Science and Innovation

A Boeing/Teaching Channel Partnership

EXTREME BIOSUITS

Teacher Handbook

Teaching Channel

Science and Innovation

A Boeing/Teaching Channel Partnership

The Boeing Company and Teaching Channel teamed in 2014 to create problem-based curricula inspired by science and engineering innovations at Boeing and informed by globally competitive science, math, and literacy standards. This two-week curriculum module and the companion video series are designed to help teachers in grades 4–8 integrate the engineering design process, aligned to science standards, into their classrooms. The collection of Teaching Channel curricula is one part of a collection of K–12 education resources intended to mark Boeing's centennial anniversary and prepare the next generation of innovators.

The materials created by this collaboration were taught by the authoring teachers in Puget Sound and Houston, and in 2015, a second group of teachers taught the lessons and provided feedback to improve the modules. As part of a second iteration of the modules, the senior science editor at Teaching Channel worked with Achieve to integrate the teachers' feedback while more closely aligning the modules to The Next Generation Science Standards (NGSS) call for significant shifts in the way science is taught and learned. In 2016, a panel of science experts from around the country convened for a two-day training with Achieve to learn how to incorporate the Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for Science. As part of the iterative process of improvement, the expert reviewers then completed an EQuIP Rubric for each module. Teaching Channel's senior science editor combined the reviewers input to create a third iteration of the modules that promotes a close alignment to standards while honoring the original expertise of the authoring teachers and engineers.

Partners at both the University of Washington's Institute for Science and Math as well as Educate Texas were instrumental in teacher recruitment for this project. Teachers and engineers in the project received training from learning scientists at the University of Washington's Institute for Science and Math Education, led by Dr. Philip Bell. He and his team also created a design template to support curricula development to promote alignment to standards and research on science learning and teaching.

Please note that the resource links provided in these lessons are intended as helpful illustrations to teachers adapting the unit for their classrooms and are not an endorsement of specific products or organizations.

Extreme Biosuits

Background and Overview

This module's essential challenge focuses on biosuit construction. Biosuits, such as spacesuits and hazmat suits, protect scientists and engineers when they work in extreme environments. In this module, students design a biosuit that must address biological necessities and assure that its user can survive multiple environments while completing key tasks.

As students design and build a model biosuit, they consider two key science ideas. First, students investigate human response to stimuli, namely stimuli caused by an extremely cold environment. Second, students consider the transfer of thermal energy in relation to the design of their biosuit.

Module Overview

In Extreme Biosuits, students design and build a model biosuit to protect scientists and engineers from an extreme environment while allowing them to perform their work comfortably. At the beginning of the module, students examine three model biosuits to determine the basic features of a biosuit. Next, students investigate the environments for their intended biosuit.

Module Authors

- **Mallory Barnhart**, 7th-Grade Teacher, KIPP Intrepid Preparatory School, Houston, TX
- **Darryl Archer**, Boeing Engineer, Houston, TX
- **Brandon Setayesh**, Boeing Engineer, Houston, TX
- **Kate Cook Whitt**, Teaching Channel Senior Science Editor

Through a science investigation, students collect data on what might happen if a scientist or engineer did not wear a biosuit in an extreme environment. Students consider ways to design biosuits so scientists and engineers can work comfortably in extreme environments. In doing so, students draw in the ideas of heat and thermal energy transfer.

Students then design a model biosuit. After designing the first draft of their biosuit, students present their proposed design solutions. Students receive feedback from their peers and engage in the redesign process before building their biosuit model. After building their biosuit model, student teams present their completed model in the final presentation and demonstration. In the presentation, students are required to justify their design decisions using relevant science ideas.

Throughout the module, students develop an understanding of human response to stimuli and the transfer of thermal energy. Students use the science ideas developed in the module to inform and justify their design decisions. Students build heavily on their understanding of engineering and the engineering design process through their work developing, testing, optimizing, and presenting their design solutions.

Extreme Biosuits
Background and Overview

Engineering Design in the Module

Biosuits protect scientists and engineers in extreme environments. In this module, students work to develop a new biosuit for a specific environment and task. Prior to designing a biosuit, students research extreme environments and investigate environmental effects on the body. With this research in mind, they design a biosuit, receive feedback from their peers, and engage in the redesign process before building their biosuit. Student teams present their completed biosuit model in the final presentation.

Sequencing

Extreme Biosuits is intended as a middle school engineering, physical science, and life science module. The module is designed to help students make progress on five performance expectations: MS-ETS1-1, MS-ETS1-4, MS-PS3-3, MS-LS1-3, and MS-LS1-8. The performance expectations address the engineering design process, conservation of energy and energy transfer, and structures and processes of living things.

Extreme Biosuits is most appropriate for use during the middle school years. Within the middle school years, this module is best used toward the end of the middle school physical science module on the conservation of energy and energy transfer and the beginning of the middle school life science module on the structure and processes of living things.

Students should have already mastered the *performance expectations*, *disciplinary core ideas*, *science and engineering practices*, and *crosscutting concepts*.

- Students should have already mastered 4-PS3.B and have made some progress on MS-PS3-3 so that they have an initial understanding of energy transfer. Ideally, students should have had exposure to MS-PS1-4 and have already modeled and describe changes in particle motion and temperature when thermal energy is added or removed from a substance. In addition, students should have mastered 4-LS1-2, which addresses information processing.
- Students should have already demonstrated deep conceptual understanding for all of the 3-5 Engineering Design performance expectations and associated science and engineering practices, disciplinary core ideas, and crosscutting concepts.
- Students should have made grade appropriate progress on the following science and engineering practices: Asking Questions and Defining Problems, Developing and Using Models, Planning and Carrying out Investigations, Constructing Explanations and Designing Solutions, and Engaging in Argument from Evidence.
- Students should also have made grade appropriate progress on the following crosscutting concepts: Influence of Science, Engineering, and Technology on Society and the Natural World, Cause and Effect, Energy and Matter, and Structure and Function.

Performance Expectations

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

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Extreme Biosuits

Connecting to the Next Generation Science Standards

The lessons and activities outlined in this module are one step in the learning progression toward reaching the performance expectations listed below. Additional supporting lessons and activities will be required. Specific connections between the performance expectations, three dimensions, and classroom activities are provided at the beginning of every lesson.

Important Note

The grade level and associated performance expectations, disciplinary core ideas, science and engineering practices, and crosscutting concepts identified throughout the module were selected to align with the Next Generation Science Standards. In classrooms using local or state standards, this module may fall within a different grade band and may address different standards. Teachers should adapt this module to meet local and state needs.

Furthermore, teachers should adapt the module to extend student learning to additional grade levels, performance expectations, disciplinary core ideas, science and engineering practices, and crosscutting concepts to meet student needs.

Performance Expectations	
The lessons and activities in this module contribute toward building understanding of the following *engineering* performance expectations: MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. **The lessons and activities in this module contribute toward building understanding of the following *life science* and *physical science* performance expectations:** MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells. MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.	
Dimension	**NGSS Element**
Science and Engineering Practices	**Asking Questions and Defining Problems** • Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. **Developing and Using Models** • Develop a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.

	• Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. Planning and Carrying Out Investigations • Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of an investigation. 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. • Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. Engaging in Argument from Evidence • Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system based on empirical evidence concerning whether the technology meets relevant criteria and constraints.
Disciplinary Core Ideas	ETS1.A Defining and Delimiting Engineering Problems • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions. ETS1.B: Developing Possible Solutions • Models of all kinds are important for testing solutions. PS3.B: Conservation of Energy and Energy Transfer • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. LS1.A: Structure and Function • In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. LS1.D Information Processing • Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. These signals are then processed in the brain, resulting in immediate behaviors or memories.
Crosscutting Concepts	Influence of Science, Engineering, and Technology on Society and the Natural World • The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Cause and Effect • Cause and effect relationships may be used to predict phenomena in natural or designed systems. Energy and Matter • The transfer of energy can be tracked as energy flows through a designed or natural system. Structure and Function • Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.

Connections to the Common Core State Standards

In addition to connecting to the *Next Generation Science Standards*, this module can support student growth in multiple *Common Core State Standards.* This module can be easily adapted to support growth in the following standards:

English Language Arts

- CCSS.ELA-Literacy.W.8.1: Write arguments to support claims with clear reasons and relevant evidence.
- CCSS.ELA-Literacy.SL.8.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- CCSS.ELA-Literacy.SL.8.4: Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Extreme Biosuits
Module Storyline

This module is designed as a coherent set of learning experiences that motivate a progressive building of understanding of disciplinary core ideas, science and engineering practices, and crosscutting concepts. The following storyline demonstrates how ideas are built across the lessons. You may find it helpful to continually reference the storyline to help frame lessons.

Driving Question:
How can we design a biosuit that can be worn in an extreme environment and that allows scientists and engineers to do their work comfortably?

Question/Problem	What Students Are Doing	What Students Figure Out
What is a biosuit?	Students examine three model biosuits, and identify criteria and constraints for their biosuit based on the environment and task.	Biosuits are designed for a particular task and environment. Design criteria and constraints depend on the task and environment.
Where will our scientist or engineer work?	Students research an environment and career. Students predict how a body might respond to the environment without a biosuit.	All the environments and careers involve cold water. The body may respond in different ways to the cold water.
What happens if our scientist or engineer does not wear a biosuit?	Students test the body's response to cold water.	Cold water slows the heart rate, lowers blood pressure, and makes the skin cold.
What materials can we use to design a biosuit?	Students design a draft biosuit and purchase materials to accomplish the task criteria.	The materials used and their structure relate to the function of the intended product.
How do we build our biosuit models?	Students work in teams to design biosuit models that meet certain criteria and constraints.	Students solve the design problem and present their solution to a public audience.

Extreme Biosuits

Day 1: What Is a Biosuit?

Grade Level	Middle School
Lesson Length	One 50-minute session (if possible, consider adding another day)

Lesson Overview

In this lesson, students are introduced to the design problem. They learn that Boeing would like to develop biosuits capable of protecting scientists and engineers in extreme environments while allowing them to do their work comfortably. Before brainstorming the design of their own biosuits, students examine three existing biosuits to use as models—space suits, wet suits, and hazardous materials (hazmat) suits. At the end of the lesson, students brainstorm possible criteria and constraints for their biosuits.

Connecting to the Next Generation Science Standards

On Day 1, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Asking Questions and Defining Problems
- Disciplinary Core Ideas: ETS1.A Defining and Delimiting Engineering Problems
- Crosscutting Concepts: Influence of Science, Engineering, and Technology on Society and the Natural World, Structure and Function

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

Performance Expectations
This lesson contributes toward building understanding of the following *engineering* performance expectations: MS-ETS1-1. *Define the criteria and constraints of a design problem* with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
Specific Connections to Classroom Activity On Day 1, students are introduced to the design problem. Students are challenged to design a biosuit that can be worn in an extreme environment, and allows scientists and engineers to do their work comfortably and safely. By examining three example biosuits, students figure out that biosuits are built for particular environments and particular tasks. Using knowledge of the specific environment and task included in the design problem, students begin to identify some of the design criteria and constraints for their biosuits. Students also consider the societal pressures driving the need for their assigned biosuits. Later in the module, students further define criteria and constraints by taking into account relevant scientific principles.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	**Asking Questions and Defining Problems** • *Define a design problem that can be solved through the development of an object, tool,* process, or system and *includes multiple criteria and constraints,* including scientific knowledge that may limit possible solutions.	Students are challenged to design a biosuit that can be worn in an extreme environment and that allows scientists and engineers to do their work comfortably and safely. This design problem can be solved through the development of a biosuit and associated tools. Students figure out that biosuits must be designed for a particular environment and a particular task, which contributes to the design criteria and constraints.
Disciplinary Core Ideas	**ETS1.A Defining and Delimiting Engineering Problems** • *The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of* scientific principles and other *relevant knowledge likely to limit possible solutions.*	Students begin to identify criteria and constraints related to the design problem. As students brainstorm criteria and constraints, they draw on relevant knowledge about the environment and task for which the biosuit is intended.
Crosscutting Concepts	**Influence of Science, Engineering, and Technology on Society and the Natural World** • *The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values*; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. **Structure and Function** • *Structures can be designed to serve particular functions* by taking into account properties of different materials and how materials can be shaped and used.	Students read about three different biosuits that are used by scientists to do scientific research and to help solve societal issues (for example, the plague). Students are presented with a design problem (keep an engineer safe and comfortable while working in extreme environments) for which they must design a technology (build a biosuit). Students comment on the societal pressures driving the need for their assigned biosuit. Students consider structures on the biosuit that may serve particular functions when completing a task.

