Britannica Expedition:LEARN!

Teacher Toolkit

Engineering and Design: Grades 3–5

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

Defining a Problem (30 minutes)

Background: The first step in the design cycle is identifying and defining the problem. In order to arrive at the best possible solution, engineers must fully understand the problem they are trying to solve. They need to know the context for the problem, such as the factors causing the problem and where the problem is happening. Allowing students to practice thinking about problems in this way develops their ability to define and conceptualize a problem. The teaching suggestions below are based on the *Expedition: Learn!* lesson "How Humans Change the Environment."

- Share with students that an engineer's job is to use science to design and build processes and tools that solve real-world problems.
- Share 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 that in this lesson, students will complete the first step of the process: identifying and defining a problem.
- Display and distribute the **Identifying a Problem organizer**.
- Share with students that they will read the article "Human Activity Affects Environments" and identify a problem that needs to be solved.
- Read the article aloud with students. After reading, think aloud and model completing the organizer using the paragraph about land environments:
    - What is the problem?
        - *The problem is people cutting down trees to build buildings.*
    - Why is the problem happening?
        - *People want or need more buildings.*
    - Who is causing the problem?
        - *Humans.*
    - When did the problem start? When does it happen?
        - *We don't know when it started, but it seems like it happens when people want new buildings.*
    - Where is the problem happening?
        - *In forests where people want to build.*
- Explain to students that once they have defined the problem, they are better able to brainstorm solutions to the problem. Consider emphasizing that further research may be necessary to focus on a specific instance or location of deforestation to make sure that they are able to come up with the best solution.

Mini-Lesson II

Criteria and Constraints (30 minutes)

Background: Identifying the criteria and constraints is an important part of the design process. 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. This lesson introduces students to the idea of both criteria and constraints. The teaching suggestions below are based on the *Expedition: Learn!* lesson "What Is the Design Process?"

- Share with 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.
- Explain that criteria are the things a design should have or do in order to successfully solve a problem. For example, an automatic door must be usable for people on foot, people in wheelchairs, and people pushing strollers or carts. It must also close in order to block out wind and precipitation.
- Explain that constraints are the things that limit the design. This might include materials available for use, the cost of making the design, and time available for building the solution. The constraints are the practical aspects of a design. While engineers may come up with all kinds of creative solutions, they also must build solutions within the parameters.
- Conduct a read-aloud of the article "Engineers Solve Problems." Emphasize the explanations of criteria and constraints.
- Present students with the idea of designing a new water bottle. Review the steps of the 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.*
- Invite students to turn and talk, completing step one by asking what problem a new water bottle could solve. For example:
    - *Kids at school need to carry water to stay hydrated during the day, and it needs to stay cool.*
- Ask students to think about the second step and what criteria, or what features, the bottle should include. For example:
    - *Criteria for a water bottle design might be that it keeps water cold for a certain amount of time, doesn't leak, and fits easily inside a backpack.*
- Then ask students to think about the constraints of the design. For example:
    - *Only recycled plastic should be used; each bottle should cost no more than 10 dollars to make; bottles should be available for purchase before the start of the next school year.*
- Emphasize that when developing solutions, engineers must consider the criteria and the constraints.

Mini-Lesson III

Generate Multiple Solutions (60 minutes)

Background: As part of the design cycle, engineers generate multiple solutions to a problem and then through experiments, test the solutions to determine which best fits the criteria and constraints. The process of generating multiple solutions allows engineers to think through numerous ways of attempting to solve a problem and to assess each to find the one that works best. In this lesson, students work together to identify a problem, discuss criteria and constraints, and generate multiple possible solutions to a problem. The teaching suggestions below are based on the *Expedition: Learn!* lesson "Natural Hazards."

- Conduct a read-aloud of the articles in the lesson "Natural Hazards."
- Remind students that engineers complete a design process when they develop solutions to a problem. Share that working to prevent harm during and after natural hazards is something that engineers have done for many years.
- Place students in groups of four or five, assign them one natural hazard from the lesson (earthquake, volcanic eruption, landslide, or tsunami), and display and distribute the **Solutions worksheet.**
- Invite student groups to identify a problem caused by their natural hazard and record it on the worksheet. For example:
    - *earthquake - buildings and bridges can collapse*
    - *volcanic eruption - lava flow can harm people*
    - *landslide - can bury entire towns*
    - *tsunami - boats and large rocks can get picked up and carried to land*
- Ask students to work through the worksheet as a team, identifying the criteria and possible constraints for their design. For example:
    - *criteria - protects people; protects land/buildings*
    - *constraints - does not interfere with daily life; does not cost too much; can be reused each time the hazard occurs*
- Encourage groups to come up with at least two potential solutions that could help protect people, animals, or the environment/structures.
- As desired, model completing the process or work with a small group that would benefit from additional support.

Check for Understanding

If you observe …	Then try …
students struggling to define a problem	providing a detailed scenario for students to use to complete the Identifying a Problem organizer. For example: • *ABC Builders want to chop down four acres of trees in the Amazon Rainforest on January 1. They plan to build an apartment and shopping complex and will displace many animals who live in that area.*
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?

Identifying a Problem

What is the problem?	
Why is the problem happening?	
Who is causing the problem?	
When did the problem start? When does it happen?	
Where is the problem happening?	

Solutions

Problem:

Criteria:	**Constraints:**

Solutions: