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS- LS2-1)	**Structure and Function** Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its parts. They analyze many complex natural and designed structures and systems to determine how they function. **Cause and Effect** They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
Develop Solutions	**Elaborate**	**Constructing Explanations and Designing Solutions** Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.	**ETS1.B: Developing Possible Solutions** A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. In any case, it is important to be able to communicate and explain solutions to others. (MS-ETS1-2)	**Cause and Effect** They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
Evaluate Solutions	**Evaluate**	**Using Mathematics and Computational Thinking** Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.	**ETS1.C: Optimizing the Design Solution** Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into	**Systems and System Models** Students can understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can

			the new design. This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. Once such a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful. (MS-ETS1-3)	also learn that models are limited in that they only represent certain aspects of the system under study. **Stability and Change** Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time
Communicate the Solution	**Evaluate**	**Engaging in Argument from Evidence** Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations. (MS-LS2-4)	**Systems and System Models** Students can understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study.

Instructional Objective	Reading Standards for Literacy in Science and Technical Subjects (5-8)	Writing Standards for Literacy in Science and Technical Subjects (5-8)
LO1a: to enumerate criteria and constraints for an engineering problem with an awareness of cause and effect and interdependence. **LO1c: to use mathematics and computational thinking to analyze and describe the structure, function and relative impact of individual sub-systems in an ecosystem.** **LO2a: to develop possible solutions to maintaining a healthy ecosystem in a closed system by understanding cause and effect, adjusting scale and quantities, and reasoning about interdependence.** **LO2c: 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 Detail** Grade 6-8: Cite specific textual evidence to support analysis of science and technical texts. **Integration of Knowledge and Ideas** Grade 6-8: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). Grade 6-8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. Grade 6-8: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.	**Text Types and Purpose** Grade 6-8: Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically. Grade 6 - 8: Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources. **Research to Build and Present Knowledge** Grades 6-8: Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

SIMOC-B2 Partnerships for 21st Century Skill Alignment — **Teacher Guide**

21st Century Skills		
Learning Outcomes	**21st Century Skill**	**Outcomes**
LO1a: to enumerate criteria and constraints for an engineering problem with an awareness of cause and effect and interdependence.	**Collaboration**	**Share ideas with others**
	Information Literacy	**Identify High-Quality Sources of Information Online**
	Critical Thinking	**Reason effectively about the requirements and solutions**
LO2a: to develop possible solutions to maintaining a healthy ecosystem in a closed system by understanding cause and effect, adjusting scale and quantities, and reasoning about interdependence.	**Collaboration**	**Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal.**
	Creativity and Innovation	**Think creatively, work creatively with others, and implement solutions.**
LO2b: to use and modify a model using evidence to establish stability over time in a dynamic engineered ecosystem.	**Technology**	**Utilize technology to collect and analyze data to modify the model and improve its accuracy.**
	Flexibility	**Demonstrate adaptability and openness to change in modifying the model to ensure its stability over time.**
LO2c: 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.	**Media Literacy**	**Evaluate and use various forms of media to gather information about interdependent relationships within ecosystems.**
	Communication	**Effectively communicate the explanation of qualitative and quantitative relationships within ecosystems to diverse audiences using appropriate language and media.**

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

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a: to enumerate criteria and constraints for an engineering problem with an awareness of cause and effect and interdependence.	Identifies most human and plant constraints, as well as the need to balance the carbon and water cycles. Identifies specific solutions to many constraints from multiple reputable sources.	Identifies most human and plant constraints, as well as the need to balance the ecosystem. Identifies solutions to some constraints from multiple reputable sources.	Identifies most human constraints and some secondary constraints, such as plants or mechanical systems. Identifies solutions to some constraints using the references provided.	Identifies some human constraints such as food, water and oxygen. Identifies solutions to at least one constraint using references provided.
LO1b: to use a computer model to collect and analyze data in order to identify patterns and imbalances in an ecosystem.	Correctly charts O_2 and CO_2 and all thresholds in clearly differentiable styles with a legend. Describes behavior clearly and concisely using complete sentences.	Correctly charts O_2 and CO_2 and all thresholds, includes a legend. Describes behavior thoroughly and correctly using correct grammar.	Approximately charts O_2 and CO_2 with and some thresholds, includes a legend. Describes behavior accurately.	Includes multiple data points from simulation connected with a line. Makes accurate statements about the data.
LO1c: to use mathematics and computational thinking to analyze and describe the structure, function and relative impact of individual sub-systems in an ecosystem.	Finds the maximum for each agent/resource Describes behavior clearly and concisely. Identifies O_2 and CO_2 responses in all agents.	Finds the maximum for at least one agent per type. Describes behavior correctly. Identifies O_2 and CO_2 responses in multiple agents.	Finds near-maximum values for at least one agent of each type. Describes behavior accurately. Identifies at least one O_2 or CO_2 response.	Records at least one value for each agent of each time from the simulation. Identifies differences in behavior between different agents.
LO2a: to develop possible solutions to maintaining a healthy ecosystem in a closed	Lists all changes in Mission 1b and describes behavior of O_2 and CO_2 clearly and concisely.	Lists most changes to Mission 1b and describes the behavior of O_2 and CO_2 correctly.	Lists some major changes to Mission 1b and describes behavior of O_2 and CO_2 accurately.	Lists some major changes to Mission 1b, describes O_2 and CO_2 differently from Mission 1a.

system by understanding cause and effect, adjusting scale and quantities, and reasoning about interdependence.	LIsts at least 5 viable changes to configuration, predicts the impact correctly, and identifies at least one second-order impact for each.	LIsts at least 5 viables changes to configuration, predicts impact reasonably, identifies some second-order impacts.	LIsts multiple viable changes to configuration and predicts impacts reasonably, identifies at least one second-order impact correctly.	Lists multiple changes to configuration, may include some misunderstandings in estimated impact.
LO2b: to use and modify a model using evidence to establish stability over time in a dynamic engineered ecosystem..	Implement all of the solutions identified in (D). Identify the key agents responsible for changes in the outcome and describe their behavior correctly. Conduct and describe at least three (3) simulations, keeping detailed records and showing reasoned attempts at improving outcomes across multiple constraints (O_2, power).	Implement most of the solutions identified in (D). Clearly describe 3 agents whose behavior was different from the preset configuration. Conduct and describe at least two (2) simulations, keeping good records and showing a logical pattern to changes based on more than 1 constraint.	Implement some of the solutions identified in (D). Describe the behavior of at least 2 agents that were affected by the changes. Propose multiple changes to the configuration which could logically improve outcomes.	Implement at least one solution identified in (D). Describe the behavior of at least one agent directly affected by that change. Propose at least one change to the configuration which could logically improve outcomes.
LO2c: 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	Demonstrates multiple iterations in mockups, shows and understanding of clarity and composition. Includes all relevant agents from SIMOC-B2 with all correct flows. Illustrates and/or describes all O_2 and CO_2 response mechanisms: e.g. human thresholds, carbonation rates, etc.	Completes three distinct mockups, shows an awareness of groupings and directionality. Include all relevant agents from SIMOC-B2 with all correct flows. Illustrate and/or describe some O_2 and CO_2 response mechanisms.	Completes at least three mockups, shows a preference for one layout over another. Include all relevant agents from SIMOC-B2 with several correct flows. Illustrate and/or describe at least one O_2 and CO_2 response mechanism.	Completes at least two mockups, shows a preference for one layout over another. Include several relevant agents from SIMOC-B2 with flows. Illustrate and/or describe at least one O_2 and CO_2 response mechanism.