Activity Guide

Engineer It!

TSONGAS INDUSTRIAL HISTORY CENTER

University of Massachusetts Lowell
Graduate School of Education

Lowell National Historical Park

Connections to National Standards and State Curriculum Frameworks

Massachusetts

Technology/Engineering (Grade 3-5)

- Identify materials used to accomplish a design task on a specific property (e.g. strength, hardness, flexibility).
- Identify and explain the difference between simple and complex machines, e.g. hand can opener that includes multiple gears, wheel, wedge, gear and lever.
- Identify relevant design features (size, shape, weight) for building a prototype of a solution to a given problem.

Physical Science (3-5)

- Differentiate between properties of materials (color, texture, hardness, etc)

Technology/Engineering (Grade 6-8)

- Given a design task, identify appropriate materials based on specific properties and characteristics.
- Identify and explain the steps of the engineering design process, i.e. identify the need problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.
- Describe and explain the purpose of a given prototype.

New Hampshire

Technology/Engineering Student Performance Outcomes (Grade 3-5)

- Practice design principles and processes in basic technological activities.
- Use information and data in the design process.
- Demonstrate appropriate problem-solving strategies and techniques for solving technical problems.

Physical Science (3-4)

- Understand that materials are used in certain products based on their properties, such as strength and flexibility.
- Recognize that products are made using a combination of technologies, such as how an escalator uses both a pulley system and an electrical motor.

Technology/Engineering Student Performance Outcomes (Grade 6-8)

- Demonstrate the accurate use of appropriate measuring tools to gather, manipulate, and communicate information.
- Apply academic concepts and practices in a technological setting.

Physical Science (5-6, 7-8)

- Recognize that manufacturing processes use a variety of tools and machines to separate, form, combine and condition natural and synthetic materials.
- Understand that design features, such as size shape, weight, and function, must be considered when designing new technology.

National Frameworks - Next Generation Science Standards
3rd-5th Grade — Engineering Design - Disciplinary Core Ideas

Students who demonstrate understanding can:
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

ETS1.A: Defining and Delimiting Engineering Problems
• Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)

ETS1.B: Developing Possible Solutions
• Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2)
• At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)
• Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3)

ETS1.C: Optimizing the Design Solution
• Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)

Middle School (6th-8th Grade) - Engineering Design — Disciplinary Core Ideas

Students who demonstrate understanding can:
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-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

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-ETS1-1)

ETS1.B: Developing Possible Solutions
• There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2)

Engineer It!

Program Description

Lowell led the way in engineering and mechanical innovation in early industrial America. Engineers incorporated simple machines into systems that solved problems to make Lowell "work".

Students
- Use the engineering design process to solve a problem.
- Visit the "River Transformed" exhibit at the history Sufflk Mill to investigate technology and materials used to solve real manufacturing problems.
- Explore the Moody Street Feeder Gatehouse to see how simple machines controlled waterpower in Lowell.

Enduring Understanding

One way, in which, people solve problems is by using a step-by-step methodology known as the engineering design process.

Theme

Lowell's remarkable success as an early industrial city was made possible in part by engineers using the EDP cycle of design choices, prototyping, and testing, steps that led to innovations in waterpower systems and textile production.

Program Objectives

At the conclusion of the program, students will be able to:
- Describe how the various steps of the engineering design process are applied to solving a problem.
- Explain how engineers use simple machines as part of a complex machine to accomplish a task or solve a problem.
- Explain how a material's properties play a role in its selection by engineers to perform certain tasks.

Historical Highlights

In 1813, Francis Cabot Lowell and Paul Moody designed and built an American version of the English power loom. Lowell had drawn design plans after observing British textile operations in 1811. Together, Lowell and Moody drew and revised plans, built and tested prototypes, and spent months fine-tuning their product. The looms were successfully tested in a factory in Waltham, Massachusetts, in 1813. In 1823, the clatter of looms could be heard in the first of many mills built along the banks of the Merrimack River. The "Lowell Experiment" was underway.

