9 Get a Grip

DESIGN

3–4 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students use the approach of biomimicry to design, test, evaluate, and redesign a mechanical gripping device to meet criteria. They use an iterative process to optimize the device in one of two ways. In doing so, they investigate the relationship between structure and function of the device and how the technology they developed can be applied. Students are formally assessed on Performance Expectation MS-ETS1-4.

NGSS CORRELATION

Performance Expectation

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.

Applying 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.

Applying MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Disciplinary Core Ideas

MS-ETS1.A Defining and Delimiting Engineering Problems: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

MS-ETS1.B Developing Possible Solutions:

A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.

There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.

Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

Models of all kinds are important for testing solutions.

MS-ETS1.C Optimizing the Design Solution:

Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design.

The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

MS-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.

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 generate data to test ideas about designed systems, including those representing inputs and outputs.

Using Mathematics and Computational Thinking: Use mathematical representations to describe and/or support conclusions and design 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.

Crosscutting Concepts

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.

Interdependence of Science, Engineering, and Technology: Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

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.

Common Core State Standards—ELA/Literacy

SL8.4: Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound and valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

WHAT STUDENTS DO

In a culminating activity, students use their prior knowledge of the design process and opposing motion to design a mechanical grabber that can pick up and move an object. Students work together to achieve the goals laid out in a scenario by following the steps of the design process.

MATERIALS AND ADVANCE PREPARATION

- *For the class*
  - * assortment of masses, 5–40 grams

- *For the teacher*
  - 1 Scoring Guide: ENGINEERING DESIGN (ENG)
  - 1 Literacy Student Sheet 2, "Developing Communication Skills" (optional)
  - 1 Literacy Visual Aid 1, "Oral Presentations" (optional)

- *For each group of four students*
  - 2 plastic eggs
  - 1 pill container, cylindrical
  - * 50 pennies (1 roll)
  - * 2 pairs of scissors
  - * 4 index cards
  - * 4 rulers
  - straws, about 20
  - assorted tape
  - string

- *For each student*
  1 Literacy Student Sheet 2, "Developing Communication Skills" (optional)
  1 Literacy Visual Aid 1, "Oral Presentations" (optional)
  1 Scoring Guide: ENGINEERING DESIGN (ENG) (optional)

Set up a testing arena as a demonstration space. If you believe it will be necessary to help students get started, construct one or more sample mechanical grabbers. If students need more support, supply a few diagrams or photos of sample solutions to the design challenge.

TEACHING SUMMARY

GET STARTED

1. Discuss the biological applications of robotics.
   a. Define robotics and provide an example of robotics in biomedical engineering.
   b. Introduce the design challenge.

DO THE ACTIVITY

2. In Part A, students build a model mechanical finger.
   a. Help students complete Step 1 of the Procedure.
   b. Students test the capabilities of their mechanical fingers.
3. In Part B, students construct and test the first round of prototypes.
   a. Review the criteria and constraints as listed in Step 3 of the Procedure.
   b. (LITERACY) Support student communication during the design process.
   c. Share student grabber prototypes.
4. Students optimize their designs to accomplish one of two Optimization Options presented.
   a. Encourage students to choose the option that suits their prototypes.
   b. Help students overcome design frustrations.
   c. Relate the variables to the Optimization Options.

BUILD UNDERSTANDING

5. Students share their designs and design process.
   a. (LITERACY) Support students in preparing an oral presentation on their design process.

b. (ENG ASSESSMENT) You can assess student presentations using the eng Scoring Guide.

c. Discuss how the structure of the grabber contributes to its function.

6. Students reflect on the unit and discuss the broader implications of design.

a. Summarize the structure and function of the three major designs in the unit.

b. Ask students, "What drives the development of new technologies and what limits them?"

c. Discuss the process of engineering design.

TEACHING STEPS

GET STARTED

1. Discuss the biological applications of robotics.

a. Define robotics and provide an example of robotics in biomedical engineering.

Review the term *biomimicry* from the previous activity and introduce the term *robotics* as introduced in the Student Book introduction. Remind students of Aimee Mullins from the "Bionic Bodies" activity, who uses prosthetic legs. Discuss some of the other uses for robotic limbs. Ask students to describe any other applications of which they are aware, such as the application of robotics in surgery.

b. Introduce the design challenge.