Basic Teacher Preparation

Organize the class into groups of 3 or 4 students. Students work in these groups throughout the module. Establish these working groups before beginning Day 1. An optional Day 1 activity can be used to build team cohesion.

Refer to the Extreme Biosuits Student Handbook ahead of time, so you can address any questions students might have. All Day 1 documents can be found on pages 1–14 in the Extreme Biosuits Student Handbook. The documents used in this lesson are:

- The Engineering Design Process (page 1)
- Welcome Letter (page 2)
- Building Our Driving Question Board (page 3)
- Examining Biosuit Models (pages 4–10)

- Biosuit Environments and Tasks (pages 11 and 12)
- Defining the Problem and Identifying Solutions (Round 1) (page 13)
- Team Roles (page 14)

To prepare for the whole group discussions, review the Talk Science Primer (refer to the Suggested Teacher Resources at the end of this lesson).

Required Preparation	Links/Additional Information
❑ Gather or purchase the required materials for the lesson	Refer to the Materials List below
❑ Download, print, and prepare the Extreme Biosuits Student Handbook packets for students	Refer to the Materials List below
❑ Review suggested teacher preparation resources and recommended websites	Refer to the Suggested Teacher Resources at the end of this lesson

Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Extreme Biosuits Student Handbook	Print the handbooks and collate them to remain sturdy for 7–10 days	1 per student	[Resource Link]

Day 1: What Is a Biosuit?

Introduction (5 minutes)

Begin the lesson by explaining to students that they are going to assume the roles of engineers who have been hired by Boeing. Boeing wants to design biosuits that can be worn in many different extreme environments, and will allow scientists and engineers to do their work comfortably and safely. Some biosuits, such as the spacesuit, have already been created. Boeing wants to take biosuit technology a step further by designing biosuits for a wide variety of extreme environments.

As Boeing employees, the students develop and test new biosuits for extreme conditions. Introduce students to the Driving Question for this module, *How can we design a biosuit that can be worn in an extreme environment, and allows scientists and engineers to do their work comfortably?* Post the Driving Question on the Driving Question Board (DQB).

Important Note

The Driving Question Board (DQB) is used throughout the module to guide student learning. Make sure the Driving Question Board is placed in a prominent location and can be easily accessed by students.

Provide students with the Extreme Biosuits Student Handbook, which contains all the information they need for this module. Point out that the handbook provides an overview and detailed descriptions of everything students need to know while they design their biosuit models.

Read the Welcome Letter on page 2 of the Extreme Biosuits Student Handbook out loud. Tell students they are going to work through the engineering design process as they design biosuits for Boeing. Reveiw The Engineering Design Process on page 1 of the Extreme Biosuits Student Handbook (The Engineering Design Process can also be found in Appendix A).

Tell students that they need to know more about the engineering design problem before beginning design work. Have students develop a list of questions about the design problem. Start by developing one question as a class, and then have students work in small groups to develop the remaining questions. Students should record their questions on Building Our Driving Question Board on page 4 in the Extreme Biosuits Student Handbook. Questions may include:

- What are biosuits?
- Why do we need biosuits?
- What are biosuits made out of?
- What kinds of extreme environments will the biosuits be used for?
- Why is it important to protect the body in extreme environments?

NGSS Key Moment

Engineers often refer to the *engineering design process* when they discuss their work. In NGSS, the Science and Engineering Practices are used in place of the engineering design process. Students should understand that the engineering design process is not necessarily linear. Rather, engineers engage in all the steps, often jumping between steps. Students might think of the engineering design process as a web of practices.

Extension

Consider showing LaunchPad: The Making of the Biosuit to provide students with additional background on Biosuits.

Whole Group Discussion: Our Questions (10 minutes)

Engage the class in a large group discussion. The goal of this discussion is to categorize student questions into a few main categories. Start by having students share the questions they developed. Then, guide students to categorize the questions. Students should search for patterns in the questions developed by students in the class. Try to come to class consensus about the categories.

At a minimum, guide the class toward developing the following three categories, although additional categories may emerge.

- What is a biosuit?
- Why are biosuits needed in certain environments?
- How can we design a model to test our biosuit?

NGSS Key Moment

Whole group discussions, particularly consensus discussions, can be an effective way to engage students in the science practices of argumentation and explanation. Leading whole group discussions requires proper preparation. Refer to the Talk Science Primer for useful strategies.

Tell students that these three questions will drive their work over the next several days. In addition, these questions will help them answer the overarching Driving Question, *How can we design a biosuit that can be worn in an extreme environment, and allows scientists and engineers to do their work comfortably?* Post the questions on the DQB so students can clearly see them. Leave space under the questions to add sticky notes.

DRIVING QUESTION BOARD

How can we design a biosuit that can be worn in an extreme environment, and allows scientists and engineers to do their work comfortably?

What is a biosuit?

Why are biosuits needed in certain environments?

How can we design a model to test our biosuit?

Mini-Lesson: What Is a Biosuit? (15 minutes)

Tell students they are going to start with the first question, *What is a biosuit?* To answer this question, students examine features of three biosuits that already exist—spacesuit, diving suit, and hazmat suit. The existing biosuits serve as a model for the design of new biosuits for different environments.

Students individually read three short articles to gather information about the existing biosuits. The articles discuss spacesuits, diving suits, and hazmat suits. The articles can be found on pages 4–10 of the Extreme Biosuits Student Handbook.

As students read, they should record notes on Examining Biosuit Models on page 4 in the Extreme Biosuits Student Handbook. Refer students to the concepts that must be summarized for each article:

- Protects against
- Key features
- Environments used In
- History

As students read and complete the graphic organizer, prompt students to think about the relationship between biosuit development and changing societal needs and desires.

NGSS Key Moment

By thinking about the relationship between biosuit development and changing societal needs driving the development of biosuits, students make progress on the crosscutting concept: Influence of Science, Engineering, and Technology on Society and the Natural World.

Extension

NASA published an article about innovations in spacesuit design. *Building the Future Spacesuit* can be found here. This article could be used to differentiate for more advanced readers or could be used as an extension.

For students who may need additional reading support, assign only one or two of the articles and have groups share their findings.

Whole Group Discussion: Defining the Problem (5 minutes)

Reference the question on the DQB, *What is a biosuit?* Have students share their findings from the readings to try to answer this question. Remind students to think about the biosuits in the articles as models for their own biosuits.

During the discussion, draw out the idea that biosuits are designed for a specific purpose, to be used in a specific environment, and as a result of a specific societal need. While all biosuits have many similarities, the differences among biosuits make them better suited for their particular environment and task. Be sure to record student ideas on the DQB.

Design Work: Defining the Problem (10 minutes)

After establishing the idea that biosuits must be designed for a specific purpose and environment, tell students that Boeing has already identified target environments for their biosuits. Each design team will be assigned to one environment and purpose.

Here are the key assignments:

- Alaska: Oil Pipeline Engineer
- Antarctica: Glaciologist
- Pacific Ocean: Deep Sea Biologists
- Gulf of Mexico: Hazardous Material Technician

Assign each group to an Environment/Task listed on pages 11 and 12 in the Extreme Biosuits Student Handbook. Allow time for students to read the description of their assignment.

NGSS Key Moment

At this point in the lesson, students make progress on MS-ETS1-1. Students have already started to define the design problem. They are now working to identify possible criteria and constraints. Throughout the rest of the module, students will continue to build on this initial list of criteria and constraints.

Emphasize the importance of considering a design task's criteria and constraints. *Criteria* typically address details such as the job a product will perform and its durability. The particular environment and task for which the biosuit is intended will likely contribute to the criteria for the design problem. *Constraints* include the limitations of creating a product, such as time or cost.

Have students begin to define the design problem and describe successful solutions. Students should record their ideas on the Defining the Problem and Identifying Solutions (Round 1) chart on page 13 in the Extreme Biosuits Student Handbook. Review the chart with students prior to having students work in groups to complete the chart.

At this point, students do not yet have information to complete the last column (*Challenges*). Students revisit this column later. In addition, students only partially fill out the first three columns (*Environment*, *Task*, and *Reason*). In later lessons, students add to these columns.

Extension

The Biosuit Environments/Tasks can be differentiated based on the needs of the group. The most straightforward Environment/Task is Alaska: Oil Pipeline Engineer. The most complicated Environment/Task is Gulf of Mexico: Hazardous Material Technician.

Returning to the Driving Question Board (5 minutes)

Reference the lesson question on the DQB, *What is a biosuit?* Ask students if they think that they made progress in answering the question. Also ask students if they think they made progress in answering any of the other questions on the board. Tell students to record their progress on a post-it note. When students are done, they should read their post-it notes out loud to the class and post them to the DQB. If students have additional questions, they should add them to the DQB.

Helpful Tip

To organize the DQB, color-code your use of sticky notes. Use one color for questions and a different color for "what we figured out" or other findings.

Design Work: Establishing Group Work Expectations (Optional) (10 minutes)

To support team development, you might choose to engage students in a team development activity with their design groups prior to completing design work.

You might also want to assign, or have team's assign, specific roles to each team member. Possible team roles and descriptions can be found on page 14 in the Extreme Biosuits Student Handbook**.** If possible, have students work as a group to determine each person's role on their team, based on their strengths and personal interests**.**

Remind students that all team members must contribute to all portions of the design problem. Team roles designate a leader in a particular area. They do not exempt students from certain tasks in the design problem.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Extreme Biosuit Student Handbook entries can be used to monitor student progress during the module. Focus specifically on the Examining Biosuit Models chart on page 4.
- The Defining the Problem and Identifying Solutions (Round 1) chart on page 13 is used in multiple lessons during this module. Use this chart to monitor student progress on key ideas.
- Consider gathering evidence of student progress through small group and whole group discussions.
- Student contributions to the Driving Question Board can also be monitored.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.

Community Connections

Many communities have companies and organizations whose employees must use protective clothing for technical or production work. Often, these companies and organizations are willing to suggest a guest speaker to talk with students.

The teacher can also have students ask parents, guardians, or family members to share information about any protective gear they use at work or home. Students can share this information and create a class Protective Clothing Chart that can be posted for students to gain a better understanding of how often protective clothing is used in various professions.

Suggested Teacher Resources

Engineering Design Process	Extreme Biosuits Teacher Handbook, Appendix A
Meeting the Needs of All Learners	Extreme Biosuits Teacher Handbook, Appendix B
Extreme Biosuits Student Handbook	[Resource Link]
Talk Science Primer	[Web Link]
Smithsonian Magazine article on Neil Armstrong's spacesuit	[Web Link]
Divers Institute of Technology article, *The History of the Wetsuit*	[Web Link]
Io9 article about the history of wetsuits	[Web Link]
How Products Are Made article about wetsuits	[Web Link]
Naval Undersea Museum article about wetsuits	[Web Link]
The North East Diving Equipment Group page	[Web Link]
wiseGEEK article about hazmat suits	[Web Link]
WCTi12.com article about hazmat oil spill cleanup	[Web Link]
The Independent article about hazmat suits and Ebola	[Web Link]
Designing the Future Spacesuit	[Web Link]
Launchpad: The Making of a Biosuit (video)	[YouTube Link]

Extreme Biosuits

Day 2: Where the Scientist or Engineer Works

Grade Level	Middle School
Lesson Length	One 50-minute session (if possible, consider adding another day)

Lesson Overview

On Day 2, students research their assigned environment and career. This helps students more clearly define the design criteria and constraints. After researching the assigned environment and career, students begin to think about the impact their environment may have on a human body. Students imagine what would happen to a scientist working in their environment without a biosuit. Students create an initial model to show and explain their predictions about what may happen to the heart, lungs, blood vessels, skin, and eyes of a scientist working in their environment without a biosuit. The emphasis of the model is explaining the HOW and the WHY of the body response to the environment.

