NGSS 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 Using Mathematics and Computational Thinking		
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 Scale, Proportion, and Quantity	Mathematics: 6.RP.A.1 6.RP.A.3 MP.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	Mathematics: 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.	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: Energy 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 energy 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	Stability and Change Interdependence of Science, Engineering, and Technology Influence of Science, Engineering, and Technology on Society and the Natural World	Mathematics: 7.EE.3 MP.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 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

PHENOMENA, DRIVING QUESTIONS AND SEPUP STORYLINE

BIOMEDICAL ENGINEERING

BIOMEDICAL ENGINEERING

Unit Issue: How science, technology, and engineering can be used to design solutions to improve the health and wellness of others.

Anchoring Phenomenon: Engineered solutions can improve people's health and functioning. Examples explored include artificial bones, artificial hands, and artificial heart valves. Students generate and answer questions such as: How can science, technology, and engineering be used to improve people's health and wellness? How are medical devices designed, tested, and improved?

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
Many people have medical conditions.	How can engineering be used to improve the lives of those living with medical conditions?	What tools and strategies can you design to deal with a broken arm? (Activity 2)	2, 3, 4, 5, 7	MS-ETS1.1 MS-ETS1-2 MS-ETS1.3	Solving problems is something that we do every day. One of the most common processes used to find solutions to problems is known as engineering. One type of engineering, biomedical engineering, focuses on engineering devices or processes to help those with medical conditions. Biomedical engineers engage in a multi- step non-linear iterative process that makes use of scientific knowledge and technology in order to find solutions that meet the needs (criteria) of the medically afflicted within certain limits (constraints). Once solutions to biomedical problems are engineered, engineers often look for ways to optimize their solutions. Common examples of optimization are: making a device cheaper, stronger, or better at specific functions.
		How has the development of artificial body parts changed lives? (Activity 3)			
		How can you design a prototype of an artificial bone that is strong yet light and flexible? (Activity 4)			
		How can you design a heart valve prototype out of common materials? (Activity 5)			
		Can you design an energy bar to meet the needs of people with specific medical conditions? (Activity 7)			

PHENOMENA, DRIVING QUESTIONS AND SEPUP STORYLINE

BIOMEDICAL ENGINEERING (continued)

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
Scientists and engineers use technologies. Technologies are often developed by engineers and scientists.	How do new technologies get developed?	What approaches can be used to solve a problem? (Activity 1)	1, 4, 5, 6, 8, 9	MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4	Solving problems is something that we do every day. One of the most common processes used to find solutions to problems is known as engineering. One type of engineering, biomedical engineering, focuses on engineering devices or processes to help those with medical conditions. Biomedical engineers engage in a multi- step non-linear iterative process that makes use of scientific knowledge and technology in order to find solutions that meet the needs (criteria) of the medically afflicted within certain limits (constraints). Once solutions to biomedical problems are engineered, engineers often look for ways to optimize their solutions. Common examples of optimization are: making a device cheaper, stronger, or better at specific functions.
		How can you design a prototype of an artificial bone that is strong yet light and flexible? (Activity 4)			
		How can you design a heart valve prototype out of common materials? (Activity 5)			
		How are science, engineering, and technology related? (Activity 6)			
		How does the structure of an arm or wing affect its function? (Activity 8)			
		How can you make a mechanical grabber that can pick up and move an object? (Activity 9)			

NGSS CORRELATIONS

BIOMEDICAL ENGINEERING

Crosscutting Concepts		Activity number
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.	2, 3, 4, 5, 8, 9
Scale, Proportion, and Quantity	Scientific relationships can be represented through the use of algebraic expressions and equations.	4
Stability and Change	Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.	7
Connections to Engineering, Technology, and Applications of Science	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	2, 3, 6, 7 , 9
	The uses of technologies and any 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. Thus, technology use varies from region to region and over time.	3, 5, 6, 7, 9
	All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.	2, 3, 6, 7
Connections to the Nature of Science	Scientists and engineers are guided by habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.	6
Science and Engineering Practices		**Activity number**
Analyzing and Interpreting Data	Analyze and interpret data to determine similarities and differences in findings.	4, 5
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.	1, 2, 3, 4, 5, 6, 9
	Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.	2