Tell students that they will use what they learned in the last activity to design and build mechanical grabbers. They will be optimized to either pick up objects quickly or pick up very heavy objects. Show students the materials they will be using to construct their mechanical grabbers and the arena from which they will pick up objects. If you have made simple prototypes that you think would help inspire students, demonstrate them to the class. Explain that every student will start by building a mechanical finger, and then students will work in groups to try and complete a design within the constraints given that meets the criteria.

DO THE ACTIVITY

2. In Part A, students build a model mechanical finger.

    a. Help students complete Step 1 of the Procedure.

    Refer to the diagram in the Student Book of the index finger and the intermediate phalange. Use your own hand and a ruler to demonstrate the different measurements that Step 1 calls for. Clarify any of the instructions, as necessary. When students have constructed their mechanical fingers and are able to articulate them by pulling the string, remind them of how the tendons pulled muscles that pulled bones in the last activity.

    Teacher's note: This activity helps students to connect the process of design to the life science content in the SEPUP middle school unit "Body Systems." See this unit for more activities on body systems. If appropriate, discuss how the tissues that make up the system in the finger are specialized for particular body functions.

    b. Students test the capabilities of their mechanical fingers.

    In Procedure Step 2, students test their fingers by picking up a container and consider the variables in the designs. Identify the four variables introduced in the step (i.e., finger length, finger thickness, number of straw pieces, length of pieces).

3. In Part B, students construct and test the first round of prototypes.

    a. Review the criteria and constraints as listed in Step 3 of the Procedure.

    Let students know that in this section, they will use what they made in Part A to create a functioning mechanical grabber. Show students how to set up a testing arena for themselves to use. Remind students that they must use their mechanical grabbers by holding them with one of their own hands and using their other hand to trigger the mechanical grabber mechanism.

    b. (LITERACY) Support student communication during the design process.

    Make sure students are recording their observations and data in their science notebooks. To facilitate group interactions, you may want to use the sentence starters found in Literacy Skill Sheet 2, "Developing Communication Skills," also found in the Student Book, Appendix E.

c. Share student grabber prototypes.

After students complete Step 4, take a few moments to have them share their prototypes with the class.

4. Students optimize their designs to accomplish one of two Optimization Options presented.

a. Encourage students to choose the option that suits their prototypes.

Students can pick an Optimization Option based on their test results from their prototypes. If needed, remind students of the variables described at the end of Step 2 and have them think about how to vary those options to get their desired outcomes. Their goal is to design a more useful hand than the prototypes.

b. Help students overcome design frustrations.

As students test and redesign, remind them that failure is part of the process and is fine as long as they learn from it. Discourage unhealthy competition in the class by explaining that every group is simply trying to optimize its own mechanical grabber. Help students see that the best solution may be a combination of other designs. Instruct students to test their redesigns, even if they are using familiar components of previous designs.

c. Relate the variables to the Optimization Options.

The variables that are critical for speed and agility (Optimization Option 1) could be the finger length. For the strength needed in Optimization Option 2, students could focus in on the number of fingers. Students may have multiple designs that have similar performance. To meet the Optimization goals, however, students may have to begin making trade-offs. For example, for a design to lift more (100g), the design may be more difficult to operate. Have students consider other optimizations, such as improved safety. For example, a grabber that is closed until activated may be safer but have reduced performance.

BUILD UNDERSTANDING

5. Students share their designs and design process.

a. (LITERACY) Support students in preparing an oral presentation on their design process.

During the Procedure, let students know that each group will give an oral presentation for its response to Procedure Step 6. Consider distributing Literacy Visual Aid 1, "Oral Presentations," also found in the Student Book, Appendix E, to help students organize what they will say. Encourage students to make attractive presentations, but stress that the evidence and ideas presented are crucial to a good presentation. For guidelines on oral presentations, see the Literacy section of Teacher Resources II, "Diverse Learners."

b. (ENG ASSESSMENT) You can assess student presentations using the ENG Scoring Guide.

You can assess student work from Procedure Part B in this activity with the eng Scoring Guide. A sample Level-4 response follows. For more information, see Teacher Resources III, "Assessment."

SAMPLE LEVEL-4 RESPONSE, PROCEDURE STEPS 3–7

Identify the Problem:

The challenge was to remove both a plastic egg and the cylinder from the test arena by picking up each object individually and lifting it out of the arena.