Connecting to the Next Generation Science Standards

On Day 2, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Asking Questions and Defining Problems, Developing and Using Models
- Disciplinary Core Ideas: ETS1.A Defining and Delimiting Engineering Problems, LS1.A Structure and Function, LS1.D Information Processing
- Crosscutting Concepts: Influence of Science, Engineering, and Technology on Society and the Natural World, Cause and Effect, Structure and Function

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

Performance Expectations
This lesson contributes toward building understanding of the following *engineering* performance expectations:
MS-ETS1-1. *Define the criteria and constraints of a design problem* with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and *potential impacts on people and the natural environment that may limit possible solutions.*
This lesson contributes toward building understanding of the following *life science* performance expectations:
MS-LS1-3. *Use argument supported by evidence for how the body is a system of interacting sub-systems composed* of groups of cells.
MS-LS1-8. Gather and *synthesize information that sensory receptors respond to stimuli* by sending messages to the brain for immediate behavior or storage as memories.

Specific Connections to Classroom Activity

In this lesson, students investigate the intended environments for their biosuits. By learning more about the intended environment and task, students are better able to articulate the design criteria and constraints for their biosuits.

As students begin to think about the impact of the environment on scientists and engineers, they predict ways the human body systems might respond to the environment. Students consider the ways in which the sensory input of cold water may change physiological functioning of various body systems. Through this process, students begin to understand that sensory receptors respond to stimuli and the human body is a system of interacting subsystems.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	**Asking Questions and Defining Problems** • *Define a design problem that can be solved through the development of an object, tool,* process, or system and *includes multiple criteria and constraints,* including scientific knowledge that may limit possible solutions. **Developing and Using Models** • *Develop a model to predict* and/or describe *phenomena*. • *Develop a model to describe unobservable mechanisms.*	By investigating the intended environment for their biosuit, students further refine their definitions of the design problem. At the end of the lesson, students develop a model to show their predictions about what happens to the body when it is exposed to cold water. In this model, students focus on how the body responds and why the body reacts the way it does.
Disciplinary Core Ideas	**ETS1.A Defining and Delimiting Engineering Problems** • *The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints* includes consideration of scientific principles and *other relevant knowledge likely to limit possible solutions.* **LS1.A: Structure and Function** • *In multicellular organisms, the body is a system of multiple interacting subsystems.* These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. **LS1.D Information Processing** • *Each sense receptor responds to different inputs* (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. These signals are then processed in the brain, *resulting in immediate behaviors* or memories.	In this lesson, students focus on identifying the key characteristics of the environment for which their biosuit is intended. By researching the environment, students can more clearly articulate design criteria and constraints. When students consider the human body's response to cold water, they predict how different body systems might respond to the cold water. Students consider how the different systems might work together. When students consider the body's response to cold water, they predict how exposure to cold water may impact the body. Through this prediction, students work with the idea that sense receptors respond to stimuli and that the body responds to the stimuli.

Crosscutting Concepts	**Influence of Science, Engineering, and Technology on Society and the Natural World** • *The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values*; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. **Cause and Effect** • *Cause and effect relationships may be used to predict phenomena in natural* or designed *systems.* **Structure and Function** • *Structures can be designed to serve particular functions* by taking into account properties of different materials and how materials can be shaped and used.	As students investigate the intended environment for their biosuit, they also consider the societal and ecological needs for the biosuit. In doing so, students think about why the engineering job is necessary to society or the natural world. As students consider the effects of cold water on the body, they develop an understanding that external stimuli can cause internal responses in the human body. Students work with the idea that certain body systems or structures serve certain functions that are necessary for human survival.

Basic Teacher Preparation

In this lesson, students conduct research on their environment and career. Students need access to books, copies, or computers that allow them to conduct independent research. You may want to identify a list of suggested websites or resources for students to use in their research. An initial list is provided in Appendix E.

Refer to the Extreme Biosuits Student Handbook ahead of time so you can address any questions students might have. Day 2 documents can be found on pages 15–18 in the Extreme Biosuits Student Handbook. The documents used in this lesson are:

- Researching Our Environment and Career (page 15)
- Defining the Problem and Identifying Solutions (Round 2) (page 16)
- Predicting the Response to Our Environment (pages 17 and 18)

To prepare for the whole group discussions, review the Talk Science Primer (See Suggested Teacher Resources for Day 1).

Required Preparation	Links/Additional Information
❑ Gather or purchase the required materials for the lesson	Refer to the Materials List below
❑ Review suggested teacher preparation resources and the recommended websites	Refer to the Suggested Teacher Resources section at the end of this lesson
❑ Identify suggested websites for student research	See Appendix E

Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Extreme Biosuits Student Handbook	Given to students on Day 1	1 per student	[Resource Link]
Computer access	Students will use web or print resources to research their assigned environment	1 per student (or group)	Available in most schools
Print resources	If computers are not available, make several print resources available to students	2 or 3 resources per group	Various web resources

Day 2: Where the Scientist or Engineer Works

Introduction (5 minutes)

Begin the lesson by referencing the DQB. Yesterday, students made progress on the question, *What is a biosuit?* Today, students begin to focus on the question, *Why are biosuits needed in certain environments?* To begin answering this question, students need to learn more about their environments. Ask students to share what they already know about their environments. Tell students that their first task today is to find out more about their assigned environment and career.

Mini-Lesson: Researching our Environment and Career (20 minutes)

Students begin to research their environment and career on their own. Refer to Researching Our Environment and Career on page 15 of the Extreme Biosuits Student Handbook. Instruct students to record their findings in the chart. Point out the three questions at the bottom of page 15 that ask about temperature.

Differentiating

To meet the needs of all learners, provide students with pre-identified resources according to their reading level.

Give students 15 minutes to research their environment and career.

After 15 minutes, have students share their findings with their group. Students should jot additional notes on page 15 as they learn more about their environment or career from their group.

Instruct students to revisit the Defining the Problem and Identifying Solutions chart they developed on Day 1 (page 13). Now that students have more information, they add to the chart. Instruct students to add additional ideas to Defining the Problem and Identifying Solutions (Round 2) on page 16 in the Extreme Biosuits Student Handbook. Again, students may not be able to fill in the last column. After Day 3, students revisit the chart again to fill in the final column.

Investigation: Predicting the Response to Our Environment (15 minutes)

Now that students know more about their environment and career, instruct students to imagine a scientist or engineer working in their environment WITHOUT wearing a biosuit. Ask students how they think the body would respond to the environmental conditions. Have students share ideas.

After a brief discussion, refer students to Predicting the Response to Our Environment on page 17 of the Extreme Biosuits Student Handbook. Read the instructions out loud. Review the body systems identified in the diagram on page 17. The diagram shows the relationship between various body systems and the integumentary system (the skin). Using the diagram, students can gain an initial sense of the ways that the body systems work together. Students build on this understanding throughout the following activity.

In this activity, students create a model of their predictions about how the body would respond to their environment. Instruct students to create their model on page 18 in the Extreme Biosuits Student Handbook. Students should focus specifically on the following five organs and body systems—heart, lungs, blood vessels, skin, and eyes. Student models should show WHAT they predict might happen to the organ or organ system. The emphasis, though, should be on the HOW and WHY the body responds in the way that they predict.

Students may struggle to connect the body response to the HOW and WHY. At this point in the process, encourage students to make their ideas public. Avoid looking for a "right" answer or an accurate explanation. Rather, encourage students to share their thinking and model their predictions.

NGSS Key Moment

The authors of NGSS emphasize the development and use of conceptual models. Conceptual models are explicit representations of a scientist's understanding of a phenomenon. They are working models that communicate the scientist's current and developing understanding. When developing conceptual models, students should focus on making their thinking public through words, pictures, and representations.

Whole Group Discussion: Sharing our Predictions (10 minutes)

After students create their models, ask students to share their models with their group members. Students should try to explain the WHAT, HOW, and WHY of their models. Bring the class together for a whole group discussion. Begin the discussion by having a few students or groups share their predictions. Press for students to share the reasoning behind their predictions. Encourage students to ask each other questions.

NGSS Key Moment

This discussion represents the first step in the process of designing an investigation—a key science and engineering practice. Although students do not actually design the investigation, they brainstorm possibilities. Later, students may compare their ideas to the actual investigation.

After sharing predictions, ask students to think about how they might test their predictions in the classroom. Have students share their ideas for testing their predictions. Remind students that all of the environments include scientists working underwater, in water that is colder than the air. Students will likely bring up the idea that they should simulate diving into cold water. They could measure the heart rate, breathing rate, blood pressure, skin response, and eye response to cold water. Tell students that in the next lesson, they work with their group to engage in that investigation to figure out how the body responds to the environment.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Biosuit Student Handbook entries can be used to monitor student progress during the module. For this lesson, focus specifically on student research on Researching Our Environment and Career on page 15.
- The developing Defining the Problem and Identifying Solutions (Round 2) chart can be used to track student progress across several lessons.
- Consider gathering evidence of student progress through small group and whole group discussions.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.

Community Connections

Some students may have parents or other relatives who work in extreme environments. Consider inviting these individuals to come to class and speak about their work environments and the challenging characteristics or features of the environment.

Suggested Teacher Resources

Meeting the Needs of All Learners	Extreme Biosuits Teacher Handbook, Appendix B.
Task Assignment Resources	Extreme Biosuits Teacher Handbook, Appendix E
Extreme Biosuits Student Handbook	[Resource Link]
CK12.org: Chapter 11, Human Biology	[Web Link]
MITK12Videos on how body counteracts changes in temperature	[YouTube Link]

Extreme Biosuits

Day 3: What If a Scientist or Engineer Does Not Wear a Biosuit?

Grade Level	Middle School
Lesson Length	One 50-minute session (if possible, consider adding another day)

Lesson Overview

In this lesson, students investigate what might happen to their scientist or engineer if he or she does not wear a biosuit in their environment. To do so, students conduct an experiment in which they monitor heart rate, breathing rate, blood pressure, skin response, and eye response to cold water. Students take measurements of all five variables prior to dunking their face or hands in cold water for 1 minute. After dunking their face or hands, students take measurements of all five variables again. Students conduct this investigation on each group member and report their results. Students should find that dunking their face or hands in cold water will change the heart rate, breathing rate, blood pressure, and skin temperature. Students may also find differences in the eye response.

When revising their model for the human body reaction to cold water, students should reason that the "cold" message must be sent from the skin to the other organs via a central processing center—the brain. Students should also consider how the various human body systems interact to maintain homeostasis when the human body is exposed to cold water. Finally, students should build on prior knowledge to reason that energy is transferred out of hotter regions or objects into colder ones.

When designing their biosuits, students should understand that they need to help the diver keep warmth, not—as commonly misunderstood at this grade level—keep the cold out. Students should keep this model in mind, along with the model of the human body response, when deciding which materials to use in their biosuits.

Connecting to the Next Generation Science Standards

On Day 3, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Developing and Using Models, Planning and Carrying out Investigations
- Disciplinary Core Ideas: PS3.B Conservation of Energy and Energy Transfer, LS1.A Structure and Function, LS1.D Information Processing
- Crosscutting Concepts: Cause and Effect

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

Performance Expectations

This lesson contributes toward building understanding of the following *life science* and *physical science* performance expectations:

MS-PS3-3. *Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*

MS-LS1-3. *Use argument supported by evidence for how the body is a system of interacting sub-systems composed* of groups of cells.

MS-LS1-8. *Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior* or storage as memories.

Specific Connections to Classroom Activity

Students engage in an investigation to determine the physiological responses to putting their face in cold water. Through this investigation, students find out that putting their face in cold water slows the heart rate, slows breathing, and lowers blood pressure. This finding demonstrates that the cold water stimuli somehow travels from the skin to the organs that respond (heart, lungs, and blood vessels). Because the message travels to so many different places, students begin to develop the idea that it must first travel to the brain. Students also consider the ways by which energy (or heat) is transferred from place to place.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	**Developing and Using Models** • *Develop a model to predict and/or describe phenomena.* • *Develop a model to describe unobservable mechanisms.* **Planning and Carrying Out Investigations** • *Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of an investigation.*	After engaging in the investigation, students develop a revised model demonstrating how the cold water stimuli can cause changes in heart rate, breathing, and blood pressure. Students also consider how the body systems work together to maintain homeostasis. After brainstorming possible investigations, students carry out an investigation to determine the physiological effects of putting their face or hands in cold water.
Disciplinary Core Ideas	**PS3.B: Conservation of Energy and Energy Transfer** • *Energy is spontaneously transferred out of hotter regions or objects and into colder ones.* **LS1.A: Structure and Function** • *In multicellular organisms the body is a system of multiple interacting sub-systems.* These sub-systems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. **LS1.D Information Processing** • *Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. These signals are then processed in the brain, resulting in immediate behaviors* or memories.	After conducting their investigation, students model what happens when they put their face or hands in cold water. Included in this model should be a description of thermal energy transfer. Students conduct an investigation to determine the physiological responses to putting their face or hands in cold water. They find that the cold water stimuli changes heart rate, breathing rate, and blood pressure. Students begin to reason that the "cold" message from their skin travels to the different organs to cause a response. Because the message travels to so many organs, students begin to reason that the message must past through a central location—the brain. Furthermore, students consider the ways that the different human body systems work together to produce a response.

