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Lesson Focus

This lesson focuses on trebuchet design. Teams of students construct trebuchets from everyday materials. They then test their trebuchets to determine the farthest distance they can hit a target with a marshmallow projectile.

Lesson Synopsis

The "Trebuchet Toss" lesson explores how trebuchets were used during the Middle Ages to launch projectiles over or through castle walls. Students work in teams of "engineers" to design and build their own trebuchets out of everyday items. They test their trebuchets, evaluate their results, and present to the class.

Age Levels

12-18

Objectives

During this lesson, students will:

- ◆ Design and build a trebuchet
- ◆ Test and refine their designs
- ◆ Communicate their design process and results



Anticipated Learner Outcomes

As a result of this lesson students will have:

- ◆ Designed and built a trebuchet
- ◆ Tested and refined their designs
- ◆ Communicated their design process and results

Lesson Activities

In this lesson, students work in teams of "engineers" to design and build their own trebuchet out of everyday items. They test their trebuchet, evaluate their results, and present to the class.

Resources/Materials

- ◆ Teacher Resource Documents (attached)
- ◆ Student Worksheets (attached)
- ◆ Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

Trebuchet Toss

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See attached curriculum alignment sheet.

Internet Connections

- ◆ TryEngineering (www.tryengineering.org)
- ◆ Trebuchets Wikipedia (<https://en.wikipedia.org/wiki/Trebuchet>)

Recommended Reading

- ◆ Catapult Design, Construction and Competition with the Projectile Throwing Engines of the Ancients (ISBN: 978-0977649709)
- ◆ Engineering in the Ancient World, Revised Edition (ISBN: 978-0520227828)

Optional Writing Activity

- ◆ Compare and contrast the trebuchet and the catapult.

Extension Ideas

- ◆ Build a wall of paper cups of a given height and challenge teams to design a trebuchet that can launch a marshmallow over it. Teams can also design a trebuchet that can launch a marshmallow through the wall with the goal of knocking down the greatest number of cups.

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For Teachers: Teacher Resource

◆ Lesson Goal

The goal of this lesson is for students to design and build a trebuchet out of everyday materials. The trebuchet must be able launch a mini marshmallow with enough accuracy to land on a pie tin. The objective is to launch the marshmallow onto the pie tin from as great a distance as possible.

◆ Lesson Objectives

During this lesson, students will:

- ◆ Design and build a trebuchet
- ◆ Test and refine their designs
- ◆ Communicate their design process and results

◆ Materials

- ◆ Student Resource Sheets and Worksheets
- ◆ One set of materials for each group of students:

- | | |
|------------------------------|---------------------------------|
| ○ 20 plastic drinking straws | ○ String |
| ○ 20 unsharpened pencils | ○ Scissors |
| ○ 20 popsicle sticks | ○ 5 metal washers |
| ○ 10 rubber bands | ○ Small piece of cloth |
| ○ 5 toothpicks | ○ Meter stick or measuring tape |
| ○ 5 paperclips or craft wire | ○ Mini marshmallows |
| ○ Masking tape | ○ Pie tin or Paper plate |

◆ Procedure

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
2. Divide students into groups of 2-3 students, providing a set of materials per group.
3. Explain that students must develop their own working trebuchet from everyday items. They must test whether their trebuchet can launch a mini marshmallow to accurately land on a pie tin. They must also test their trebuchets to find the maximum distance at which they can hit the target. The trebuchet that can hit a pie tin from the farthest distance possible is the winner.
4. Students meet and develop a plan for their trebuchet. They agree on materials they will need, write or draw their plan, and then present their plan to the class.
5. Student teams may trade unlimited materials with other teams to develop their ideal parts list.
6. Student groups next execute their plans. They may need to rethink their plan, request other materials, trade with other. Students should record their results measuring both the distance the projectile was launched as well as the distance the marshmallow landed from the target.
7. Teams then complete an evaluation/reflection worksheet, and present findings.

◆ Time Needed

Two to three 45 minute class periods.

