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Lesson Focus

Lesson focuses on how wind energy can be generated on both a large and small scale. Student teams design and build a working windmill out of everyday products and learn about anemometer and site testing. Student windmills must be able to sustain the wind generated by a fan or hairdryer at medium speed at 3 feet (one meter) and rotate, lifting a small object upward. Students evaluate the effectiveness of their windmill and those of other teams, and present their findings to the class.



Lesson Synopsis

The "Working with Wind Energy" activity explores the growing use of wind energy to generate or augment energy in businesses and homes worldwide. Students work in teams of "engineers" to design and build their own windmill out of everyday items which they select and purchase with a budget. They test their windmill, evaluate their results, and present reflections to the class.

Age Levels

8-18.

Objectives

- ◆ Learn about wind energy and wind turbines.
- ◆ Learn about engineering design.
- ◆ Learn how engineering can help solve society's challenges.
- ◆ Learn about teamwork and problem solving.

Anticipated Learner Outcomes

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

- ◆ wind energy
- ◆ interaction of technology and societal issues
- ◆ engineering design
- ◆ teamwork

Working with Wind Energy

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Lesson Activities

Students explore the impact of how technology can positively impact the world by learning about wind energy and equipment used for both site testing and the conversion of wind to energy. Students explore the technology behind wind energy, find out about site studies, and work in teams to develop a windmill out of everyday items. They test their windmill, evaluate their own designs and those of other students, and present their findings to the class.

Resources/Materials

- ◆ Teacher Resource Documents (attached)
- ◆ Student Resource Sheet (attached)
- ◆ Student Worksheet (attached)



Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- ◆ TryEngineering (www.tryengineering.org)
- ◆ National Renewable Energy Laboratory - Wind Research (www.nrel.gov/wind)
- ◆ Wind Europe (<https://windeurope.org>)
- ◆ Danish Wind Industry Association (www.windpower.org)
- ◆ Global Wind Energy Council (www.gwec.net)
- ◆ Global Wind Day (www.globalwindday.org)

Recommended Reading

- ◆ Wind Power: Renewable Energy for Home, Farm, and Business (ISBN: 1931498148)
- ◆ Wind Energy Basics: A Guide to Small and Micro Wind Systems (ISBN: 1890132071)
- ◆ The Homeowner's Guide to Renewable Energy (ISBN: 086571536X)

Optional Writing Activity

- ◆ Write an essay about whether a wind farm -- even if it would provide energy to the local area -- would be a good idea to put in the center of your hometown. What about on the Thames River in London or just off of a resort beach area?

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For Teachers: Teacher Resource

◆ **Lesson Goal**

Students explore the impact of how technology can positively impact the world by learning about wind energy and equipment used for both site testing and the conversion of wind to energy. Students explore the technology behind wind energy, find out about site studies, and work in teams to develop a windmill out of everyday items. They test their windmill, evaluate their own designs and those of other students, and present findings to the class.

◆ **Lesson Objectives**

- ◆ Learn about wind energy and wind turbines.
- ◆ Learn about engineering design.
- ◆ Learn how engineering can help solve society's challenges.
- ◆ Learn about teamwork and problem solving.

◆ **Materials**

- ◆ Student Resource Sheets and Worksheets
- ◆ Hairdryer or Fan; small object for each team to lift (suggestions: toy car, yoghurt cup filled with a few coins, tea bag, battery, pencil)
- ◆ One set of materials for each group of students: wooden stick, wooden spoons, small wooden (balsa) pieces, bendable wire, string, paperclips, rubber bands, toothpicks, aluminum foil, tape, dowels, glue, paper, cardboard, plastic wrap, or other materials you have available.

◆ **Procedure**

1. Show students the various Student Reference Sheets and recommended internet sites. These may be read in class, or provided as 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 windmill from everyday items, and that the windmill must be able to withstand a medium speed fan for one minute while winding a string to lift a small object such as a tea bag. (Note: as an extra challenge, test the windmill's ability to lift heavier objects such as coins or washers.)
4. Students will be given a "budget" from which they will need to purchase materials you provide. Assign a cost for each item that will result in the average team being able to purchase at least 30 material parts.
5. Students meet and develop a plan for their windmill. They agree on materials they will need, write or draw their plan, and then present their plan to the class.
6. Student groups next execute their plans and may exchange materials or order more materials from the teacher, or may also trade unlimited materials with other teams to develop their ideal parts list. They will need to determine the "cost" of their design, however, which will be factored in to determine the most efficient classroom design.
7. Next....teams will test their windmills with the fan or hairdryer set up. (Note: you may wish to make the fan available during the building phase so they can test their windmill during the building phase prior to the classroom test.)
8. Teams then complete an evaluation worksheet, and present findings to the class.