Crosscutting Concepts	**Cause and Effect** • *Cause and effect relationships may be used to predict phenomena in natural or designed systems.* **Energy and Matter** • *The transfer of energy can be tracked as energy flows through a designed or natural system.*	Students observe the physiological effects of putting their face or hands in water. They can use data from the investigation to predict what might happen when the body is exposed to other similar situations. Students also consider the cause and effect of thermal energy transfer.

Basic Teacher Preparation

In this lesson, students conduct an investigation to measure the physiological response to putting their face or hands in cold water. If possible set up the lab materials prior to the lesson. Each group should have a bucket of cold (ice) water, a stopwatch, and a clear ruler. If available, this lesson can be enhanced by adding a heart rate and blood pressure monitor. If you choose to use a heart rate and blood pressure monitor, plan to introduce students to the use of the technology.

Refer to the Extreme Biosuits Student Handbook ahead of time so you can address any questions students might have. All Day 3 documents can be found on pages 19–23 of the Extreme Biosuits Student Handbook. The documents used in this lesson are:

- Testing the Response to Our Environment (pages 19 and 20)
- Revising Our Model (page 21)
- Reflections—What If Our Scientist or Engineer Does Not Wear a Biosuit? (page 22)
- Defining the Problem and Identifying Solutions (Round 3) (page 23)

To prepare for the whole group discussions, review the Talk Science Primer (see Suggested Teacher Resources for Day 1).

Required Preparation	Links/Additional Information
❑ Gather or purchase the required materials for the lesson	Refer to the Materials List below
❑ Review suggested teacher preparation resources and the recommended websites	Refer to the Suggested Teacher Resources section at the end of this lesson
❑ Set up lab stations	Refer to the Materials List below

Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Extreme Biosuits Student Handbook	Given to students on Day 1	1 per student	[Resource Link]
Bucket of ice water	Use just enough ice to make the water notably colder than the air	1 per group	Available in most schools

Stopwatch	To time heart rate and breathing rate	1 per group	[Resource Link]
Heart rate and blood pressure monitor (Optional)	To measure heart rate and blood pressure	1 per group	[Resource Link]
Clear ruler (in/cm)	To measure eye response	1 per group	[Resource Link]

Day 3: What If Our Scientist or Engineer Does Not Wear a Biosuit?

Introduction (5 minutes)

In the last lesson, students brainstormed ways to test what might happen if their scientist or engineer worked in their environment without a biosuit. In this lesson, students test what will happen to the scientist or engineer by testing the effects of cold water on the body.

Refer students to Testing the Response to Our Environment on pages 19 and 20 in the Extreme Biosuits Student Handbook. Emphasize the idea that the goal of this investigation is to figure out what might happen to the body when it is exposed to cold water. Review the procedures with students.

Helpful Tip

If heart rate monitors and sphygmomanometers (blood pressure cuffs) are available, use them in this investigation. You will likely need to teach students how to use the devices. If you do not have the technology available, have students take their pulse manually and skip the blood pressure measurement.

Investigation: Testing the Response to Our Environment (15 minutes)

Allow students to work in groups to complete the investigation. Be sure students record their data in the data table on page 20 in the Extreme Biosuits Student Handbook.

As students conduct the investigation, circulate to monitor student work and engage students in sense-making discussions. Discussion prompts may include:

- *Do you notice any trends in your data?*
- *Are your results what you expected?*
- *Why do you think x happened?*
- *Why do you think x responded one way and y responded a different way?*

Whole Group Discussion: Trends in the Data (5 minutes)

After all groups have completed the investigation, engage students in a whole group discussion. Ask students if they noticed any data trends. Students should notice that the heart rate, breathing rate, and blood pressure went down. They should also notice that the skin got cold. Ask students why they think these things happened. Press for students to supply reasoning.

Students might say that the cold water sent a message to the organs to cause them to slow down. Ask students how they think the message got to many different organs at the same time.

Help students develop the idea that the message first needed to pass through the brain, which then sent a message to body parts to tell them to slow down. The evidence for this was that so many body parts slowed down in response to one stimuli. Make sure that all students feel comfortable with this idea before moving on.

NGSS Key Moment

Developing the idea that the message from the skin must pass through a central processing area (the brain) before sending a message to the other organs is a critical step in the learning progression for LS1.D.

Ask students to think about WHY heart rate and breathing rate slowed down and why blood pressure dropped when the face was exposed to cold water. Push students to think about the advantages and disadvantages of this response. If students are stuck, encourage them to continue to work with their ideas and make their thinking public.

Many students may have predicted that the heart rate will speed up when the face is placed in cold water. Students might reason that by speeding up the heart rate, the body is trying to warm up. This would be an example of a typical homeostatic mechanism (the body gets cold, so the brain tells the body to do something to warm it up). Students may be very confused as to why the heart slows down. Push students to work with this confusion. You may ask questions such as:

- *In what other cases does our heart slow down?*
- *What happens to the rest of the body when the heart slows down?*
- *How does a slow heart rate relate to our breathing rate?*
- *Can you think of any other animals that regularly put their faces (or bodies) in cold water? Do you think they have the same response? How does that help us think about humans?*

Guide students to the idea that a slower heart rate means that oxygen is being transported around the body at a slower rate. That leads to a slower breathing rate. This translates to the idea that the person could hold their breath for longer periods of time. This is a well-known response in most mammals called the *mammalian diving response*.

The mammalian diving response is advantageous in most cases, so protecting divers from cold water may seem confusing. On one hand, the body responds to cold water by protecting interacting body systems. On the other hand, working in cold water is very difficult for divers! Encourage students to explore these ideas. Eventually, push the idea that even though the human body naturally responds to cold water in ways that protect a diver, divers must be comfortable so they can do their work successfully.

Extension

The response tested in this investigation is called the *mammalian diving response*. Scientific American published an article about the mammalian diving response that may be interesting to some students. The article can be found here.

Investigation: Revising our Model (10 minutes)

Once students have started to work with the idea that a slower heart rate may allow a person to hold their breath for a longer period of time but that cold water might prevent a diver from successfully doing their job, have students draft a revised model of the body response to cold water.

Have students read the Revising Our Model directions on page 21 of the Extreme Biosuits Student Handbook. Students should refer to their Draft Model on page 18 in the Extreme Biosuits Student Handbook. The revised model should clearly incorporate evidence from the investigation and science ideas from the discussion. Press students to justify their reasoning for why the message *must* have traveled to the brain. Also press students to incorporate the idea that all of the body systems work together.

Finally, have students incorporate the idea of *thermal energy transfer* into their models. Students should model that energy is transferred from hotter regions or objects into colder ones. Students need to understand that they need to help the diver keep warmth in and cold out. Students need this understanding later, when they begin developing their biosuits.

Have students share their models in their small groups and the whole group.

NGSS Key Moment

By revising their models, students are demonstrating their developing understanding of LS1.D. Students should cite evidence for the changes in their models. Comparing the model developed on Day 3 to the model developed on Day 2 will provide insight regarding progress along LS1.D.

NGSS Key Moment

At this point in the modeling process, students need to draw on science understanding developed as part of MS-PS1-4, which addresses the kinetic model of thermal energy transfer.

Mini-Lesson: What If Our Scientist or Engineer Does Not Wear a Biosuit? (10 minutes)

After completing their revised model, have students individually reflect on what they figured out in this investigation. Instruct students to respond to the prompts on page 21 in the Extreme Biosuits Student Handbook. Also have students complete Defining the Problem and Identifying Solutions (Round 3) on page 23. Students should now be able to complete the final column, labeled *Challenges,* of the chart.

Whole Group Discussion: What If Our Scientist or Engineer Does Not Wear a Biosuit? (Optional) (5 minutes)

Ask students to think about what might happen if scientists and engineers do not wear biosuits when working in extreme conditions. Push students to identify the reasons why the cold water may be dangerous to scientists and engineers working in the field. Ask students to share their ideas about designing biosuits.

NGSS Key Moment

This discussion helps students to further define the design problem. Students should realize that a biosuit must minimize the transfer of thermal energy from the human to the environment. This realization aids in the connection to MS-PS3-3 in the next lesson.

Extension

Ask students to think about why the mammalian diving response is beneficial for most mammals. Help students to think carefully about the response in different situations (such as hunting for food vs. completing a scientific task). Reading this article in the Dartmouth Undergraduate Journal of Science may help with understanding.

Returning to the Driving Question Board (5 minutes)

Reference the lesson question on the DQB, *Why are biosuits needed in certain environments?* Ask students if they think they made progress in answering the question. Also ask students if they think they made progress in answering any of the other questions on the board. Tell students to record their progress on a sticky note. When students are finished, they should read their sticky notes out loud to the class and post them to the DQB. If students have additional questions, they should add them to the DQB.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Extreme Biosuits Student Handbook entries can be used to monitor student progress during the module.
- Use revised student models (page 21) in comparison to initial student models (page 18) to monitor growth on key learning for this lesson.
- Use What If Our Scientist or Engineer Does Not Wear a Biosuit student reflections on page 22 to get a sense of student thinking.
- Compare all three rounds of Defining the Problem and Identifying Solutions (pages 13, 16, and 23) to observe student growth throughout the module.

- Consider gathering evidence of student progress through small group and whole group discussions.
- Student contributions to the Driving Question Board can also be monitored.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.

Community Connections

Ask students to talk to an adult at home to brainstorm other examples of the mammalian diving response. Encourage students to brainstorm situations in which this response may be beneficial or harmful to mammals.

Suggested Teacher Resources

Meeting the Needs of All Learners	Extreme Biosuits Teacher Handbook, Appendix B
Extreme Biosuits Student Handbook	[Resource Link]
Mammalian diving response	[Web Link]
Mammalian diving reflex	[Web Link]
Conduction: Heat Conduction through Materials	[Web Link]
Molecular Workbench: Heat	[Web Link]

Extreme Biosuits

Days 4 and 5: Materials We Can Use to Develop a Biosuit

Grade Level	Middle School
Lesson Length	Two 50-minute sessions (if possible, consider adding another day)

Lesson Overview

Students link the ideas of human response to stimuli to thermal energy transfer. Students realize that to keep their diver safe, they must limit the thermal energy transfer from the human body to the surrounding environment. Students select materials for their biosuits that minimize the transfer of thermal energy.

Students are also introduced to the budgetary constraints that impact biosuit development, and they learn which materials may be used in their designs. Students start to map their environmental and budgetary constraints. Key considerations include:

- *What material choices help ensure survival in extreme environments?*
- *What body parts need to be protected?*
- *What are the costs of the materials?*
- *How might cost impact final selection?*
- *Will the planned biosuit enable the scientist or engineer to perform their tasks?*

Connecting to the Next Generation Science Standards

On Days 4 and 5, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Asking Questions and Defining Problems, Constructing Explanations and Designing Solution
- Disciplinary Core Ideas: ETS1.A Defining and Delimiting Engineering Problems, ETS1.B Developing Possible Solutions, PS3.B Conservation of Energy and Energy Transfer
- Crosscutting Concepts: Influence of Science, Engineering, and Technology on Society and the Natural World, Energy and Matter, Structure and Function

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

Performance Expectations

This lesson contributes toward building understanding of the following *engineering* performance expectations:

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

MS-ETS1-4. *Develop a model* to generate data for iterative testing and modification *of a proposed object, tool, or process* such that an optimal design can be achieved.