Brainstorm Solutions:

My group tried to figure out how many "fingers" from Part A we would need to grab the object. We came up with a bunch of ideas to make it look like a hand, but then thought that maybe three would be enough to lift something. We thought we would design it to easily move the fingers so we could find the best configuration.

Design:

Even with only one person operating our grabber, it was able to pick up and remove objects from the test arena. We used the ruler as an arm and then made three fingers out of straws, paper, tape, and string. We taped our fingers to the ruler so the fingers were all on the same side of the ruler and tested it. The we put one finger on the other side so that when the strings were pulled, the three fingers would close like when a bird grabs a branch.

Test and Evaluate:

Initial Grabber Data

Prototype	Number of fingers	Rate (eggs/min)
3 fingers, all on one side	*3*	*12*
3 fingers, one opposite the other two	*3*	*24*

The tests showed that the second prototype we made was better.

Redesign:

We wanted to optimize our design to meet the Optimization Option 1 criteria, so we needed to make our grabber work faster. We remembered from our earlier tests that shorter fingers seemed to close faster than longer fingers, which makes sense because the string doesn't need to be pulled as far to make the fingers curl. So we wondered if shorter fingers would be better. We rebuilt our grabber with shorter fingers but kept the other variables the same. We tried a few different lengths to get a grabber that could both close quickly and still pick up objects. The ideal length was 30 cm long.

Optimize Grabber Data

Prototype	Rate (eggs/min)
Short straw	*15*
Long straw	*24*
Medium straw	*30*

Share:

All the groups presented their final designs to the class and discussed the design process that they used.

c. Discuss how the structure of the grabber contributes to its function.

   Ask students to describe the structures in their solutions, such as the individual fingers made of straws paper and string. Then have them describe the functions of their solutions, for example, to grab the object on both sides and simultaneously pull. Ask students to talk about how the relationship between structure and function in their solutions made the designs successful.

6. Students reflect on the unit and discuss the broader implications of design.

   a. Summarize the structure and function of the three major designs in the unit.

      Have students work in pairs to create a table of the three major designs created in this unit. Students should identify the structure and function of them and then share their ideas with each other and the class. In this way, the crosscutting concept of structure and function is supported in this activity.

Three Designs

Design	Structure	Function
Artificial bone	*Reinforced plastic tubes*	*Light and strong*
Heart valve	*Joint of tube with ball or finger glove that lets liquid through*	*Control flow in one direction*
Robotic grabber	*Strings pull through plastic tubes to form a grabber around an object*	*Hold and lift object*

Review how structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.

b. Ask students, “What drives the development of new technologies and what limits them?”

Make a brainstorming list like the one below:

Drivers:

Desire to do something you can’t

Desire to make something more useful

Desire to make something more cheaply

Limitations:

Not enough money

Not enough time

Material properties

Social climate

Lack of resources

Remind students of the crosscutting concepts of the interdependence and the influence of science, engineering, and technology. The development of robotics and limitations of its 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.

c. Discuss the process of engineering design.

Find commonalities in the ways that students worked throughout the unit on their designs, such as brainstorming, testing, and redesigning. In this culminating activity, sum up what students were able to accomplish since the first activity, “Save Fred.” Let students reflect on the work they have done in this unit and how it is similar to professional engineers.

EXTENSION

For this Extension to build a complete elbow-to-hand structure, students may want to use materials beyond those provided in the kit. Make clear what materials are and are not allowed.

SAMPLE RESPONSES TO ANALYSIS

1. What were the most rewarding and most frustrating parts of your engineering design process?

   Student responses may vary. One sample response is shown here:

   The most frustrating part was optimizing for strength because we added string to do that. The additional strings made it too hard to operate. We finally gave up on that and went for more cuts of straw so that it wrapped all the way around the cylinder.

2. How did your redesign improve your product?

   Student responses may vary. One sample response is shown here:

   The design improved because it initially could only do the quickness test well and the optimization allowed our grabber to also pick up heavy weight.

3. What were the limitations of your grabber model?

   Student responses may vary. One sample response is shown here:

   Our grabber could not pick up more than 80 g whereas some other ones could. Also, our grabber was not waterproof so it could not be used underwater. Lastly, we needed a second hand to operate it so it would not work well for someone with only one operable hand.

4. What are some of the benefits of designing your mechanical arm as a group compared with working individually?

   Student responses may vary. One sample response is shown here:

   Although working individually allows more individual control over the prototype, working in a group allows more to get done because you can work simultaneously at tasks and use different ideas. The product was better using everyone's ideas and abilities compared with just one person's.