Over the next 25 years, Lowell engineers developed an elaborate system of power canals to channel water from the Merrimack to turn water wheels in the mills. James B. Francis and other engineers set their minds to improving the water wheels to convert falling water into mechanical energy (kinetic energy). In 1847, using the Lowell system as a laboratory, Francis adapted and perfected a turbine of French design. This turbine captured more than 85% of the potential energy of falling water, far more than the earlier water wheels.

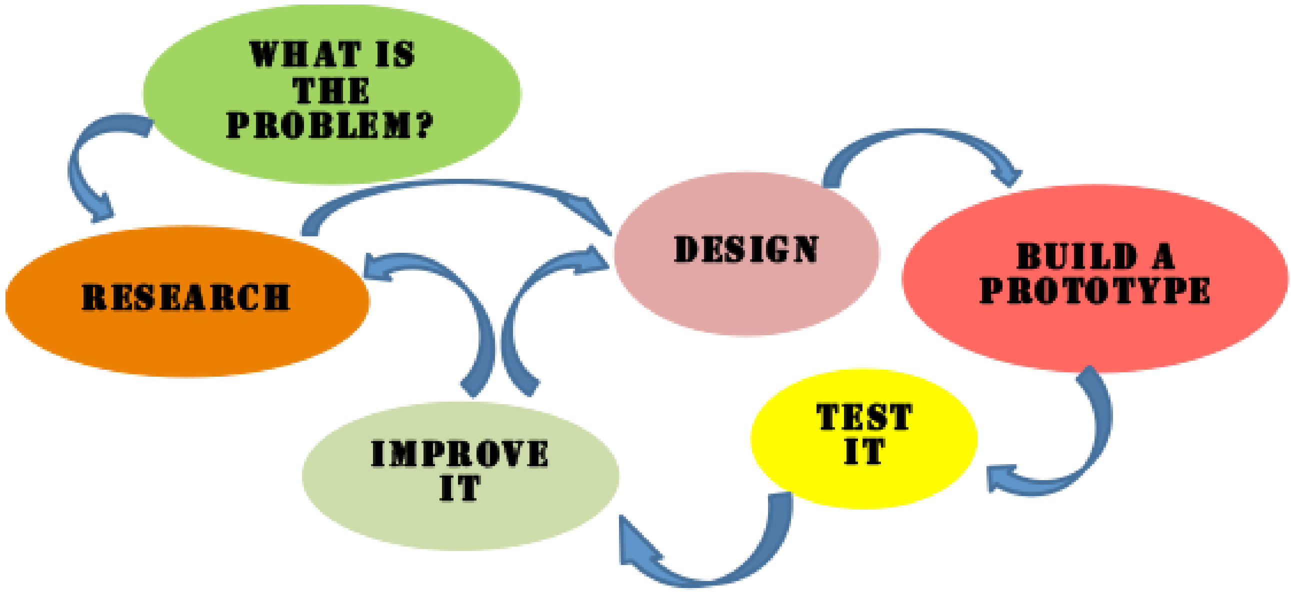
Engineers and mechanics designed and built turbines to capture the energy of falling water; steam engines to supplement the waterpower; flywheels, line shafts, and leather belts to transmit power; cards, spinning frames, and power looms to transform raw cotton into woven cloth; and railroad locomotives to pull freight trains transporting raw material to the mills and finished goods to market.

Engineering

- The **engineering design process (EDP)** is a series of steps that engineering teams use to guide them as they solve problems. To determine how to build something, engineers gather information and conduct research to understand the needs of the challenge to be addressed. Then they brainstorm many imaginative possible solutions. They select the most promising idea and embark upon a design that includes drawings and decision-making about materials, construction, manufacturing, fabrication technologies to use. They create and test many prototypes, making improvements until the product design is good enough to meet their needs.

- Simple machines make "work" easier and can be combined to make complex machines.

- Engineers make choices about construction materials based on the materials' properties and how they will perform at a designated task.



This engineer is using a leveling rod to determine the grade (slope) of the canal bottom. Engineers altered the slope of the bottom of the canals to help water flow efficiently to the turbines. 1895. *Center for Lowell History, University of Massachusetts Lowell.*

Testing Materials for Strength

Introduction
In this activity, students will examine different materials to determine their strength and determine how engineers select certain materials for particular jobs. Students will come to understand that the strength of a material does not depend only on the composition of the material itself; changing a material's shape can also affect the way it resists forces.