◆ **Time Needed**

Two to three 45 minute sessions.

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Student Resource: **Blade Options**

◆ **Blade Design**

Blades come in many shapes and sizes, and there is continuing research into which design is best. It turns out that the optimal design really depends on the application, or where and how the blade will be used. Designers look at the "tip speed ratio" that determines efficiency. This is the ratio between the speed of the wind and the speed the blade tip. High efficiency 3-blade-turbines have tip speed/wind speed ratios of between 6 and 7.



◆ **How Many Blades?**

Most wind turbines use either two or three blades. Research indicates that as more blades are added there is a increase in aerodynamic efficiency, but this efficiency decreases dramatically with each added blade. For example, increasing the number of blades from one to two can yield a six percent increase in aerodynamic efficiency, but increasing the blade count from two to three yields only an extra three percent in efficiency. And, of course, there are cost implications too. Each additional blade in a design will increase the cost of the end product, so engineers have to factor in both the increased efficiency and the increased cost of manufacturing to determine a design that will be the best for an application. Aesthetics is also a consideration. A small, two or three blade design might be best for a residential area, where a homeowner just wants to pull from the wind enough energy to power their own home, and would prefer a quieter option. A giant 12 blade design would not look very nice atop their home and would perhaps generate more energy than they need, and likely more noise too! To the right you can see how NASA tested a one-bladed rotor configuration.

◆ **Materials**

Early windmills were made of wood with canvas sails. These deteriorated over time and required care – but they represented the materials readily available! More recently, older mechanical turbine blades were made out of heavy steel...but now many are made using fiberglass and other synthetic materials that offer strength at lower weights. And, lower weight building materials can result in larger blades to catch more wind in applications where size and space are less of an issue. Manufacturers also use epoxy-based composites which may offer manufacturing advantages over other materials because the process has less impact on the environment and can result in a smoother surface finish. Carbon fibers have also been identified as a cost-effective method to further reduce weight and increase stiffness. Smaller blades can be made from light metals such as aluminum. Engineers will be working in this field for years to come to determine the optimal shape, weight, and materials to generate energy most efficiently!



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Student Worksheet:
Design Your Own Windmill

You are working as a team of engineers who have been given the challenge to design a windmill out of everyday items. Your windmill will need to be able to withstand wind from a fan for at least one minute while winding a string or wire to lift a light object such as a teabag. You are working on a budget and will have to "purchase" materials from your teacher to create your design. You may return materials, exchange materials with other teams, but will need to determine the "cost" of your windmill – the least expensive design that meets the challenge will be considered the most efficient design! Your windmill may be vertical (pointing upward from a table) or horizontal (pointing off the edge of a table).



◆ **Planning Stage**

Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your windmill. You'll need to determine what materials you want to use -- keep in mind that your design must be strong enough to withstand wind from a fan or hairdryer and the base cannot move so it will have to be secured to a table or shelf. Consider the shape of your planned blades....what will work best? 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 and Budget:

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Student Worksheet (continued):

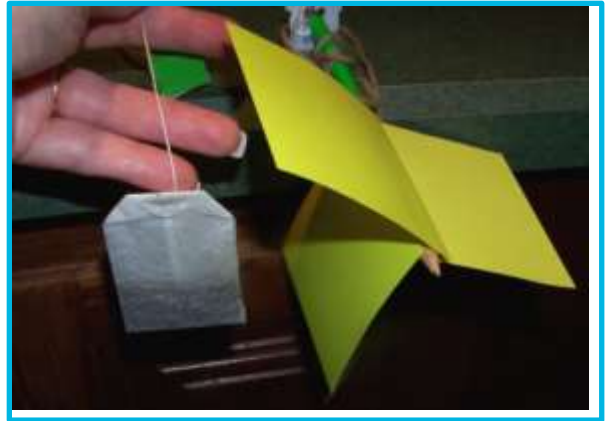
◆ Construction Phase

Build your windmill. 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 and budget.

◆ Testing Phase

Each team will test their windmill using a classroom fan or hairdryer -- each windmill will be tested using the same wind speed -- medium -- at a distance of three feet (one meter). You'll need to make sure your windmill can operate for

a minute at this speed while winding a light object up with a string. 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 Wind Energy" lesson:

1. Did you succeed in creating a windmill that operated for a minute that could lift an object? 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?
4. If you could have had access to materials that were different than those provided, what would your team have requested? Why?

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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

- ◆ 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

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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-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.
- ◆ 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)

Energy

Students who demonstrate understanding can:

- ◆ MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

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.

Engineering Design

Students who demonstrate understanding can:

- ◆ HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

◆ 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.

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For Teachers:***Alignment to Curriculum Frameworks*****◆Standards for Technological Literacy - All Ages****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.