5. Thomas Edison, with the help of those working in his lab, invented over 1,000 devices, including the movie camera, the telegraph, and the phonograph (record player). He once said, "It is what you do after failure that counts." What did he mean? Explain your answer with an example from your work during this unit.

Thomas Edison was referring to the redesign phase, in which prototypes or models of inventions are improved by revision or are scrapped in favor of better plans. Rarely does an invention turn out well on the first try, and yet from failure one can learn how to improve and succeed.

Student responses for the second part of the item may vary. One sample response is shown here:

In our design, we were not able to grab anything in our first prototype. We figured out it failed because the "fingers" were not long enough to go around the egg. We used the failure to figure out what length we should use.

6. How could your design be used in a real-world biomedical application? Describe a potential problem and who could benefit from it.

   Robotic arms are useful as prostheses for patients who have lost an arm or its use. They can also be useful in manipulating hazardous materials, negotiating inaccessible environments, surgery, or any other context requiring fine motor control.

REVISIT THE GUIDING QUESTION

How can you make a mechanical grabber that can pick up and move an object?

A mechanical grabber can be made by constructing a series of mechanical fingers and putting them together to create a robotic arm. The design can vary, but the basic principle is that the individual fingers wrap around the object and grab it using the science principles found in the last activity about opposable muscle groups.

ACTIVITY RESOURCES

KEY VOCABULARY

function

model

optimize

robotics

structure

variable

ENGINEERING DESIGN SOLUTIONS (ENG)

When to use this scoring guide:

This scoring guide is used when students design, evaluate, and refine solutions.

What to look for:

- Response includes a complete design relevant to the problem to be solved
- Response includes evidence of how well the design meets criteria within the defined constraints
- Response indicates how scientific ideas and concepts relate to the successful design

Level	Description
Level 4 Complete and correct	The student's design: • meets all of the criteria within the defined constraints, AND • has further improved on the design, AND • uses relevant scientific concepts to explain why any revisions were made to optimize the design.
Level 3 Almost there	The student's design: • meets all of the criteria within the defined constraints, AND • explains the relevant scientific concepts.
Level 2 On the way	The student's design: • meets all of the criteria but exceeds the defined constraints OR • meets some of the criteria within the defined constraints.
Level 1 Getting started	The student's design does not meet any of the criteria.
Level 0	The student proposes no design or an irrelevant design.
x	The student had no opportunity to respond.

NAME ______________________________ DATE ______________

DEVELOPING COMMUNICATION SKILLS

COMMUNICATING	SENTENCE STARTERS
To better understand	*One point that was not clear to me was . . .* *Are you saying that . . .* *Can you please clarify . . .*
To share an idea	*Another idea is to . . .* *What if we tried . . .* *I have an idea. We could try . . .*
To disagree	*I see your point, but what about . . .* *Another way of looking at it is . . .* *I'm still not convinced that . . .*
To challenge	*How did you reach the conclusion that . . .* *What makes you think that . . .* *How does it explain . . .*
To look for feedback	*What would help me improve . . .* *Does it make sense, what I said about . . .*
To provide positive feedback	*One strength of your idea is . . .* *Your idea is good because . . .*
To provide constructive feedback	*The argument would be stronger if . . .* *Another way to do it would be . . .* *What if you said it like this . . .*

ORAL PRESENTATIONS

- Your presentation time is short. Focus your presentation on the most important ideas you need to communicate.
- Communicate clearly by planning your words in advance. When speaking, talk slowly and loudly, and look at your audience.
- Group members should ask for and give each other support if they need help expressing a key word or concept.
- Include graphs and maps when possible. Make sure the type or handwriting and the images are large enough for everyone in the audience to see them.
- While you have your own opinions on a topic, it is important that you present unbiased and complete information. Your audience can then make their own conclusions.
- All the members of a group must participate.
- Since any group member may be asked to answer questions from the class, all group members should fully understand the presentation.
- In a group presentation, you could all play the role of different experts when presenting your information. The class would represent the community members who might be making a decision on the issue.

UNIT OVERVIEW

BIOMEDICAL ENGINEERING

Listed below is a summary of the activities in this unit. The total teaching time as listed is 13–18 periods of approximately 45–50 minutes each (approximately 3–4 weeks if you teach the activities as recommended every day).