This lesson contributes toward building understanding of the following *life science* and *physical science* performance expectations:

MS-PS3-3. *Apply scientific principles to design*, construct, and test *a device that either minimizes or maximizes thermal energy transfer.*

Specific Connections to Classroom Activity

An important step in defining the criteria and constraints of the design problem is made in this lesson as students relate the science ideas embedded in MS-PS3-3 to the design problem. At this point in the module, the science ideas developed during Days 1 through 3 become instrumental to solving the design problem.

In this lesson, students begin to work with the idea of energy transfer to design a biosuit. The biosuit must minimize the transfer of thermal energy. With science ideas in mind, students develop a model of their proposed biosuit and a justification for how it might work.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	**Asking Questions and Defining Problems** • *Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.* **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.* • *Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.*	After working with the design problem for the first three lessons, students further define the problem by adding science ideas to determine possible solutions. Students work with the ideas of energy transfer and human response to stimuli. In this lesson, students begin the process of finding materials and drafting a design product. Students begin the design cycle by engaging in the initial steps of constructing the design product.
Disciplinary Core Ideas	**ETS1.A Defining and Delimiting Engineering Problems** • *The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions.* **ETS1.B: Developing Possible Solutions** • *Models of all kinds are important for testing solutions.*	Students consider relevant scientific principles while they consider possible design solutions. As students determine the possible materials to use in their design product, they consider the ideas of thermal energy transfer and human response to stimuli. This lesson helps students further define the design problem by including relevant science ideas. Students develop biosuit models prior to building their biosuits in subsequent lessons. Students justify their design decisions using their models.

	PS3.B: Conservation of Energy and Energy Transfer • *Energy is spontaneously transferred out of hotter regions or objects and into colder ones.*	After investigating the human response to cold water, students realize that they must protect the diver. To do so, students must minimize thermal energy transfer from the body to the external environment. Students work with ideas related to thermal energy transfer as they determine which materials to use and how to construct their biosuits.
Crosscutting Concepts	**Influence of Science, Engineering, and Technology on Society and the Natural World** • *The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values;* by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. **Energy and Matter** • *The transfer of energy can be tracked as energy flows through a designed or natural system.* **Structure and Function** • *Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.*	While designing their biosuits, students consider the use of their technology by society. Students realize that the biosuits must serve a particular function in a particular environment. As students select materials for their biosuits, they consider the flow of thermal energy from the human body to the surrounding environment. Students purposefully design structures (biosuits) using different materials to serve a particular function. In designing biosuits, students must take into account the intended function and the various materials that can be used.

Basic Teacher Preparation

Students continue to work with their teams. In this lesson, each team creates specific parts of a biosuit, rather than an entire biosuit model, to address the tasks. The full biosuit testing occurs on the final presentation day.

For this lesson, and the subsequent build day lessons, all required materials must be available and organized in a way that makes it easy for student teams to “purchase” materials. Materials should be set up in a secure place in a way that resembles a store and ensures that students cannot retrieve materials without teacher permission.

Students should be guided as needed during group discussions and time management to make sure they manage their time to meet the day’s deliverables.

Refer to the Extreme Biosuits Student Handbook ahead of time so you can address any questions students might have. All Day 4 and 5 documents can be found on pages 24–27 of the Extreme Biosuits Student Handbook. The documents used in this lesson are:

- Biosuit Draft Sketch (page 24)
- Materials List (page 25)
- Draft Team Budget Sheet (page 26)
- Actual Team Budget Sheet (page 27)

Required Preparation	Links/Additional Information
❑ Gather or purchase the required materials for the lesson	Refer to the Materials List below
❑ Review suggested teacher preparation resources and the recommended websites	Refer to the Suggested Teacher Resources at the end of this lesson
❑ Set up the materials "store"	Refer to the Materials List below

Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Extreme Biosuits Student Handbook	Given to students on Day 1	1 per student	[Resource Link]
Ski gloves		2 or 3 pairs per class	Bring from home or ask students to provide
Rubber gloves		2 or 3 pairs per class	Bring from home or buy at local store
Goggles		3 or 4 per class	Purchase [Web Link]
Snorkel		2 per class	Bring from home or purchase [Web Link]
2-liter bottles		3 per class	Bring from home
Plastic tubing		10–12 feet per class	Plastic tubing [Web Link]
Felt		Several yards per class	Felt [Web Link]
Buckets		3 per class	Bring from home or buy at local store
1-gallon milk jugs		3 per class	Bring from home or buy at local store
Plastic cups		3–5 per class	Bring from home or buy at local store
Aluminum pans		2 per class	Bring from home or buy at local store
Cotton balls		50 per class	Bring from home or purchase [Web Link]
Wire hangers		3 per class	Bring from home or buy at local store

Aluminum foil		25 feet per class	Bring from home or buy at local store
Flashlight		2 per class	Bring from home or purchase [Web Link]
Plastic wrap		25 feet per class	Bring from home or buy at local store
Newspapers		10 sheets	Bring from home
Tweezers		2 per class	Bring from home or purchase [Web Link]
Dish soap		1 bottle per class	Bring from home or buy at local store
Duct tape		1 roll per class	Bring from home or buy at local store
Masking tape		1 or 2 rolls per class	Bring from home or buy at local store
String		10 feet per class	Bring from home or buy at local store
Cardboard boxes		5 small boxes per class	Bring from home or buy at local store
Hot glue gun		1 per group	Bring from home or purchase [Web Link]
Scissors		Several per class	Available in most schools
Stapler		Several per class	Available in most schools

Day 4: Materials We Can Use to Develop a Biosuit

Introduction (5 minutes)

Begin the lesson by referencing the DQB. Remind students that their goal is to design a biosuit that can be worn in an extreme environment and allow a scientist or engineer to do their work comfortably. Review the ideas that students have already developed (*What is a biosuit? Why are biosuits needed in certain environments?*). Tell students that they are now going to work with the third question on the DQB, *How can we design a model to test our biosuit?*

Ask students to recall why it may be dangerous for scientists or engineers to work in an extreme environment. Lead a short discussion about the dangers of working in extreme environments.

Whole Group Discussion: Minimizing Thermal Energy Transfer (10 minutes)

Engage students in a whole group discussion about the design features of their biosuits. Ask students to think about what features the biosuit must have in order to keep the scientist or engineer warm and still enable the scientist or engineer to do his or her job.

During the discussion, place an emphasis on the ideas of heat and energy. Ask students to recall what they already know about energy. At this point in the learning progression, they should know that the term *heat* in everyday language refers to *thermal energy,* and thermal energy is the motion of atoms or molecules in a substance. Students should also have a beginning understanding of the idea that energy can be transferred between two objects. During this discussion, push students to consider how energy is transferred. Students should think deeply about how to keep their scientist or engineer warm by minimizing the energy transfer from the body to the environment.

NGSS Key Moment

This discussion is a key moment in the module because it links MS-LS1-8 to MS-PS3-3 in the context of an engineering design challenge. Because the human body responds to stimuli, biosuits must be designed to reduce thermal energy transfer. In this discussion, students link the two key science ideas to the design problem.

Students must begin to consider the ideas of energy transfer during this discussion. During Days 4 and 5, students experiment with various materials to keep their scientist or engineer warm. During this experimentation, students begin to develop a better understanding of the idea that the types of matter present in a system matters in terms of energy transfer.

Design Work: Biosuit Draft Sketch (10 minutes)

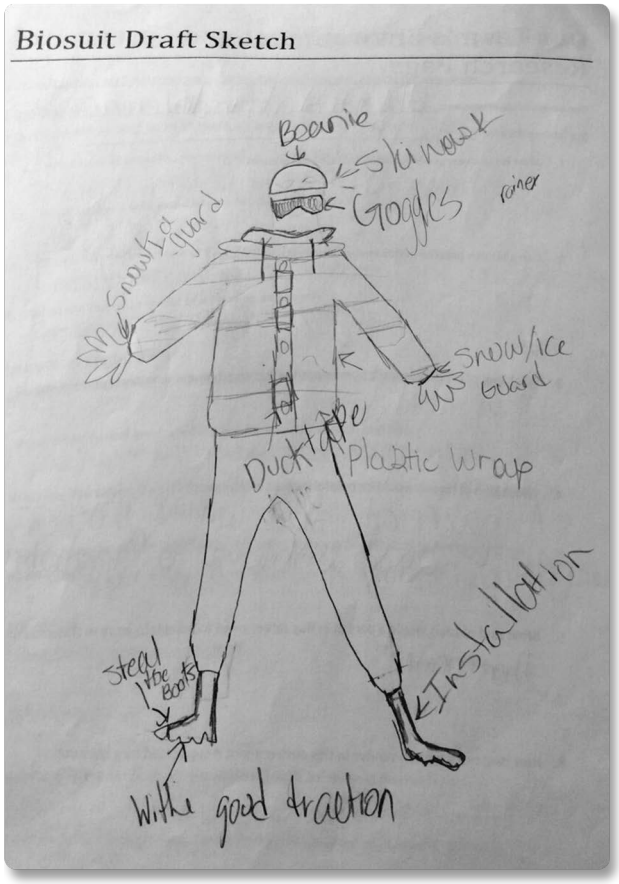
Now that students have started to consider the idea of energy transfer in the biosuit, have students work with this idea as they begin to draft their biosuits.

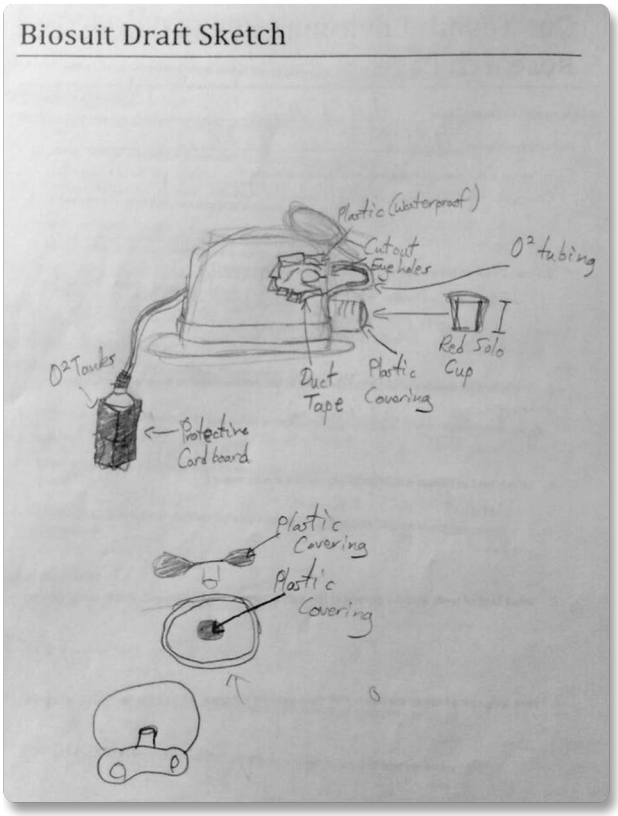
Have students turn to Biosuit Draft Sketch on page 24 in the Extreme Biosuits Student Handbook. Instruct students to begin to brainstorm biosuit features. Students work in teams to sketch an initial draft of their biosuits.

Remind students that they need to think carefully about the energy transfer from the human to the ocean system. Students should justify their design decisions using science ideas.

NGSS Key Moment

As students engage in design work, they should continually reference the science ideas developed on Days 1 through 3. Encourage students to continually refer to the ideas embedded in MS-LS1-8 and MS-PS3-3 (response to stimuli and thermal energy transfer). By doing so, students continue to build on MS-LS1-8, MS-PS3-3, and MS-ETS1-1.





Images provided by Renee Crawford.

Design Work: Materials Research (15 minutes)

Once students have an initial draft of their biosuits, show students the available materials. Reference the Materials List for Budgeting on page 25 in the Extreme Biosuits Student Handbook. Also, place the materials around the room, so students can examine all the materials.

Tell students that before selecting materials, they need to consider the properties of each material. Their goal is to determine which materials would be best suited for their biosuit model, given the constraints of the performance task and its related environment. Allow students to test which materials work as better insulators. For instance, students may wrap an ice cube in equal thicknesses of felt, layered aluminum foil, and newspaper, and measure which ice cube lasts the longest. After testing the materials, have students include their selected materials on their Biosuit Draft Sketch on page 25 in the Extreme Biosuits Student Handbook

Tell students that the available materials can also be used to represent materials that are not available in the classroom. For example, the aluminum foil could represent a bullet proof layer or Mylar. The felt could represent nylon layers. The rubber could represent neoprene. Students may choose to do additional materials research on their own.

