Britannica Expedition:LEARN!

Teacher Toolkit

Engineering and Design: Grades 6–8

OVERVIEW:

While the main goal of science is to construct explanations and theories that explain phenomena, the main goal of engineering is to design and build processes and tools that solve real-world problems. Engineers use scientific principles and practices during the design cycle (also called the engineering design process). This is a systematic process that includes:

- Identifying and defining a problem or human need
- Developing solutions through brainstorming and research
- Producing and testing models and/or prototypes
- Evaluating and improving solutions, leading to better designs

Students who understand engineering and design are able to use design-cycle thinking to attack problems and can incorporate the necessary steps into rigorous problem solving and solution design. They understand that the design process is an ongoing cycle in which solutions to problems continue to improve at the same time that new problems are identified. They also understand the connections between science and engineering and that both fields are data-driven and involve iterative experimentation.

Students are expected to understand and incorporate criteria and constraints into the design cycle, use scientific principles to design a solution to a problem, use evidence to evaluate a solution, and compare solutions to decide which better meets the criteria and constraints.

The following strategies are designed to scaffold and support students in engineering and design concepts in science texts in *Expedition: Learn!* While each of the mini-lessons below are based on specific articles and lessons within *Expedition: Learn!*, they can be adapted to meet the needs of your classroom.

Mini-Lesson I

Review Criteria and Constraints (15 minutes)

Background: Students may be familiar with criteria and constraints of design solutions, but a review will help students as their use of the design cycle becomes more in-depth and sophisticated. The criteria and constraints are established early in the process and are used throughout the cycle to evaluate and compare solutions. A good solution addresses the problem by meeting the minimum criteria while also adhering to the constraints. The teaching suggestions below are intended to follow the *Expedition: Learn!* lesson "Engineering and the Design Process."

- Remind students that when engineers design a process or tool to solve a problem, there are certain things they need to consider. These things are called criteria and constraints.
- Invite students to turn and talk, discussing their understanding of criteria and constraints. After a minute, ask a student to share out. Sample response:
    - Criteria are features that a solution must have in order to meet the need and be considered successful. Constraints are factors that limit the possible solutions. Some constraints include the types of materials available and the amount of money budgeted for the design. Solutions may also be constrained by the current understanding of science and the possible impacts of the design on people and the environment.
- Review the steps of the engineering design process:
    - Define and understand the problem.
    - Develop possible solutions through research and brainstorming.
    - Optimize the design by making it the best it can be.
- Present students with the problem: they must design a car that is good for the environment.
- Invite students to turn and talk, discussing what criteria the car needs to meet, or what features the car should include. Sample response:
    - *Criteria for a car that is good for the environment might be that it does not use fossil fuels, it doesn't make a lot of noise, it doesn't emit smoke, and it adds something to the air that improves the quality.*
- Ask students to think about the constraints of the design. For example:
    - *It should not be too expensive because we want people to buy it. The materials needed to make it must exist and be available on Earth. It needs to be able to drive on existing roadways with existing speed limits.*
- Emphasize that when developing solutions, engineers must consider the criteria and the constraints to ensure that their solutions both solve the problem and are capable of being created or implemented.

Mini-Lesson II

Incorporating Scientific Principles in Design (30 minutes)

Background: Incorporating scientific principles and ideas is an important part of engineering. For example, engineers must understand and be able to use Newton's laws of motion to design tools, objects, and machines that use forces to move things, such as when the engines of a rocket create downward blasts that push the rocket up into space. The teaching suggestions below are based on the *Expedition: Learn!* lesson "Newton's Third Law."