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
1. **Investigation: Save Fred!** Students are introduced to the process of engineering by solving a simple physical problem. The activity elicits and builds on students' ideas about how to develop a successful solution.	engineering, engineer, scientist LITERACY	Gather gummy candies.		1–2
2. **Investigation: Me, An Engineer?** By simulating an injury to the dominant arm, students use their ingenuity and some simple supplies to invent solutions to problems they encounter accomplishing everyday tasks. Through the experience, students consider the practical needs of people with disabilities and the impact of biomedical engineering.	biomedical engineer	Gather clothing, shoes, hair clips, dolls, boxes, glue, scissors, tape; set up stations; prepare Student Sheets.		1–2
3. **Reading: Bionic Bodies** Students explore the application of biomedical engineering through the case studies of three individuals. These cases show that individual needs, desires, and values help drive the development of new technologies.	constraint, criteria, biomedical engineering LITERACY, MATHEMATICS	Prepare Student Sheet.	EXP A2	1–2
4. **Design: Artificial Bone Model** Students are challenged to design, build, and test models of an artificial bone to meet criteria. They analyze the quantitative data from different prototypes and combine ideas to optimize their designs.	criteria, constraint, model, prototype, variable, optimize LITERACY, MATHEMATICS	Gather balances, digital scale, pennies; cut strips of paper; set up testing stations; prepare Student Sheets.	ENG Proc.	2–3
5. **Design: Artificial Heart Valve** Students apply the engineering design process to developing a model for an artificial heart valve. Students create initial prototypes, test, evaluate, and redesign their solutions in an iterative engineering design process.	engineering design process, aortic valve, model, prototype, variable, optimize LITERACY	Gather plastic bins, sponges, mops, scissors, tape, colored pencils; construct sample valves; prepare Student Sheets.	ENG Proc. E&T A5	2–3
6. **Reading: The Work of an Engineer** Students explore the discipline of engineering in more detail. They read about the interplay between science, engineering, and technology in the development of new products.	technology, engineering design process, engineer, scientist LITERACY	Prepare Student Sheet.	E&T A4	1–2

BIOMEDICAL ENGINEERING (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
7. **Investigation: Snack Bar** Students evaluate the ingredients of various snack bars to determine how each design best meets criteria. Then they design a snack bar to meet particular nutritional need of a specific medical condition.	carbohydrate, fat, protein, criteria, constraints, evaluating designs MATHEMATICS	Prepare Student Sheets.	ARG Proc., A4	1–2
8. **Laboratory: Investigating Biomechanics** Students explore the biomechanics of muscles and tendons in a chicken wing as background knowledge to later design a gripping device. This information on the structure and function of a wing is used to develop a model of movement.	biomimicry, function, structure, tendon	Buy chicken wings; gather bleach, garbage bags, forceps, dissection scissors and trays.	MOD A2	1–2
9. **Design: Get a Grip** Students use the approach of biomimicry to design, test, evaluate, and redesign a mechanical gripping device to meet criteria. They use a reiterative process to optimize the device in one of two ways.	design, structure, function model, robotics, engineering design process, optimize LITERACY	Gather pennies, scissors; set up testing stations; prepare Student Sheet.	ENG Proc.	2–3

NGSS UNIT OVERVIEW

BIOMEDICAL ENGINEERING

Performance Expectation 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.

Performance Expectation MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Performance Expectation MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Performance Expectation 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.

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
1. **Investigation: Save Fred!** Students are introduced to the process of engineering with a scenario that engages them in solving a simple problem. The activity elicits and builds on students' ideas about how to develop a successful solution. The processes used by scientists and engineers are compared and contrasted.	MS-ETS1.A MS-ETS1.B	Asking Questions and Defining Problems		
2. **Investigation: Me, an Engineer?** Students are challenged to design tools and strategies to solve the practical problem of using one arm to complete daily tasks. Within the criteria and constraints of the problems, students navigate the environment and optimize their solutions. The activity concludes with an opportunity for students to define and analyze a design problem in their everyday lives.	MS-ETS1.A MS-ETS1.C MS-ETS1.B	Asking Questions and Defining Problems	Structure and Function Interdependence of Science, Engineering, and Technology Influence of Science, Engineering, and Technology on Society and the Natural World	
3. **Reading: Bionic Bodies** Students explore the application of biomedical engineering through the case studies of three individuals. These cases show that individual needs, desires, and values help drive the technologies and the limitations of their use. Students read about the role of criteria and constraints in the design process. Students are formally assessed on Performance Expectation MS-ETS1-1.	MS-ETS1.A	Asking Questions and Defining Problems	Interdependence of Science, Engineering, and Technology Influence of Science, Engineering, and Technology on Society and the Natural World Structure and Function	ELA/Literacy: RST 6-8.1 RST 6-8.9 RST.6-8.2