Remind students that they may want to consider including multiple layers in their biosuit.

Design Work: Budgetary Planning (10 minutes)

Refer students to Materials List for Budgeting on page 25 in the Extreme Biosuits Student Handbook. Inform teams that they have a $25,000 budget, and it cannot be exceeded. Allow 5 minutes for each student to complete a Draft Team Budget Sheet on page 26 in the Extreme Biosuits Student Handbook. Next, have students share their individual budgets with their teams, and then, as a team, come to consensus on a proposed budget. Instruct students to record their actual budget on the Actual Team Budget Sheet on page 27 in the Extreme Biosuits Student Handbook.

NGSS Key Moment

By considering the budget, students consider relevant constraints to the design problem. This helps students make progress on MS-ETS1-1.

Day 5: Materials We Can Use to Develop a Biosuit

Introduction (5 minutes)

Refer students to the Engineering Design Process on page 1 in the Extreme Biosuits Student Handbook. Point out to students that they should have already come to consensus on the best solution (Step 4) and they are now going to construct their prototype (Step 5).

Design Work: Materials Purchase (10 minutes)

Remind student teams that they have a $25,000 budget that cannot be exceeded. Have teams select and purchase their team materials based on their agreed upon budget. As students purchase materials, they must provide a justification for each purchase. The justification must reference at least one of the two key science ideas—the human body response to cold or thermal energy transfer.

Helpful Tip

Have at least one copy of the **Materials List for Budgeting** available at the store.

Consider staggering purchasing throughout Days 4 and 5.

Students must justify their purchases using the criteria for the job (for example, the scientist or engineer needs to see in the dark). If a justification seems insufficient, the student group needs to revise their justification and try again.

Design Work: Design and Build (25 minutes)

The groups begin to construct their biosuit models. Students should use the Biosuit Draft Sketch on page 24 in the Extreme Biosuits Student Handbook to modify and improve their model ideas before purchasing materials.

As students work, prompt students to justify their decisions and provide reasoning. Circulate around the teams and ask questions that focus on the key science ideas.

Example questions include:

- *I noticed that you selected aluminum. What does the aluminum represent? Why did you think aluminum was the best choice? Why did you think the aluminum was better than the felt? (Push students beyond budgetary constraints and toward science ideas.)*
- *How does this allow the scientist or engineer to get the job done?*
- *How does your biosuit protect your diver?*
- *How does your biosuit minimize energy transfer?*
- *Why did you decide to use two layers instead of three?*
- *What materials would add if you had an unlimited budget? Why?*

Important Note

The materials available to students do not meet all the specifications and resources that real engineers might be able to access. However, as students think more about the functional needs of the biosuit for task completion and survival needs in extreme environments, they should relate the materials they select to actual materials that would be used in an authentic "build" situation. For example, more costly biosuits might use neoprene or Mylar materials (among others). Students should provide several reasons and connect their thinking to their draft sketch and eventual biosuit descriptions and presentations—the more, the better. Students should indicate what each selected material helps them to achieve and explain whether tradeoffs, such as cost and availability, were or were not a factor in making their selection.

Lesson Close (10 minutes)

Tell students that in the next lesson, they will have 5 minutes to prepare to present their biosuit design and budget to other teams. The goal of each presentation is to receive feedback for possible design improvements and/or budget considerations.

Guide students to reflect on how they plan to share their design and budget with other teams. Inform teams that each member must have a speaking role in presenting their design, model construction (to date), and budget.

Inform teams that after they have received feedback from the other teams, they might want to redesign and/or rework their budget. Emphasize the importance of justifying design decisions with science ideas or evidence from investigations.

Helpful Tip

To save time, consider having the marketing manager on each team coordinate the presentation throughout Days 4 and 5.

Helpful Tip

Consider having a shoebox or plastic tub for each team to store their supplies and model.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Extreme Biosuit Student Handbook entries can be used to monitor student progress during the module. For this lesson, focus specifically on the Biosuit Draft Sketch on page 24 and the justifications for purchases on page 26.
- Carefully check student justifications at the store to monitor student understanding. Listen for key understandings about heat transfer and material properties.

- Consider gathering evidence of student progress through small group and whole group discussions.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.

Community Connections

Have students ask their parents, guardians, or adult family members to share how budgetary considerations and tradeoff decisions impact work projects and/or home decisions.

Suggested Teacher Resources

Meeting the Needs of All Learners	Extreme Biosuits Teacher Handbook, Appendix B
Extreme Biosuits Student Handbook	[Resource Link]

Extreme Biosuits

Days 6, 7, and 8: How to Build Our Biosuit Models

Grade Level	Middle School
Lesson Length	Three 50-minute sessions

Lesson Overview

On Day 6, student teams participate in a *critical friends tuning protocol* to give and receive feedback on their biosuit designs and budget. Student teams then reflect on the peer feedback and decide how to redesign their model to optimize its performance. On Days 7 and 8, students construct their biosuit models to meet all of the criteria for their task assignment and environmental conditions. Additionally, students collaborate to make tradeoff decisions based on a range of constraints—especially budgetary constraints. Students also prepare an accompanying presentation that shows how each feature of their biosuit enables scientists and engineers to comfortably work in extreme conditions.

For additional presentation information, refer to the Welcome Letter on page 2 in the Extreme Biosuits Student Handbook, and the Final Presentation guidelines on page 30 in the Extreme Biosuits Student Handbook.

Connecting to the Next Generation Science Standards

On Days 6, 7, and 8, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Developing and Using Models, Constructing Explanations and Designing Solutions, Engaging in Argument from Evidence
- Disciplinary Core Ideas: ETS1.B Developing Possible Solutions, PS3.B Conservation of Energy and Energy Transfer
- Crosscutting Concepts: Energy and Matter, Structure and Function

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

Performance Expectations
This lesson contributes toward building understanding of the following *engineering* performance expectations:
MS-ETS1-4. *Develop a model to generate data for iterative testing and modification of a proposed object, tool,* or process *such that an optimal design can be achieved.*
This lesson contributes toward building understanding of the following physical science performance expectations:
MS-PS3-3. *Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*

Specific Connections to Classroom Activity

The focus of Days 6, 7, and 8 is on MS-ETS1-4. In these lessons, students build biosuit models. On Days 9 and 10, students test their biosuits to generate data for iterative testing. To develop a model biosuit, students must apply their understanding of thermal energy transfer.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	**Developing and Using Models** • *Develop a model to generate data to test ideas about designed systems,* including those representing inputs and outputs. **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.* • *Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.* **Engaging in Argument from Evidence** • *Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system based on empirical evidence concerning whether the technology meets relevant criteria and constraints.*	In previous lessons, students developed a conceptual model of their understanding of the human response to stimuli. In this lesson, students build a different kind of model. Students develop a physical model of a biosuit, so they can generate data to test ideas about their designed system. After brainstorming design products in earlier lessons, students begin to engage in the process of designing their biosuit model. When students develop their final presentations, they make an argument, from evidence, about why their biosuit will work and why Boeing should built the biosuit.
Disciplinary Core Ideas	**ETS1.B: Developing Possible Solutions** • *Models of all kinds are important for testing solutions.* **PS3.B: Conservation of Energy and Energy Transfer** • *Energy is spontaneously transferred out of hotter regions or objects and into colder ones.*	Students realize that they must develop a biosuit model so they can test it under simulated conditions. The biosuit model will be useful in collecting data to revise and redesign the model. In later lessons, students test their models. In their models, students attempt to minimize energy transfer between two objects, so they can keep their scientist warm. Students consider the amount and types of material to use in their design to minimize energy transfer.
Crosscutting Concepts	**Energy and Matter** • *The transfer of energy can be tracked as energy flows through a designed or natural system.* **Structure and Function** • *Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.*	While designing their biosuit model, students consider the energy transfer from the human body to the surrounding environment. Students attempt to design structures in order to limit the energy transfer. Students consider specific materials that may aid in the limit of energy transfer.

Basic Teacher Preparation

Preparation for this three-day block is the same as that for Days 4 and 5. All required materials must be available and organized for easy student access. Materials should be set up in a secure place in a way that resembles a store, so students can only retrieve materials with the teacher's permission. In addition, students need a secure location to store their purchased materials and model iterations.

Monitor student teams to ensure team members remain on task and fulfill their team roles to meet daily deliverables.

Refer to the Extreme Biosuits Student Handbook ahead of time so you can address any questions students might have. All Day 6 through 8 documents can be found on pages 28–30 in the Extreme Biosuits Student Handbook. The documents used in this lesson are:

- Feedback Template (page 28)
- Redesign Sketches (page 29)
- Final Presentation (page 30)

Required Preparation	Links/Additional Information
❑ Gather or purchase the required materials for the lesson	Refer to the Materials List below
❑ Review suggested teacher preparation resources and the recommended websites	Refer to the Suggested Teacher Resources at the end of this lesson
❑ Set up the Materials Store	Refer to the Materials List below
❑ Ensure that appropriate technology is available for students to create their presentations (such as, computers with slideshow software installed)	

Materials List

All materials available on Days 4 and 5 must also be available on Days 6, 7, and 8.

Day 6: How to Build Our Biosuit Models

Introduction (5 minutes)

Refer students to the Feedback Template on page 28 in the Extreme Biosuits Student Handbook. Give teams 5 minutes to set out their Biosuit Sketches and decide how each member of the team will answer questions from other teams. Remind students that every team member must participate in the feedback question and answer session.

Design Work: Biosuit Critical Friends (40 minutes)

Explain to students that they are going to participate in a critical friends tuning protocol to give and receive feedback. Remind students that when they receive feedback from a visiting team, they do not need to defend their design or verbally respond to the feedback. They are to take notes on the feedback. They have time, as a team, at the end of the feedback session to process their feedback and make team decisions regarding any changes to design, tradeoffs, or budget.

Have student teams rotate to other teams in 5 minute cycles to provide feedback on designs, tradeoffs, and budgets. A timing schedule for the feedback rotations, along with student question prompts is below. Consider posting the questions for students.

- **Presenting Team:** 1 minute to explain their environment, design, budget decisions, and justification based on science ideas.
- **Visiting Team:** 2 minutes for clarifying questions. Each member of the visiting team must ask at least one question. Suggested questions include:
    - *How did you decide what to include in your draft sketch?*
    - *What are your criteria?*
    - *What are your constraints?*
    - *What design tradeoffs have you made? Why?*
    - *What science ideas influenced your decisions?*
- **Visiting Team:** 2 minutes for team members to give suggestions—one suggestion per person—to the team. Guide students to give their feedback starting with, "I'm wondering…" For example, "I'm wondering if your design might be stronger if you put a cuff on the end?" When making suggestions, students should *always* justify their suggestions with science ideas. For instance, the suggestion about the cuff should reference the transfer of thermal energy. During this time, receiving teams do not respond to the "I'm wondering" feedback. They annotate feedback ideas in the *Critical Feedback* section on their Feedback Template.
- Teams then rotate to another team's design and repeat the process.

Ideally, teams give and receive feedback to three other teams. Not all teams will get to give and receive feedback to every team. After the three rounds of feedback, teams complete the *Team Reflection* section of the Feedback Template on page 28 in the Extreme Biosuits Student Handbook and decide on any design changes. Teams then complete the *Adjustments and Action Plan* section of the Feedback Template.

Lesson Close (5 minutes)

Teams reflect on any design changes they may want to include as part of the feedback cycle. Teams should use page 29 in the Extreme Biosuits Student Handbook to capture their Redesign Sketches.

Helpful Tip

Consider adding an exit ticket that requires team members to rate themselves—and each other—on time management and overall contribution to the project for each day. All ratings should include at least 1 or 2 explanatory sentences.

Day 7: How to Build Our Biosuit Models

Introduction (5 minutes)

Have student teams complete a team role check-in, in which each team member describes what they plan to accomplish during today's build time. Each team member should review their identified tasks for completion and share with the group any challenges or assistance needed.

Helpful Tip

Consider having students track individual contributions using a time-tracking chart.

