5E's Lesson Plan: How does a Windmill Work?

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Grades: 9-12
Eleva-Strum Central

Central Concept: Renewable Energy

Concept(s): Students will learn the basic parts of a windmill, how different blade designs affect output, and how energy is transferred from wind into useable mechanical energy. A basic understanding of how windmills works will be used to develop an understanding of how the modern wind turbines work. This lesson will give students the opportunity to explore how energy is captured by the wind and converted into useable energy, in this case into work to lift masses. Students will use the engineering design process and scientific method to design, build, test and improve their models.

Wisconsin Science Standards
C.12.3 Evaluate the data collected during an investigation, critique the data-collection procedures and results, and suggest ways to make any needed improvements

D.12.7 Qualitatively and quantitatively analyze changes in the motion of objects and the forces that act on them and represent analytical data both algebraically and graphically.

Classroom Management Goals/Skills
- Use attention-getting strategies
- Utilizes technology to enhance implementation

Instructional Objectives
Students will
- Know the fundamental parts of a windmill/wind turbine
  - Identify key parts of a windmill or wind turbine
- Be able to use the scientific method to isolate and adjust variables in a model windmill
  - Identify variables in the experiment
  - Identify how the independent variable affected the dependent variable
- Understand energy conversions/transfers and how a windmill follows the law of conservation of energy
  - Define the law of conservation of energy
  - Identify conversions
  - Calculate potential energy of system
- Understand the conversion of wind energy to mechanical energy
  - Define mechanical energy
  - Answer how is wind energy converted to mechanical energy

Vocabulary:
Blade Pitch: Angle of the blades with respect to the plane of rotation.

Drag: friction of the blades against air molecules as they rotate (air resistance).
Drive shaft: rod connected to the hub
Energy: the ability to cause change
Energy transformation: the conversion of energy from one form to another
Friction: a force that resists the relative motion of two bodies in contact
Hub: central piece that connects the blades to the drive shaft
Kinetic energy: energy of a moving object
Mechanical energy: Sum of the energy in a system (Kinetic energy plus potential energy)
Power: The rate at which work is done
Windmill: uses wind to do work such as lift water, grind grain
Wind turbine: uses wind to spin blades to turn a generator to capture electricity
Work: the amount of energy over a distance by a force (must be in the same direction)
Torque: a force that causes rotation around an axis.

Safety: Make sure students are behind and not to the side of wind turbines while they are being tested. Make sure students do not stick anything into the box fans or electric outlets. Remind students that projectiles are not allowed.

ENGAGE:

Previously: Students have been studying energy.

Today (2-3 periods): Students will explore blade design as a means of collecting energy from the wind. Students will apply the scientific method to create the blades best designed for lifting weight. First students will focus on developing a hypothesis around a testable variable (number, length, material, etc). Then students will develop a prototype to make sure they can get the hub to spin. Students will then make adjustments to the blades and test to get their design to lift a cup of weights and therefore create a model windmill. (Not a wind turbine because it is being used to do work)

Relation to future learning: This lesson will be used as a transition into renewable energy and future concerns of energy usage. Students will also use the blades designed today to test for wattage. This data will be used to determine if their designs would create enough power to recharge their devices. The same blades will also be used outside (weather permitting) to gather information about wind around the school grounds.

Catch students' interest and connect: Ask students: what is a windmill? How is a windmill different from a wind turbine? Have you seen a windmill? Have you seen a wind turbine? Show students pictures of windmills and wind turbines. Discuss previous experiences with each.

Compelling why: How can wind do work for you?
(Specific to our district: How can wind power your device?)

EXPLORE:

Students will be given a set of blade materials. Students may work individually or with one other person. Students should think about the pictures they saw, the similarities and differences. Students should share ideas of variables they will want to consider: friction, pitch, size, number, how to attach blades to dowel, etc. From this discussion, students should make a blueprint of the design they think will work the best (lift the most weight). Students should then decide what variable they would like to explore (number, length, weight, pitch, width). Students should develop a hypothesis to test.