Guiding Question
How do the properties of different materials affect their tension and compression strength, making them more suitable for some jobs than others?

Objectives
Students will be able to:
- Identify material with high and low tension and compression strengths
- Categorize what type of engineering task (i.e., a building, a bridge, furniture, etc.) each material would be appropriate for

Materials
- Materials may include (teacher discretion): string, rubber bands, styrofoam, sponges, marshmallows (or other candy like Tootsie Rolls or Jolly Ranchers), brick, metal, copper wire, small blocks of wood, leather
- 1 vise, 1 pair of pliers, and 1 ruler per group of students (Note: A C-clamp can be used in place of a vise. C-clamps are readily available in hardware stores.)
- Copies of "Materials Testing Worksheet"

Discussion
Explain to students that building materials withstand **tension** and **compression** to different degrees. Tell students that this activity will help them understand that because materials have unique properties, some are better suited for certain jobs than others. For example, brick has a high capacity for compression but has no capacity for tension.

Action
Gather as many different kinds of materials as you can find, using the ones listed above as a guide. Divide the class into groups and provide each with samples of the different materials, along with a vise, a pair of pliers, and the "Materials Testing Worksheet." Have one member of each group be responsible for recording the group's observations by filling in the chart on the "Materials Testing Worksheet." Have groups test each material for strength under tension and compression according to the following guidelines. Then, based on their results, ask them to identify what type of engineering task each material would be useful for.

Compression Test: Put the object in a vise and tighten. Note if the object changes shape or remains intact.

Tension Test: Put one end of the object in a vise. Hold the other end of the object in your hand or with pliers and pull slowly. Note if the object changes shape or remains intact. Measure how far the object can be pulled before it breaks apart.

Conclusion

When students have finished testing the materials, ask the groups to share their findings. Ask students: In what ways were you surprised by how some of the materials responded under tension and compression? What unexpected results did you get during the experiment? What tasks are the various materials best suited for?

Frameworks & Standards Connections

MA Science and Technology/Engineering Curriculum Frameworks

Technology/Engineering (3-5)

- Identify materials used to accomplish a design task on a specific property (e.g. strength, hardness, flexibility)

Physical Science (3-5)

- Differentiate between properties of materials (color, texture, hardness, etc.)

Technology/Engineering (6-8)

- Given a design task, identify appropriate materials based on specific properties and characteristics.

NH Performance Outcomes

Technology/Engineering (3-5)

- Materials have many different properties.

Physical Science (3-4)

- Understand that materials are used in certain products based on their properties, such as strength and flexibility.

Materials Testing Worksheet

1. Test each material for strength under compression and tension.
   - Compression: Put the object in a vise and tighten. Record what happens to the material and rate its performance.
   - Tension: Put one end of the object in a vise. Hold the other end of the object in your hand or with pliers and pull slowly. Measure how far the object can be pulled before it breaks apart. Record what happens to the material and rate its performance.

2. Record your observations in the chart. Use the following scale to indicate how resistant each material is to the forces: V–very good, G–good, F–fair, P–poor.

3. Decided what type of engineering task each material would be appropriate for.

Material	**Compression**		**Tension**		
	Observation	Rating	Observation	Rating	Engineering Task
Example: *Sponge*	*dented in, became compacted*	*G*	*Stretched, then tore under tension, 2 inches*	*F*	*cleaning up chemical spills*

Post-Visit Activities

Innovate It!

Introduction
In this activity, student teams will use the engineering design process to innovate a new design for either a school desk or pet feeder.
Guiding Question
How does the engineering design process facilitate the research and design of an innovative product?

Objectives

Students will be able to:
- Execute the engineering design process steps by making educated choices about materials selection and product design.

Materials
- Copies of the two “Innovate it!” instruction sheets for student groups.
- Cardboard, tape, and other found items for students to use in the construction of their prototypes.
- Technology to project video from YouTube for classroom viewing

Discussion
Review the **engineering design process** and the considerations that engineers make when going through the process to innovate a new product.