- Remind students that it is the job of engineers to design and build processes and tools that solve real-world problems.
- Review the steps of the engineering design process:
    - *Define and understand the problem.*
    - *Develop possible solutions through research and brainstorming.*
    - *Optimize the design by making it the best it can be.*
- Explain to students that when working through the process, it is important that engineers understand the scientific principles related to the problem and their possible solutions.
- Remind students that all forces act in pairs and Newton's third law of motion describes these pairs of forces. It states that for every force, there is a reaction force that is equal in size but in the opposite direction. Reiterate that a force is a push or a pull.
- Display the image of the bottle car from the article "Applications of Newton's Third Law."
- Ask students to think about how they could incorporate action and reaction force pairs into the design of a bottle car in order to make it go faster or farther.
- Review that when two objects interact, they apply forces to each other that are equal in size but opposite in directions. The way in which the two objects move in response to the forces depends on their mass and the sum of the other forces acting on each object.
- Distribute the **Newton's Law and the Design Process worksheet**.
- Invite students to draw the action force and reaction force acting on a bottle car. For example:
    - *action force - orange arrow (air comes out of the balloon), reaction force - green arrow (the car moves forward)*
- Invite students to work in small groups, brainstorming and recording possible modifications to the design of the car that would change the forces in ways that could make the car move faster or farther.
- Ask student groups to share their ideas, explaining a modification and how they believe it would make the car move faster or farther.
- As time and resources allow, consider having students build the bottle cars and choose one of their modifications to implement and test.

Mini-Lesson III

Solving Environmental Problems (20 minutes)

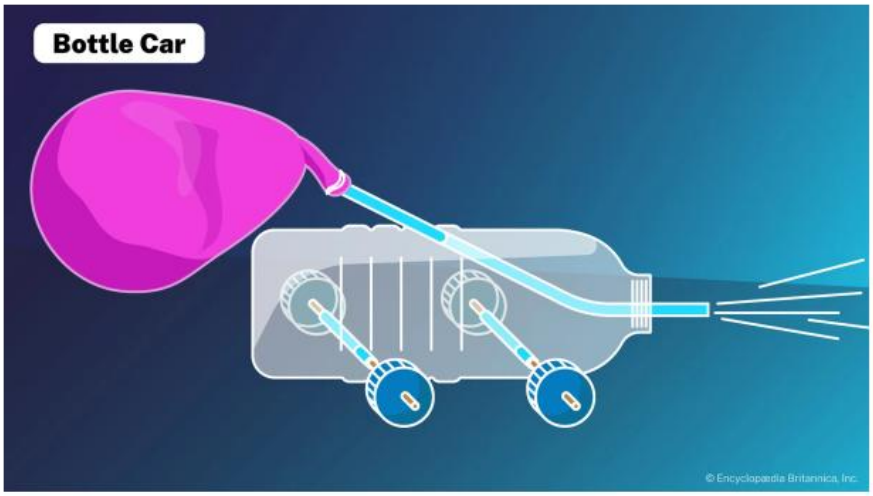
Background: The engineering design process works across scientific disciplines. Environmental engineers use the design cycle to solve problems related to the health of Earth and its inhabitants. This lesson provides students with an opportunity to use the design process to solve one of the problems facing Earth today. The teaching suggestions below are based on the *Expedition: Learn!* lesson "Monitoring and Minimizing Human Impact."

- Remind students that engineers work to design tools or processes that solve problems. Emphasize that environmental engineers work to solve problems related to the health of Earth or the people, animals, or plants on Earth.
- Review the engineering design process:
    - Define and understand the problem.
    - Develop possible solutions through research and brainstorming.
    - Optimize the design by making it the best it can be.
- Share with students that they will use the engineering design process to think of solutions to an environmental problem.
- Invite students to identify one of the problems from the lesson (animal and plant extinction, human water use, land use, or pollution). Place students in groups to work with other students who chose the same problem.
- Display and distribute the **Engineering Design Process organizer**. Ask students to work together to define the problem they will try to solve, identify criteria and constraints, brainstorm proposed solutions, and determine how they could test their solutions.
- As time allows, consider inviting each group to present their problem and possible solutions to the class.

Check for Understanding

If you observe …	Then try …
students struggling to generate criteria and constraints	provide students with a series of questions to help guide them. For example: • Who will need to use your solution? • Will your solution need to work every time, or only sometimes? • How much money do you have to spend? • How soon does the problem need to be solved? • Could your solution possibly cause other problems that need to be considered?
students having trouble understanding and applying Newton's third law to the design process	building a model bottle car and conducting a demonstration of how it works. After demonstrating, invite students to think aloud about how modifications to the car might make it go faster or farther. As time and resources allow, test these modifications to determine if they are viable solutions. Possible modifications: • bigger balloon, smaller balloon, longer straw, wider straw, different type of bottle, different type of wheel, etc.

Newton's Law and the Design Process



Modification	How or why will this make the car go faster or farther?

Engineering Design Process

Problem:

Criteria:	Constraints:
Solutions:	**Test Procedure:**