Students will be given points for a detailed blueprint and testable hypothesis

Students should make a set of practice blades. Students will attach these to the hub and stand in front of the fan. Students may need to problem solve to make sure the blades spin. Friction needs to be overcome for rotation to occur. (If blades do not spin: make sure all blades are pitched/angled the same direction. Try changing the angle of the pitch.) At this point, students are not testing to lift weight, just to modify blade design and set-up.

Students will be assessed by getting something to spin in the wind.

Students will then modify blade design and test to for the maximum amount of lift. Attach the blades to the wind tower/ fan set-up. Add weights (washers) one at a time into the cup until the blades can lift no more. (Fan speed and distance from the fan will be constant) Students should record data. Students will be encouraged to conduct a trial, measure results, make modifications, test again (utilize scientific method) until they are satisfied with their project in the allocated time.

Students will be assessed by how well they document their results and changes. Students will be assessed by how they preform in the weightlifting challenge.

Students will be assessed on potential energy calculations accuracy.

EXPLAIN

Reassemble the class. Give each group an opportunity to share their results. Students should explain how they modified their original design and the weight they were able to lift. (If time allows, run a competition in class to see who has the most success) Explain why different designs worked better.

Show students Popular Mechanics "10 Wind Turbines that Push the Limits of Design." Share how different designs can work. http://www.popularmechanics.com/science/energy/solar-wind/4324331

Students will have to show basic knowledge through correct use of vocabulary.

Students will have to answer questions about their models:

- *Which variable did you choose for the independent variable?*
- *How was the dependent variable affected?*
- *Of the top performing group: How did they modify their blade to be successful?*
- *How did you reduce friction in your windmill?*

How was energy transferred as the windmill spun?
How were you able to maximize your blades turning force?

ELABORATION

Set up two or three student models. Use these models to explain the energy transfers. Use the models to emphasize energy loss during each transfer. Point out the parts of the windmill (blades, rotor, hub, drive shaft).

Using the models. Calculate the potential energy created by each set-up. Energy, measured in Joules, is equal to mass, measured in kilograms, times the acceleration due to gravity (9.81 m/s^2) times the height the cup is lifted, measured in meters. This is also work because the mass times acceleration due to gravity gives us weight or a force and the height is a distance.

Using the student models, time how long it takes to lift each cup of masses to the determined height. Using this time, calculate the power of the lift. Power, measured in Watts, equals energy, measured in joules, divided by time in seconds.

EVALUATION

Students will answer a short assessment. If possible, completed on Edmodo or Socrative.

REFLECTION

Students were actively engaged throughout the lesson. Students who are low achieving in other areas found great success.

RESOURCES

KIDWIND PROJECT – http://learn.kidwind.org/teach

KIDWIND POWERPOINT: Wind turbine blade design – http://learn.kidwind.org/teach

Popular Mechanics - http://www.popularmechanics.com/science/energy/solar-wind/4324331

Student Handout "How Does A Windmill Work?"

Name ________________________________
Partner _______________________________
Date __________________________________
Class Period ___________________________

1. List possible variables that could be tested and how they could be altered.

2. Selected variable from the above list is __________________________. It will be changed by ___________________________________.

3. Our hypothesis is:

4. Our initial blade design (attach other paper if needed).

5. The results of our initial design are:

6. Here are our modifications and results

7. Explain which blade design was the most successful. Explain why you think this design worked the best.

8. The energy produced by our turbine was ______________________________
   Show work here!

9. The power produced by our turbine was ______________________________
   Show work here!

Assessment Questions:

Give the best answer to each of the following questions. Make sure to answer all parts of the question.

1. Draw a model of your windmill. Label the blades, driveshaft, hub, and rotation.

2. Explain how a windmill is different from a wind turbine.

3. Complete the following problem: If a windmill lifts 5 washers each with a mass of .005kg a distance of 0.6m, how much work is done?

4. Explain why windmills have so many blades and most wind turbines have three.