BIOMEDICAL ENGINEERING (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
4. **Design: Artificial Bone Model** Students are challenged to design, build, and test models of an artificial bone to meet criteria. They analyze the quantitative data from different prototypes and combine ideas to optimize their design. The hands-on experience demonstrates the engineering design process without it yet defined.	MS-ETS1.A MS-ETS1.B MS-ETS1.C MS-LS1.A	Asking Questions and Defining Problems Developing and Using Models Constructing Explanations and Designing Solutions Analyzing and Interpreting Data Using Mathematics and Computational Thinking	Structure and Function	Math: MP.2 6.RP.A.1 7.RP.A.2 ELA/Literacy: SL8.4
5. **Design: Artificial Heart Valve** Students apply the engineering design process to developing a model for an artificial heart valve. After reading about the societal need for this technology, students create initial prototype designs. Students test and evaluate their designs before redesigning them. They optimize their solutions in an iterative process that identifies the best characteristics of each prototype. Students compare designs with their peers and evaluate which ones meet the criteria and constraints of the problem. Students are formally assessed on Performance Expectation MS- ETS1-3.	MS-ETS1.B MS-ETS1.C MS-LS1.A	Asking Questions and Defining Problems Developing and Using Models Construction Explanations and Designing Solutions Analyzing and Interpreting Data Engaging in Argument from Evidence	Influence of Science, Engineering, and Technology on Society and the Natural World Structure and Function	Math: MP.2 ELA/Literacy: SL8.4
6. **Reading: The Work of an Engineer** Students explore the discipline of engineering in more detail. They read about the interplay between science, engineering, and technology in the development of new products. They consider the positive benefits and negative environmental consequences of biomedical advances. Students are formally assessed on Performance Expectation MS-ETS1-1.	MS-ETS1.A	Asking Questions and Defining Problems	Interdependence of Science, Engineering, and Technology Influence of Science, Engineering, and Technology on Society and the Natural World Connections to Nature of Science	ELA/Literacy: RST 6-8.1 RST.6-8.9 RST.6-8.2 WHST.6-8.9

BIOMEDICAL ENGINEERING (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
7. **Investigation: Snack Bar** Students examine food that has been designed for specific medical conditions. They evaluate designs using a systematic process to determine how each design meets the needs of a specific condition. The evaluation depends on mathematical reasoning and analyzing data to find the solution that best meets the criteria. Then students develop their own snack bar designs to address the needs of another condition. Students are formally assessed on Performance Expectation MS- ETS1-2.	MS-ETS1.B MS-ETS1.A MS-LS1.C	Engaging in Argument from Evidence Constructing Explanations and Designing Solutions Using Mathematics and Computational Thinking	Interdependence of Science, Engineering, and Technology Influence of Science, Engineering, and Technology on Society and the Natural World	Math: MP.2 7.EE.3
8. **Laboratory: Investigating Biomechanics** Students explore the biomechanics of muscles and tendons in a chicken wing as background knowledge to later design a gripping device. This information on the structure and function of a wing is used to develop a model of natural movement. Students are introduced to the concept of biomimicry, which is a popular engineering approach that leads to a more limited, but often successful, solution.	MS-ETS1.A MS-ETS1.B MS-LS1.A	Developing and Using Models Constructing Explanations and Designing Solutions Connections to Nature of Science	Structure and Function	
9. **Design: Get a Grip** Students use the approach of biomimicry to design, test, evaluate, and redesign a mechanical gripping device to meet criteria. They use the engineering design process to optimize the device in one of two ways. In doing so, they investigate the relationship between structure and function of the device and how the technology they developed can be applied. Students are formally assessed on Performance Expectation MS-ETS1-4.	MS-ETS1.A MS-ETS1.B MS-ETS1.C MS-LS1.A	Asking Questions and Defining Problems Developing and Using Models Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions	Structure and Function Interdependence of Science, Engineering, and Technology Influence of Science, Engineering, and Technology on Society and the Natural World	ELA/Literacy: SL8.4