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Lesson Focus

Lesson focuses on how watermills generate power. Student teams design and build a working watermill out of everyday products and test their design in a basin. Student watermills must be able to sustain three minutes of rotation. As an extension activity, older students may design a gear system that is powered by the watermill. Students then evaluate the effectiveness of their watermill and those of other teams, and present their findings to the class.

Lesson Synopsis

The "Working with Watermills" lesson explores how watermills have helped harness energy from water through the ages. Students work in teams of "engineers" to design and build their own watermill out of everyday items. They test their watermill, evaluate their results, and present to the class.

Age Levels

8-18.



Objectives

- ◆ Learn about engineering design.
- ◆ Learn about planning and construction.
- ◆ Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- ◆ structural engineering and design
- ◆ problem solving
- ◆ teamwork

Lesson Activities

Students learn how watermills have been used throughout the ages to harness the power of water. Students work in teams to develop a their own watermill out of everyday items, then test their watermill, evaluate their own watermills and those of other students, and present their findings to the class.

Working with Watermills

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Resources/Materials

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

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- ◆ TryEngineering (www.tryengineering.org)
- ◆ Waterwheel Factory (www.waterwheelfactory.com)
- ◆ U.S. Geological Survey Hydroelectric Power (<https://water.usgs.gov/edu/hyhowworks.html>)
- ◆ Society for the Preservation of Old Mills (www.spoom.org)

Supplemental Reading

- ◆ Cathedral, Forge and Waterwheel: Technology and Invention in the Middle Ages (ISBN: 0060925817)
- ◆ Windmills and Waterwheels Explained (ISBN: 1846740118)

Optional Writing Activity

- ◆ Write an essay or a paragraph about how engineering has helped reduce human work over the ages.

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For Teachers: Teacher Resource

◆ **Lesson Goal**

Lesson focuses on how watermills generate power. Student teams design and build a working watermill out of everyday products and test their design in a basin. Student watermills must be able to sustain three minutes of rotation. As an extension activity, older students may design a gear system that is powered by the watermill. Students then evaluate the effectiveness of their watermill and those of other teams, and present their findings to the class.

◆ **Lesson Objectives**

- ◆ Learn about engineering design.
- ◆ Learn about planning and construction.
- ◆ Learn about teamwork and working in groups.

◆ **Materials**

- ◆ Student Resource Sheet
- ◆ Student Worksheets
- ◆ Water source, large basin or sink, tape, stopwatch or clock, measuring cup or pouring device -- if you use a five gallon jug of water, you can recycle it for each group's test.
- ◆ One set of materials for each group of students:
 - Styrofoam cylinder, plastic or wooden spoons, small wooden (balsa) pieces, bendable wire (such as florist or craft wire), string, paperclips, rubber bands, toothpicks, aluminum foil, tape, wooden dowels, plastic or wax coated food container lids, or other materials.



◆ **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. Students should review the U.S. Geological Survey website about how hydroelectric power works at <https://water.usgs.gov/edu/hyhowworks.html>.
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 watermill from everyday items, and that the watermill must be able to rotate for three minutes without falling apart in order to be a success.
4. Students meet and develop a plan for their watermill. They agree on materials they will need, write or draw their plan, and then present their plan to the class.

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For Teachers:
Teacher Resource (continued)

5. Student teams may request additional quantities of any of the materials provided, up to two sets of materials per team. They may also 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 teams, or start over.
7. Next....teams will test their watermills in a large basin with water. They have to be able to secure their watermill so it does not move from a central place and does not roll forward to one side.
8. Teams then complete an evaluation/reflection worksheet, and present their findings to the class.



◆ **Time Needed**

Two to three 45 minute sessions

◆ **Tips**

For older students suggest they create a gear system to lift an object using the energy from the wheel turning. This can be executed with spools of thread glued to the end of a stick, with rubber bands and perhaps string. Challenge students to lift a weight using the water power.

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Student Resource: **Watermills through History**

A watermill is a structure that uses a water wheel or turbine to drive a mechanical process such as ground flour or lumber production, or metal shaping (rolling, grinding or wire drawing). A watermill that generates electricity is frequently called a hydroelectric plant.

The ancient Greeks and Romans are thought to be the first to use water to power their mills. In the early 1st century BC, the Greek epigrammatist Antipater of Thessalonica referenced a waterwheel which was effectively used to grind grain and reduce human work.

The Romans built some of the first watermills outside of Greece for grinding flour and spread the technology for constructing watermills throughout the Mediterranean.

◆ How Does it Work?

A watermill works by diverting water from a river or pond to a water wheel, usually along a channel or pipe. The water's force drives or pushes the blades of the wheel (or turbine) which then turns or rotates an axle that drives whatever machinery is attached to it. After turning the waterwheel, the water exits the watermill. Sometimes mills are stacked along a waterway so that water passes through multiple mills turning many wheels.

◆ Horizontal or Vertical?

Watermills that use water wheels with a horizontal wheel and vertical shaft are sometimes called "Greek Mills." A "Roman Mill" refers to a watermill that uses a vertical wheel (on a horizontal shaft). Greek style mills are the older and simpler of the two designs, but they require high water velocity to work well. The Roman style mills are much more complicated in their component parts and require gears to transfer the power from a shaft with a horizontal axis to one with a vertical axis.



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Student Worksheet:
Design Your Own Watermill

You are a team of engineers who have been given the challenge to design your own watermill out of everyday items. Your wheel will need to be able to withstand a three minute water test.

◆ **Planning Stage**

Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your watermill. You'll need to determine what materials you want to use -- keep in mind that all your parts will be exposed to water. 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.



Materials Needed:

Working with Watermills

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Student Worksheet (continued):

◆ Construction Phase

Build your watermill. 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 watermill in a classroom basin. You'll need to time your test to make sure your watermill can operate for three minutes without falling apart. Be sure to watch the tests of the other teams and observe how their different designs worked.

◆ 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 Working with Watermills lesson:

1. Did you succeed in creating a watermill that operated for three minutes? 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?

Working with Watermills

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

- ◆ Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ◆ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

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

- ◆ Science and technology in local challenges

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
- ◆ Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ◆ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

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

- ◆ Science and technology in society

For Teachers:
Alignment to Curriculum Frameworks

◆ **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
- ◆ Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ◆ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

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

- ◆ Natural resources
- ◆ Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

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

- ◆ Historical perspectives

◆ **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.

Energy

- ◆ 4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Earth and Human Activity

Students who demonstrate understanding can:

- ◆ 4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

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.

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For Teachers:
Alignment to Curriculum Frameworks

◆ **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.
- ◆ MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆ **Next Generation Science Standards Grades 9-12 (Ages 14-18)**
Energy

Students who demonstrate understanding can:

- ◆ HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

◆ **Standards for Technological Literacy - All Ages**

The Nature of Technology

- ◆ Standard 2: Students will develop an understanding of the core concepts of technology.
- ◆ Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- ◆ Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- ◆ Standard 5: Students will develop an understanding of the effects of technology on the environment.

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.

Abilities for a Technological World

- ◆ Standard 11: Students will develop abilities to apply the design process.
- ◆ Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- ◆ Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.
- ◆ Standard 20: Students will develop an understanding of and be able to select and use construction technologies.

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