View the “IDEO Shopping Cart” video on YouTube. IDEO (pronounced “eye-dee-oh”) is an award-winning global design firm that takes a human-centered, design-based approach to helping organizations in the public and private sectors innovate and grow. In this video from ABC’s “Nightline,” IDEO staff work through the engineering design process to innovate the design of a standard shopping cart.

Action
Student groups work together on their choice of product – either school desk or pet feeder – to innovate a new design. As they work through the steps of the engineering design process, part of the "Test it" phase will be to present the design to their classmates and make changes to their initial design based on the feedback.

Conclusion
What research/information influenced the design choices your group made?
What was their experience with the engineering design process? What applications might it have to other parts of their life?

Frameworks & Standards Connections

MA Science and Technology/Engineering Curriculum Frameworks
Technology/Engineering (6-8)

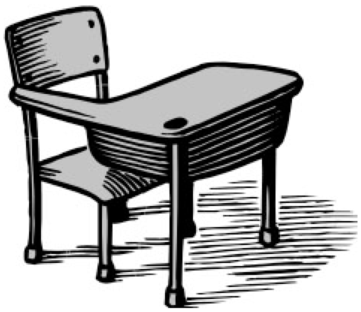
- Identify and explain the steps of the engineering design process, i.e., identify the problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.

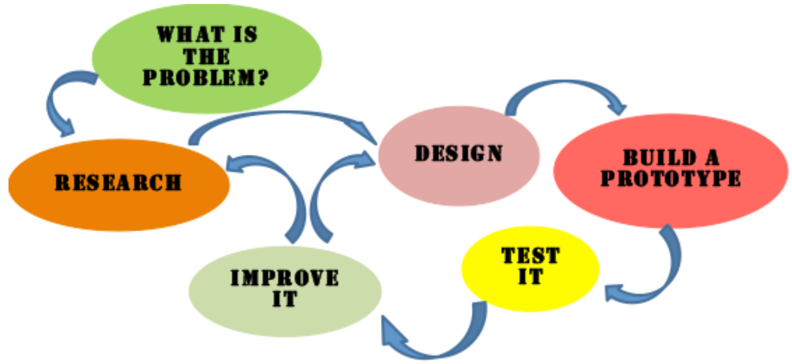
NH Performance Outcomes
Tech/Engi Student Performance Outcomes (3-5)

- Practice design principles and processes in basic technological activities.
- Use information and data in the design process.

Innovate It!

Design a better desk.





What's the Problem?
Today's school desks were designed for students in the19th century. Your challenge is to design a desk for the 21st century student.

Research
- What do your classmates want to be able to do at their desk?
- What types of accommodations will make the desk better for them to work at?
- What materials will your desk be made out of?

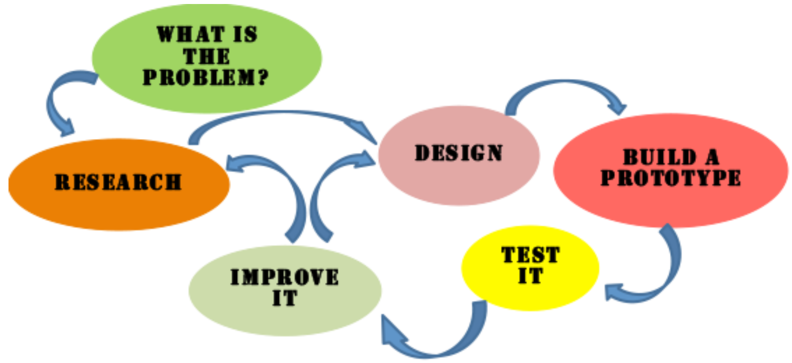
Design
Sketch out your design. Be sure to label the design's unique features.

Build a Prototype
Using cardboard, tape, and other found items, construct a prototype (model) of your design.

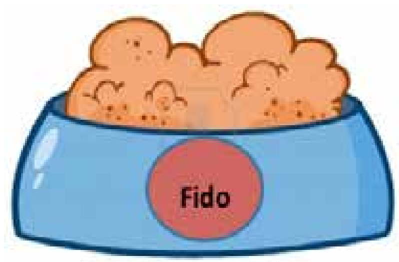
Test It
Present your design to the class. Have your classmates give you feedback about the various features of your prototype.