Be sure to remind the class that ALL students should contribute to ALL tasks, even though one individual may be in charge of certain tasks. For instance, the team marketing manager should not develop the presentation alone. All student input is necessary.

Design Work: Biosuit Build (40 minutes)

Groups continue to construct their biosuit models. Students should also begin to work on their biosuit presentations as outlined in Final Presentation on page 30 in the Extreme Biosuits Student Handbook. During this time, monitor each team by checking in with team members and asking clarifying questions regarding their next steps and task list for the day. Also ask groups questions that focus on the science ideas, criteria, and constraints included in their designs.

Examples of questions include:

- *Why did you decide to use* x*?*
- *Why did you decide to include the* y *feature in your design?*
- *What science idea impacted your decision to include* z*?*
- *How will your biosuit minimize energy transfer from the scientist or engineer to the local environment?*
- *How will your biosuit protect your scientist or engineer?*

NGSS Key Moment

Make sure the key science ideas of response to stimuli and thermal energy transfer are central in the design process. If students begin to lose sight of these ideas, refocus them through guiding questions. At this point in the design process, students should be building on their understanding of science ideas to develop a design product (the biosuit).

Helpful Tip

Consider posting anchor charts in the classroom to ensure students have the science in mind. For instance, an outline of the human body with some critical systems could invite teams to post notes with ideas about protecting those systems and how they relate to one another. Another chart could gather teams' ideas about conducting and insulating materials.

Lesson Close (5 minutes)

Teams continue to manage their budgets and continue purchasing materials as needed. They should also check to see which tasks are on track and which will need special attention during the next lesson.

Helpful Tip

Have team members create a checklist of what they accomplished today, and what they still need to accomplish to finish their deliverables during the next two class sessions.

Day 8: How to Build Our Biosuit Models

Design Work: Biosuit Build (35 minutes)

This session provides students with a second day to design their models and prepare their presentations. The day's activities should generally mirror Day 7.

Extension

Consider adding the requirement that teams must supply data showing that their biosuit works. Students can design their own investigations to collect data on their biosuit design.

Design Work: Design Decisions (15 minutes)

To conclude the design work, instruct students to independently write a paragraph justifying their team's design choices. Students should refer to their Defining the Problem and Identifying Solutions (Rounds 1–3) charts on pages 13, 16, and 23 in the Extreme Biosuits Student Handbook, and Final Presentation on page 30 when crafting their final arguments. Consider using the Argument Scoring Guide (see Appendix D) to assess student arguments.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Extreme Biosuit Student Handbook entries can be used to monitor student progress during the module. For this lesson, focus specifically on the Redesign Sketches (page 29).
- Monitor student progress using student justifications for design choices. Consider using the Argument Scoring Guide (see Appendix D) to assess student arguments.
- Consider gathering evidence of student progress through small group and whole group discussions.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.

Community Connections

Have students ask their parents, guardians, or adult family members if they have ever worked on a project at work where they collaborated with a team. Have students ask about the challenges and benefits of collaborative teamwork.

Suggested Teacher Resources

Meeting the Needs of All Learners	Extreme Biosuits Teacher Handbook, Appendix B
Argument Scoring Guide	Extreme Biosuits Teacher Handbook, Appendix D
Extreme Biosuits Student Handbook	[Resource Link]

Extreme Biosuits

Days 9 and 10: Biosuit Testing, Presentation, and Reflection

Grade Level	Middle School
Lesson Length	Two 50-minute sessions

Lesson Overview

During the final two lessons, students accomplish their performance task by completing their biosuit models. They also finish and give their team presentations.

Connecting to the Next Generation Science Standards

On Days 9 and 10, students demonstrate understanding of the performance expectations and three dimensions developed throughout the entire module. These lessons serve as a performance assessment in which all the performance expectations and dimensions are addressed in the final presentation. Please reference the performance expectations, disciplinary core ideas, science and engineering practices, and crosscutting concepts referenced in this module's front matter.

Basic Teacher Preparation

The culminating project assumes that students give presentations to an authentic audience, which could include other teachers and adults from outside the classroom, such as parents, guardians, family members, and volunteers (engineers and scientists) from the community. Secure their participation in advance. Prepare the materials for the testing stations ahead of time.

Helpful Tip

Depending on the number of groups, student presentations may last beyond Day 10.

Review the Biosuit Environments and Tasks on pages 11 and 12 in the Extreme Biosuits Student Handbook and the Testing Stations Guide in the Suggested Teacher Resources at the end of this lesson. Also, if you plan to spread the team presentations over two class sessions, announce which groups are on each day to ensure they are ready.

Review Final Presentation on page 30 of the Extreme Biosuits Student Handbook to remind students of the presentation expectations.

Required Preparation	Links/Additional Information
❑ Gather or purchase the required materials for the lesson	Refer to the Materials List below
❑ Review suggested teacher preparation resources, the recommended websites, and Testing Stations Guide	Refer to the Suggested Teacher Resources at the end of this lesson
❑ Ensure appropriate computer technology is available for student presentations	

Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Baby pools or fish tank	These are used to conduct underwater assembly tasks	4 per class	Have students bring from home or purchase [Web Link]
PVC pipe		1 or 2 per class	Purchase [Web Link]
PVC elbows		3 or 4 per class	Purchase [Web Link]
Dirt		3 or 4 per class	Bring from home or environs
Food coloring		1 box	Bring from home or buy at store
KNEX®, Legos®, or other plastic blocks		10–12 feet per class	Bring from home or purchase [[Web Link]]
Small rubber hammer		1 per class	Purchase [Web Link]
Ice block	Make at home and embed a rock or fossil	1 per class	Make at home
Tweezers		1 or 2 per class	Bring from home or purchase [Web Link]
Rocks		Several	Gather from environs
Sand		1 bag	Purchase [Web Link]
Plastic fish or fishing worms		2 or 3	Purchase rubber fish [Web Link] or plastic fish [Web Link]
Vegetable oil		1 bottle	Bring from home or buy at local store
Stuffed bird or rubber ducks		1 or 2	Bring from home

Day 9: Biosuit Testing, Presentation, and Reflection

Introduction (10 minutes)

Use Final Presentation on page 30 in the Extreme Biosuits Student Handbook to review final presentation expectations with students. In addition, give each group 15 minutes to prepare for their final performance test. Remind students that their presentations must be presented before they attempt the performance test. This time may also be used for last-minute biosuit model construction and fitting.

Design Work: Biosuit Presentations and Performance Tests (40 minutes)

Have each group give their presentations, either in a previously assigned order or have groups volunteer. Groups must first give their digital presentations, outlining their design, research, constraints, and budget details. After the presentation, the group performs their assigned test with the biosuit model they created. Only one team member should attempt the performance test.

Each group's presentation and testing should last approximately 5 minutes. Sufficient time should be provided for audience questions. Use the Presentation Rubric (see Appendix C) to grade each team's performance. You may need to modify the rubric to meet your needs.

Day 10: Biosuit Testing, Presentation, and Reflection

Design Work: Biosuit Presentations and Performance Tests (30 minutes)

Each student team has 5 minutes to give their presentations and test their biosuit models. Allow time for questions from the audience.

After all the presentations have been completed, engage the class in a discussion around their successes and challenges as they worked as engineering teams throughout the module.

Image provided by Renee Crawford.

Mini-Lesson: Project Reflection and Design Optimization (10 minutes)

After all teams have presented and tested their biosuits, instruct students to individually complete their Project Reflection and Design Optimization on page 31 in the Extreme Biosuits Student Handbook. Then, give students an additional 5 minutes to Think-Pair-Share their answers.

Lesson Close (10 minutes)

Popcorn around the room and have students share some of their responses to the first three questions on Project Reflection and Design Optimization. Remind students that as part of the engineering design process, they would engage in multiple testing, presentation, and redesign iterations before their biosuits would be ready for client presentation. Conclude the discussion with student answers to, *If you had to do the project again, what would you change about it and why?*

Assessment

Use the final presentation as a summative assessment for the unit. A Presentation Rubric is available in Appendix C.

Community Connections

If audience members from the engineering community (or elsewhere) are invited, ask them to share situations in their work setting where they present and test their ideas.

Suggested Teacher Resources

Presentation Rubric	Extreme Biosuits Teacher Handbook, Appendix C
Extreme Biosuits Student Handbook	[Resource Link]

Testing Stations Guide

Each team will need a specific setup to conduct their performance test, based on their assigned task. The four testing areas should be prepared before presentations begin.

Oil Pipeline Engineer—Alaska

The Oil Pipeline Engineer test requires a large plastic bin of cold muddy (brown) water that contains a PVC pipe attached to another with a damaged PVC elbow. Students must take apart the two pipes and replace the damaged elbow with a new one while seeing and breathing underwater. In addition, students must keep their hands and heads dry and warm.

Students do not submerge their entire heads, and they breathe using a snorkel, as if it is attached to an air tank.

Glaciologist—Antarctica

The Glaciologist test requires a large block of ice with many rocks frozen in it. The ice is submerged in clear water. Students must work with their hands, wearing protective gloves they created and using tool(s) they constructed, to retrieve the rocks from the ice while breathing underwater. In addition, students must keep their hands and heads dry and warm.

Students do not submerge their entire heads, and they breathe using a snorkel, as if it is attached to an air tank.

Deep Sea Biologist—Pacific Ocean

The Deep Sea Biologist test requires of a large plastic bin with water dyed black that contains rocks, sand, and plastic fish at the bottom. Students construct a tool that can "see" underwater and collect a specimen while keeping it alive and returning it to the outside of the bin while breathing underwater. Students must protect their hands and head during the task.

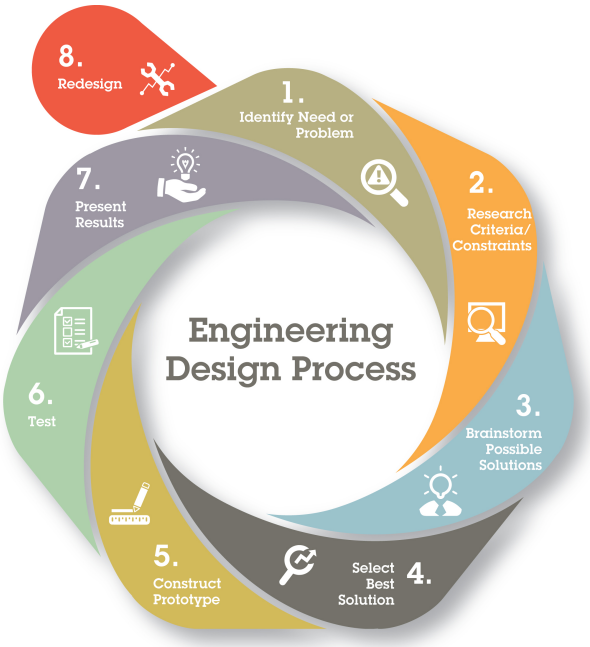
Students do not submerge their entire heads, and they breathe using a snorkel, as if it is attached to an air tank.

Material Engineer—Gulf of Mexico

The Material Engineer test requires a bin of water that contains an "oil spill" (vegetable oil and food coloring) as well as small stuffed birds. Students must clean up as much oil as possible wearing their mask/helmet and gloves, using the tool(s) and clean up materials they created.

Students do not submerge their entire heads, and they breathe using a snorkel, as if it is attached to an air tank.

Appendix A
Engineering Design Process



Step 1 Identify the Need or Problem

Describe the engineering design challenge to be solved. Include the limits and constraints, customer description, and an explanation of why solving this challenge is important.

Step 2 Research Criteria and Constraints

Research how others have solved this or similar problems, and discover what materials have been used. Be sure to thoroughly research the limitations and design requirements for success.

Step 3 Brainstorm Possible Solutions

Use your knowledge and creativity to generate as many solutions as possible. During this brainstorming stage, do not reject any ideas.

Step 4 Select the Best Solution

Each team member presents their solution ideas to the team. Team members annotate how each solution does or does not meet each design requirement. The team then agrees on a solution, or combination of solutions, that best meets the design requirements.

Step 5 Construct a Prototype

Develop an operating version of the solution.

Step 6 Test

Test your solution. Annotate the results from each test to share with your team.

Step 7 Present Results

Present the results from each test to the team.