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Student Resource: **History and Mechanics of the Trebuchet**

◆ **History of the Trebuchet**

A trebuchet is a type of catapult that was used during the Middle Ages to launch projectiles during battle. Trebuchets can be distinguished from other types of catapults in that they do not use stored tension (such as in twisted ropes or flexed wood) to launch objects. Projectiles launched by trebuchets included rocks for smashing through castle walls, venomous snakes, beehives, and even dead animals to spread disease. Since trebuchets required aiming, they were typically used to hit stationary targets such as buildings, walls, and even other trebuchets. A trebuchet has much better accuracy than other types of catapults. Trebuchets were effective during battle because they could be set up a safe distance away from a castle, and the archers guarding it, while still causing significant amounts of damage. Many castles also had trebuchets inside their walls to launch projectiles at their enemies. Since trebuchets had the ability to launch objects very far into the air they could do so from behind castle walls without being seen. A sturdy trebuchet could launch a projectile weighing 300 pounds over 300 yards!



During the Second Punic War in 213 BC Archimedes developed several powerful, accurate catapults to defend Syracuse against the Romans. According to legend, he also developed a trebuchet-like war-machine known as the Archimedes Claw. Although the exact design is not known, it is believed that the claw was a large trebuchet-like or crane-like machine that dropped a hook or anchor onto enemy ships from above, either capsizing or sinking them. Early forms of the trebuchet were observed in China as early as 4 BC and in Europe in 6 BC. Once gunpowder was invented, the trebuchet became obsolete somewhere around the 16th Century.

◆ **What are the parts of the Trebuchet?**

There are two basic types of trebuchets: a traction trebuchet and a counterweight trebuchet. Both the traction trebuchet and the counterweight trebuchet consist of a base, an arm and a sling. The base of the trebuchet is what provides the support to the device. Oftentimes, the base of the trebuchet is on wheels for mobility. The arm of the trebuchet is essentially a long beam on a pivot that acts as a lever to fling the projectile. A sling holds the projectile in place at the long end of the arm (farther away from the pivot). The sling could be a pouch that holds the projectile in place. The sling could also consist of a rope which is attached to the projectile and then loosely tied to a release pin at the end of the arm. The rope is designed to slide off the release pin when the arm swings around. In a counterweight trebuchet, a counterweight is attached to the short end of the arm, closer to the pivot. The traction trebuchet on the other hand relies on people pulling down on the short end of the arm with ropes.

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Student Resource:
History and Mechanics of the Trebuchet
(continued)

The following are some science concepts to keep in mind when you are designing and testing your trebuchets.

◆ **Levers**

In addition to his numerous accomplishments, Archimedes is considered to be the first person to explain the principles behind levers. Based on his findings he was quoted saying "Give me a place to stand, and I will move the Earth." Levers are one of the six types of simple machines. A lever is a rigid object that is used with a fulcrum or pivot point to increase the amount of mechanical force applied to an object. A trebuchet is considered a class 1 lever. In a class 1 lever the force is applied to one end of the arm, the load on the other end, and a pivot point or fulcrum is in the middle. A playground see-saw is also a class 1 lever.



In a trebuchet the force (counterweight) is much greater than the load (projectile). The fulcrum or pivot point on a trebuchet is not directly in the middle as it is in a see-saw. Here, the pivot point is closer to the counterweight, or the end where the force is being applied.

Mechanical advantage is the factor by which the force or torque put into a mechanism is multiplied. We can calculate the mechanical advantage of any simple machine by dividing the output force by the input force. Another way to calculate the mechanical advantage of a lever is by dividing the length of the effort arm (distance between the fulcrum and the force) by the length of the resistance arm (distance between the fulcrum and the load or projectile).

$$MA = \frac{\text{Output force (at load)}}{\text{Input force (applied)}}$$

$$MA_{\text{lever}} = \frac{\text{Length of Effort Arm}}{\text{Length of Resistance Arm}}$$

Work is how much energy is transferred by a force acting over a distance. The formula for work is $W = F \times D$. The greater the mechanical advantage the less force required, but it must be applied over a greater distance. The amount of work does not change.