Science and Engineering Practices		Activity number
Constructing Explanations and Designing Solutions	Construct an explanation that includes qualitative or quantitative relationships between variables that predict or describe phenomena.	8
	Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.	4, 5, 9
	Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.	5, 7, 9
	Optimize performance of a design by prioritizing criteria, making trade-offs, testing, revising, and retesting.	4, 5, 9
Developing and Using Models	Develop a model to predict and/or describe phenomena.	8
	Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	4, 5, 9
	Evaluate limitations of a model for a proposed object or tool.	4, 9
Engaging in Argument from Evidence	Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	5, 7
Using Mathematics and Computational Thinking	Use mathematical representations to describe and/or support scientific conclusions and design solutions.	4, 7, 9
	Create algorithms (a series of ordered steps) to solve a problem.	1
	Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.	7
Connections to the Nature of Science	Scientific knowledge is based on logical and conceptual connections between evidence and explanations.	8
Disciplinary Core Ideas		**Activity number**
Defining and Delimiting Engineering Problems (ETS1.A)	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 is likely to limit possible solutions.	1, 2, 3, 4, 6, 7, 8, 9
Defining and Delimiting Engineering Problems (ETS1.A)	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.	4, 5, 9
	There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	4, 5, 7, 9
	Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.	1, 2, 4, 5, 9
	Models of all kinds are important for testing solutions.	4, 5, 8, 9

Disciplinary Core Ideas		Activity number
Optimizing the Design Solution (ETS1.C)	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.	4, 5, 9
	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. 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.	2, 4, 5, 9
Structure and Function (LS1.A)	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.	5, 8, 9
Organization for Matter and Energy Flow in Organisms (LS1.C)	Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.	7
Performance Expectations		**Activity number**
Engineering Design (ETS1)	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-ETS1-1)	3
	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. (MS-ETS1-2)	7
	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. (MS-ETS1-3)	5
	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-ETS1-4)	9

COMMON CORE STATE STANDARDS: CONNECTIONS AND CORRELATIONS

BIOMEDICAL ENGINEERING

Making Connections in ELA

As with all SEPUP instructional materials, this unit introduces multiple opportunities for students to engage in a range of ELA practices and skills that are important grade-specific goals of the common core state standards and are also essential to the sensemaking students are doing throughout the unit. Specifically, in activities 3 and 6, students engage with readings focused on criteria and constraints in engineering and design processes to summarize and analyze information (RST.6-8.2) and compare their findings to other activities in the unit (RST.6-8.9). They draw evidence on (RST.6-8.1; WHST.6-8.2) how medical devices are developed and on the interdependence between science, engineering, and technology. This is an essential step to students asking questions and defining problems in the context of a series of design challenges embedded throughout the unit. As students take on scaffolded design challenges in activities 4 and 5, they orally share their designs and design processes with other students (SL.8.4). The unit culminates with a final design challenge in activity 9, where students apply what they have learned throughout the unit to design a mechanical grabber using an iterative engineering design process. They orally present their design and design process to the class and discuss the challenges and rewards of engineering design (SL.8.4). Specific literacy strategies are embedded throughout the unit to support student development of these ELA skills and practices. In addition, Appendix E: Literacy Strategies in the Student Book contains optional resources to support reading, writing and oral communication.

<table>
<tr><th colspan="2">Common Core State Standards – English Language Arts</th><th>Activity number</th></tr>
<tr><td rowspan="3">Reading in Science and Technical Subjects (RST)</td><td>Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (RST.6-8.1)</td><td>3, 6</td></tr>
<tr><td>Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (RST.6-8.2)</td><td>3, 6</td></tr>
<tr><td>Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (RST.6-8.9)</td><td>3, 6</td></tr>
<tr><td>Speaking and Listening (SL)</td><td>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. (SL.8.4)</td><td>4 , 5, 9</td></tr>
<tr><td>Writing in History/Social Studies, Science, and Technological Subjects (WHST)</td><td>Draw evidence from informational texts to support analysis, reflection, and research. (WHST.6-8.9)</td><td>6</td></tr>
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Making Connections in Mathematics

This unit introduces multiple opportunities for students to engage in math practices and skills that are important grade-specific goals of the common core state standards and are also essential to the sensemaking students are doing throughout the unit. Specifically, mathematical reasoning (MP.2) plays a key role as the students evaluate designs based on criteria, constraints, and quantitative data. This takes place in activities 4, 5, and 7. In addition, activity 4 introduces students to strength-to-mass ratio (6.RP.A.1; 6.RP.A.3), a criteria they use to evaluate designs of artificial bone models. Lastly, in activity 7, students conduct a series of mathematical calculations ("Energy Bar Calculations") to compare nutritional data and evaluate competing energy bars for people with different medical conditions (7.EE.B.3).

Common Core State Standards – Mathematics		Activity number
Mathematical Practice (MP)	Reason abstractly and quantitatively. (MP.2)	4, 5, 7
Ratios and Proportional Reasoning (RP)	Understand the concept of a ratio, and use ratio language to describe a ratio between two quantities. (6.RP.A.1)	4
	Use ratio and rate reasoning to solve real-world and mathematical problems. (6.RP.A.3)	4
Expressions and Equations (EE)	Solve multi-step, real-world and mathematical problems posed with positive and negative numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; assess the reasonableness of answers using mental computation and estimation strategies. (7.EE.B.3)	7