Step 8 Redesign

Determine a redesign to address failure points and/or design improvements. The design process involves multiple iterations and redesigns. Redesign is based on the data from your tests, your team discussions as to the next steps to improve the design, and the engineering design process Steps 1 through 7.

Once your team is confident of a prototype solution, you present the results to the client. The client may:

- Accept your solution as is, or
- Ask for additional constraints and criteria to be included in the solution. At this point, you and your team revisit the engineering design process and resume the iterative redesign cycle.

Appendix B
Meeting the Needs of All Learners

Every learner is unique. To meet the needs of all learners in your class, consider the following strategies:

- Provide students with sentence stems for models, arguments, and explanations (see below).
- Use a graphic organizer to help students organize their thinking prior to creating their final presentation (see below).
- Prior to each group discussion, engage students in individual or small group discussions to help them prepare to share their ideas in a larger group.
- Provide students with a vocabulary list using the Glossary.
- Offer additional extension problems or challenges in math or science.
- Provide students with additional time to formulate their ideas prior to sharing with the class.
- Offer opportunities for students to engage in additional investigations to extend learning. This may include additional readings, science investigations, or research.

Design Problem:
Science Ideas related to the Design Problem:
First Draft Design Solution: *Reflection/Modifications Needed:*
Second Draft Design Solution: *Reflection/Modifications Needed:*
Final Design Solution and Justification:

Sentence Stems

Contributed by Karl Muench, Collins Middle School, Salem, MA

Claim

You frame the question and answer it. This may take a sentence or a paragraph. Examples of claim sentences include the following.

- Analysis (breaking down the elements)
  - Our analysis looked at the parts and their function in …
  - We know from our data that … is comprised (made of) …, … and …
- Comparison (similarities and differences)
  - … (A) and … (B) are alike in that both …
  - However, while … (A) does this …, the other, … (B), does this …
- Evaluation (testing against a set of rules)
  - The … (subject of study) best matched the rule that …
  - In the situations involving …, the … (subject of study) showed …
- Problem/solution
  - … is a problem, and the best solution is …
  - Very often, … will have a problem with … The way to fix it is …
- Cause/Effect
  - … causes … to happen.
  - … is created when …
  - … if … then …

Give a preview of how you will prove your claim. Follow the above statements with the word ***because***.

Evidence

Include research and results of demonstrations or your own experimentation that support your claim. In science, you need to cite ALL available evidence, even some that may work against your claim. (You can deal with that issue by using reasoning.)

- Analysis
  - We conducted this experiment … The results are shown in the following table.
  - We graphed … over … and saw this pattern …
  - In most cases, we saw … Sometimes, however, … would happen.
  - We found the following analysis of this in our research … (direct quotes with sources)
- Comparison
  - We compiled the following T-chart showing where these things are alike and unalike.
  - In this Venn diagram, we can see where these things are similar and different.
  - In both cases, … is true. But only for ... is … true.
  - We have both things on this graph. You can see here … where they meet.
- Evaluation
  - We were looking for the following criteria … The following met those criteria … The following did not meet those criteria …

- The rule … applies to the following … and does not work for …
- Scientists say … (quotation with source). We found this applied to ...

- Problem/Solution
  - These sources … point to this issue …
  - We tested our prototypes by … These were the results …
  - Experts such as … (sources) say … is a common problem.
  - … (source) emphasizes that … is a problem, with this possible solution ...
- Cause/Effect
  - Every time … happened, … would happen.
  - Scientists believe that … is caused by … (quote with source)
  - The following graph shows how … influences …
  - This chart shows when … happens (or is present) and what happens next.
  - Statistics indicate that ...

Reasoning

You need to explain in your own words how your evidence supports your claim. In the case of evidence that contradicts your claim, you must explain why other evidence has more merit or reliability.

- Analysis
  - The evidence supports our claim because …
  - The graph shows that as … rises, … rises/falls at a (steady or increasing) rate. This allows us to predict …
  - Taking the evidence as a whole shows …
- Comparison
  - These things behave similarly when … but differently when …
  - Considering these similarities and differences indicates …
  - Looking at the chart of evidence, we see how … is similar to …, but different in ...
- Evaluation
  - If … is true, we should see … This is exactly what we see in the case(s) of …
  - Every time (or almost every time) we tried this …, this happened …
  - ... did not meet our criteria as well as …, eliminating it as an option.
- Problem/Solution
  - As you can see, our test (or research) indicates this solution will solve the problem because …
  - Our research and testing found … can best solve this problem by …
  - We were looking for this … and found it in ...
- Cause/Effect
  - The evidence shows that … causes … because …
  - Looking at the data, we see that … followed … every time.
  - Our research shows that scientists support that … causes … because ...
- Dealing with contrary evidence
  - By looking at all of this, we can see that these data … are outliers.
  - While some scientists say …, most scientists agree that …
  - Some of our results are less reliable because ...

Appendix C
Presentation Rubric

The Presentation Rubric is intended to be used as a guide for the development of the assessment for the final presentations. Teachers should tailor the rubric to fit the module's specific needs and design problem.

Science and Innovation
A Boeing and Teaching Channel Partnership
PRESENTATION RUBRIC

	No Evidence	Beginning	Developing	Advanced
Quality of Design Product NOTE: This section should be tailored to assess specific module and performance expectations.	Design product fails to address most aspects of the performance task. Design product shows no evidence of thoughtful problem solving. Design product shows evidence of low-quality craftsmanship.	Design product addresses some aspects of the performance task. Design product shows little evidence of thoughtful problem solving. Design product shows evidence of mediocre-quality craftsmanship.	Design product addresses most aspects of the performance task. Design product shows some evidence of thoughtful problem solving. Design product shows evidence of mostly high-quality craftsmanship.	Design product addresses all aspects of the performance task. Design product shows clear evidence of thoughtful problem solving, deliberation, and decision making. Design product shows clear evidence of high-quality craftsmanship.
Explanation of Science Ideas Science ideas include science and engineering practices, disciplinary core ideas, and crosscutting concepts. NOTE: This section should be tailored to assess specific module and performance expectations.	Relevant science ideas are not addressed. Evidence is not cited.	Most relevant science ideas are stated and partially described in relation to the design problem. Some evidence is cited. Evidence was gathered through science investigations or critical analysis of existing sources.	All relevant science ideas are stated and described in relation to the design problem. Several lines of evidence are cited. Evidence was gathered through science investigations or critical analysis of existing sources.	All relevant science ideas are clearly stated and described in detail in relation to the design problem. Multiple lines of evidence are cited. Evidence was gathered through science investigations or critical analysis of existing sources.
Organization	The presentation does not include all of the required components. The presentation does not have a main idea or presents ideas in an order that does not make sense.	The presentation includes most of the required components. The presentation moves from one idea to the next, but the main idea may not be clear or some ideas	The presentation includes all of the required components. The main idea is clearly stated. The presentation moves from one idea to the next in a logical order, emphasizing main	The presentation includes all of the required components and either provides additional information for each component or adds additional components relevant to the presentation.

		may be in the wrong order.	points in a focused, coherent manner.	The main idea is clearly stated. The presentation moves from one idea to the next in a logical order, emphasizing the main points in a focused, coherent manner. (CC 6-8. SL.4)
Presenting Skills	The presenter does not look at the audience and reads notes or slides. The presenter wears clothing inappropriate for the occasion. The presenter mumbles or speaks too quickly or slowly. The presenter speaks too softly to be understood.	The presenter makes infrequent eye contact and reads notes or slides most of the time. The presenter dresses professionally. The presenter speaks clearly most of the time, although sometimes too quickly or slowly. The presenter speaks loudly enough for most of the audience to hear, but may speak in a monotone.	The presenter keeps eye contact with audience most of the time and only glances at notes or slides. The presenter dresses professionally. The presenter speaks clearly and not too quickly or slowly. (CC 6-8.SL.4) The presenter speaks loudly enough for everyone to hear and changes tone to maintain interest. (CC 6-8.SL.4)	The presenter engages the audience by drawing their sustained attention. The presenter maintains eye contact with the audience most of the time and only glances at notes or slides. (CC 6-8.SL.4) The presenter dresses professionally. The presenter speaks clearly and not too quickly or slowly. (CC 6-8.SL.4) The presenter speaks loudly enough for everyone to hear and changes tone to maintain interest. (CC 6-8.SL.4)

Appendix D
Argument Scoring Guide

Aspect of the Argument	Point Value 0	1	Comments or Suggestions
[redacted]			
Identify role, audience, and task (1)			
Accurately complete task		X2	
[redacted]			
Claim			
The claim is sufficient.			
The claim is accurate.			
Evidence			
Includes data/research			
Includes an analysis of the data/research			
Includes an interpretation of the analysis			
Reasoning: Justification of the Evidence			
Explains why each piece of evidence is important/relevant			
Links the evidence to a scientific concept or principle			
Identifies a line of logic or values that define success			
Reasoning: The Challenge			
Alternative explanation(s) explained clearly			
Demonstrates why the alternative explanation is inaccurate			
Mechanics			
Order and arrangement of sentences enhances argument			
Appropriate word usage, spelling, grammar, and punctuation			
Total Score		/15	

Adapted from: Sampson, Victor, and Sharon Schleigh. Scientific Argumentation in Biology. Arlington, VA: NSTA, 2013

Appendix E
Task Assignment Resources

Suggested Resources

Alaska Pipeline and Pacific Deep Sea Biologist Resources

Career	
Deep Sea Biologist – Visiting Investigator	[Web Link]
So You Want to Be A Deep Sea Biologist?	[Web Link]
Pipeline Engineering Jobs	[Web Link]
Pros and Cons of a Career in Pipeline Engineering	[Web Link]
Dangers	
10 Essentials for Cold Water Comfort	[Web Link]
Diver's Medical Alert Articles	[Web Link]
Pressure Injuries from Scuba Diving	[Web Link]
Wetsuits and Drysuits for Scuba Diving	[Web Link]
Information About How a Wetsuit Works	[Web Link]
Wetsuit Thickness Guide and Temperature Chart	[Web Link]

Suggested Resources

Antarctica Glaciologist

Career	
Glaciologist Career Profile	[Web Link]
Glaciologists: What They Do	[Web Link]
Information About Glaciologists	[Web Link]
Dangers	
How Dangers are Glaciers?	[Web Link]
Glaciology Projects and Research	[Web Link]
Arctic Survival	[Web Link]
Survival Tips in the Artic	[Web Link]

Working in Cold Environments	[Web Link]
Physiological Responses to the Thermal Environment	[Web Link]

Suggested Resources

Gulf of Mexico Hazmat Technician

Career	
Hazmat Technician Information	[Web Link]
What Does a Hazardous Materials Removal Worker Do?	[Web Link]
Spill Tech: Responsible Environmental Management	[Web Link]
Dangers	
US Department of Labor: Chemical Hazards and Toxic Substances	[Web Link]
How Do I Work Safely with Toxic Materials?	[Web Link]
Oil, Water, and Chemical Pollution	[Web Link]
US Department of Labor: Hazardous Materials Remover Workers	[Web Link]
Training Marine Oil Spill Response Workers	[Web Link]

Glossary

The key terms below are frequently used in the module. Students should develop a strong conceptual understanding of each term throughout the module. Definitions from dictionary.com unless otherwise noted.

bio-	A combining form meaning “life.”
biosuit	Any kind of protective suit that enables a human to maintain homeostasis while working in an environment that would not support human life.*
budget	An estimate, often itemized, of expected income and expenses for a given period in the future.
constraint	Limitation or restriction.
criteria	A standard of judgment or criticism; a rule or principle for evaluating or testing something.
engineer	A person trained and skilled in the design, construction, and use of engines or machines, or in any of various branches of engineering.
engineering design process	A series of steps that engineers follow to come up with a solution to a problem.*
hazardous	Full of risk; perilous; risky.
homeostasis	The tendency of a system, especially the physiological system of higher animals, to maintain internal stability, owing to the coordinated response of its parts to any situation or stimulus that would tend to disturb its normal condition or function.
Mylar	A brand of strong, thin polyester film used in photography, recording tapes, and insulation.
Neoprene	An oil-resistant synthetic rubber, used chiefly in paints, putties, linings for tanks and chemical apparatus, and in crepe soles for shoes.

**Definition developed by module authors.*