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Student Worksheet:
Design Your Own Trebuchet

You are a team of engineers who have been given the challenge to design your own trebuchet out of everyday items. The trebuchet should be designed to launch a marshmallow so it can land on a pie tin from as far a distance as possible. The trebuchet that can accurately hit the pie tin from the greatest distance is the winner. You may use the materials which have been provided to you, but the rubber bands may not be used to power the arm or slingshot the marshmallow.

◆ **Planning Stage**

Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your trebuchet. You'll need to determine what materials you want to use.



Draw your design in the box below, and be sure to indicate the description and number of parts you plan to use. Present your design to the class.

You may choose to revise your teams' plan after you receive feedback from class.

Design:

Materials Needed:

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Student Worksheet (continued):

◆ Construction Phase

Build your trebuchet. Tip: You may want to experiment with the weight of your counterweight, sling length, and the placement of your arm’s pivot point. During construction you may decide you need additional materials or that your design needs to change. This is ok – just make a new sketch and revise your materials list.

◆ Testing Phase

Each team will test their trebuchet. Your object is to launch a marshmallow as far a distance as possible and land on the pie tin target. Be sure to watch the tests of the other teams and observe how their different designs worked.

Trebuchet Test Results		
	Projectile Distance	Distance from Landed Target
Test 1		
Test 2		
Test 3		
Average		

◆ Evaluation Phase

Evaluate your teams' results, complete the evaluation worksheet, and present your findings to the class.

Use this worksheet to evaluate your team's results in the Trebuchet Toss Lesson:

1. Did you succeed in creating a trebuchet that could launch a marshmallow to accurately land on a pie tin? If so, what was the maximum distance achieved? If not, why did it fail?
2. Did you decide to revise your original design or request additional materials while in the construction phase? Why?
3. Did you negotiate any material trades with other teams? How did that process work for you?

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For Teachers:

Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (<http://www.nextgenscience.org/>)
- International Technology Education Association's Standards for Technological Literacy (<http://www.iteea.org/TAA/PDFs/xstnd.pdf>)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (<http://www.nctm.org/standards/content.aspx?id=16909>)
- U.S. Common Core State Standards for Mathematics (<http://www.corestandards.org/Math>)
- Computer Science Teachers Association K-12 Computer Science Standards (<http://csta.acm.org/Curriculum/sub/K12Standards.html>)

◆ National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ◆ Properties of objects and materials

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ◆ Science as a human endeavor

◆ National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ◆ Motions and forces

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ◆ History of science

◆ National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- ◆ Motions and forces

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ◆ Historical perspectives

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For Teachers:
Alignment to Curriculum Frameworks

◆ **Next Generation Science Standards Grades 3-5 (Ages 8-11)**

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- ◆ 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Engineering Design

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.

◆ **Next Generation Science Standards Grades 6-8 (Ages 11-14)**

Engineering Design

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.

◆ **Principles and Standards for School Mathematics (ages 11 - 14)**

Measurement Standard

- Apply appropriate techniques, tools, and formulas to determine measurements.
 - ◆ solve simple problems involving rates and derived measurements for such attributes as velocity and density.

◆ **Principles and Standards for School Mathematics (ages 14 - 18)**

Measurement Standard

- Apply appropriate techniques, tools, and formulas to determine measurements.
 - ◆ analyze precision, accuracy, and approximate error in measurement situations.

◆ **Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)**

Measurement and data

- Measure and estimate lengths in standard units.
 - ◆ CCSS.Math.Content.2.MD.A.1 Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
 - ◆ CCSS.Math.Content.2.MD.A.3 Estimate lengths using units of inches, feet, centimeters, and meters.

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***For Teachers:
Alignment to Curriculum Frameworks***

◆ Standards for Technological Literacy - All Ages

Design

- ◆ Standard 8: Students will develop an understanding of the attributes of design.
- ◆ Standard 9: Students will develop an understanding of engineering design.
- ◆ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

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