Improve It
Based on the feedback from your classmates, write up a description on how you would change your desk's features.

Innovate It!



Design a better pet feeder.



What's the Problem?
Your challenge is to design a pet feeder – for a cat, dog, bird, or hamster.

Research
- What do your pet owners want to their pet feeder to be able to do?
- What types of accommodations in the pet feeder will make the owner's life easier/better?
- What materials will your pet feeder be made from?

Design
Sketch out your design. Be sure to label the design's unique features.

Build a Prototype
Using cardboard, tape, and other found items, construct a prototype (model) of your design.

Test It
Present your design to the class. Have your classmates give you feedback about the various features of your prototype.

Improve It
Based on the feedback from your classmates, write up a description on how you would change your pet feeder's features.

Post-Visit Lesson Project Rubric:
The purpose of the project is to assess student knowledge and application of the engineering design process.

	Below Expectations	**Meets Expectations**	**Above Expectations**
Research - Students collected information in order to design their prototype to the needs of the "client."	Students gathered an insufficient amount of research to inform their prototype design.	Students gathered a sufficient amount of research to inform their prototype design.	Students gathered additional research to inform their prototype design.
Process - Students followed the EDP – designing and building a prototype.	Students neglected to follow all steps of the EDP and did not record their design choices.	Students followed most steps of the EDP and recorded their design choices.	Students followed all steps of the EDP and recorded their design choices.
Test it - Students presented their design and received feedback from classmates.	Students' presentation covered few details of their research and design choices.	Students' presentation covered their research and design choices.	Students' presentation covered their research, design choices, and additional information about their process.
Improve it - Students noted how they would improve their prototype based on class feedback.	Students' write-up included insufficient information as to what they would do to improve their prototype based on class feedback.	Students' write-up included what they would do to improve their prototype based on class feedback.	Students' write-up included additional information about what they would do to improve their prototype based on class feedback.

TERMS

Tension: a force that tends to produce an elongation or stretching of a material or structure.

Compression: a force that tends to shorten or squeeze something, decreasing its volume.

Prototype: an early sample or model built to act as a thing to be replicated or learned from.

Innovation: the alteration of what is established by the introduction of new elements or forms. Innovation differs from invention in that innovation refers to the use of a better and, as a result, novel idea or method, whereas invention refers more directly to the creation of the idea or method itself. Innovation differs from improvement in that innovation refers to the notion of doing something different rather than doing the same thing better.

BIBLIOGRAPHY

Q: If my class should read one book before they visit the Tsongas Industrial History Center, what would it be? A: *The New Way Things Work* by David Macaulay

Students:
Macaulay, David. *The New Way Things Work*. Boston: Houghton Mifflin Harcourt, 1998. Text and numerous detailed illustrations introduce and explain the scientific principles and workings of hundreds of machines.

Riley, Peter. *Materials (Everyday Science Series)*. New York: Gareth Stevens Publishing, 2002. An introduction to various types of materials and their different properties.

Teachers:
Baine, Celeste and Cathi Cox-Boniol. *Teaching Engineering Made Easy: A Friendly Introduction to Engineering Activities for Middle School Teachers (2nd Edition).* Calhoun, LA: Bonamy Publishing, 2006. Teacher-tested activities to get students thinking like engeineers.

Macaulay, David. *Mill*. Boston: Houghton Mifflin, 1983. Excellent discussion of how water power works; extensively illustrated.

These Locks and Canals employees are demonstrating the measurement of water flow in Lowell's canals for visiting engineers in 1878. Flow measurement was important for maximizing water power efficiency and determining the appropriate cost of water used by each mill. 1895. *National Park Service. Lowell National Historical Park Collection.*

The Tsongas Industrial History Center is a joint educational enterprise sponsored by the University of Massachusetts Lowell and Lowell National Historical Park. Established in 1987, its goal is to encourage the teaching of industrial history in elementary and secondary schools.

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