BLOWIN' IN THE WIND (2 Hours)

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In this activity, students will create their own windmills and test them against the models made by their classmates.

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- An exploration of how to use the design process.
- An exploration of the factors that affect windmill efficiency.

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Students will gain an understanding of the engineering design process by designing efficient windmills.

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aluminum pie tins
corrugated cardboard
2 pencils with erasers
2 straight pins
coffee stirrer
tape
glue
toothpicks

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stop watch
pencil
one toothpick
foam block (approximately 15 cm x 15 cm x 5 cm)
electric fan

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toy pinwheel

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8. Students will develop abilities to apply the design process. C. The design process is a purposeful method of planning practical solutions to problems.

STEPS FOR *BLOWIN' IN THE WIND*

1. **b l}x8¡{+Ln t¢t ¥E** Open the class by showing them a pinwheel. Then, show them the adjacent picture of a large **£tyo+ ¡}mtyp**. Discuss the similarities and differences between the two structures, including what they are used for. Ask students how they think these structures were designed. Guide the students by asking them how they would design a product. Would they just build a full scale version first or would they build a small model to test out the design? How would they know what kinds of materials are best? Do they think the wind speed will affect the performance of the wind turbine? Tell them that engineers ask questions like this during the design process. During this activity, they will use the design process to create a windmill.

This wind turbine is used to supply electricity. It was designed by engineers who used a design process to come up with a solution to the problem of how to use the wind to generate electricity.

2. Distribute the *Blowin' in the Wind* handout and materials to each group of 2–4 students.

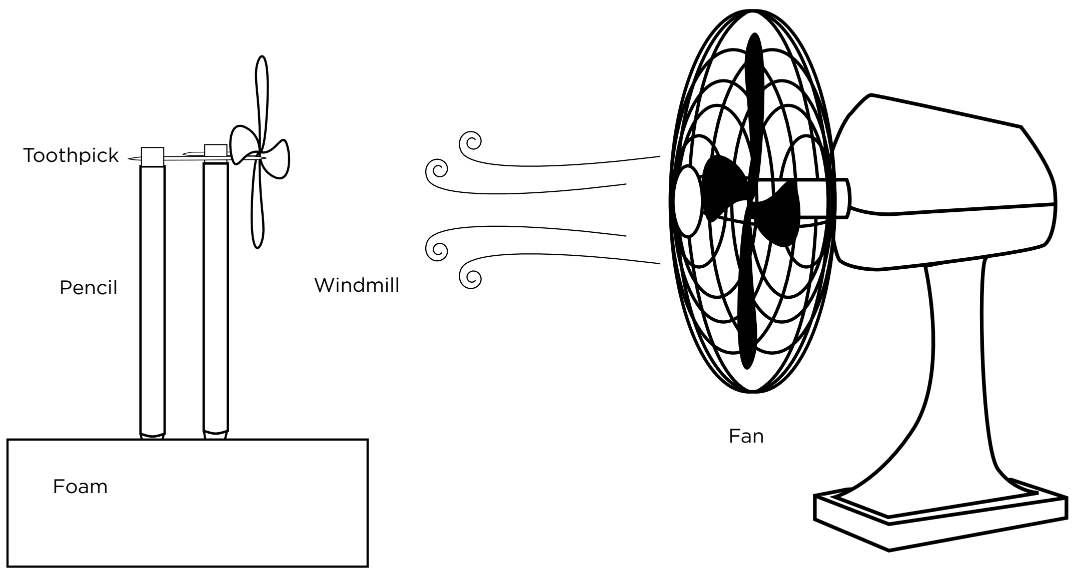
3. This activity is largely student-directed. Tell the students that the goal of the project is to build a windmill that is more efficient than any of their classmates' windmills. Efficiency will be measured by the speed at which the windmill blades turn: the faster they turn, the more efficient the windmill. The handout includes a description of how to build the base of the windmill. Tell the students that the rest is up to them.

4. Before students begin their design process it is important to discuss fan blade design. Ask them about the different attributes that a blade design could have. They should think of width and length, as well as curvature, and material. They could also think of the number of blades. Discuss how each of these might affect the efficiency of the windmill. For example, if the blades are too large the windmill might be too heavy to be turned by the wind. If they are too small then they might not pick up enough passing wind. Tell them to look at the pinwheel and the picture of the wind turbine again. The students should notice that in both cases the blades tilt backwards somewhat. This is one design principle that they should try to work into their design.

5. The students are given a basic setup, shown below, for the base of the windmill. This consists of a pencil, a piece of a coffee stirrer, and a straight pin. The students will also receive aluminum pie tins and corrugated cardboard to build the blades of the windmill. Students may use toothpicks to create support for the blades. Students should make a sketch of their final design on the handout. Before they begin, have them answer the questions in the handout, which will help guide them in their design.

6. If students are having trouble attaching the blades to the stirrer then suggest that they create a blade that has a tab on the bottom. This small tab can be taped to the stirrer without interfering with the flow of the air through the blades.

7. Set up the testing mechanism in front of a fan. Assemble the clicking mechanism by sticking a toothpick into the eraser end of a pencil. After you have done that, push the pencil into the foam block. The windmill to be tested should also be pushed into the foam so that it does not wobble when the fan is turned on. When testing the windmills, make sure that the blades are barely able to touch the toothpick. Otherwise, it may substantially slow down an otherwise good design. The diagram below shows how the setup should look. When the fan is turned on, the blades of the windmill should turn. As each blade hits the toothpick, it should make a faint clicking sound.



8. Have each group test its windmill individually. The students on each team should take the following roles: timer, visual counter, click counter, and recorder. The timer will use a stopwatch to count out 10 seconds. The click counter will count how many click sounds occur during the 10-second trial. The visual counter will confirm the number of revolutions by visually counting how many revolutions occur. To help the visual counter out, you may want to suggest that one of the windmill blades be shaded a different color with a marker. If there is a discrepancy between the results from the two counters, help the students to average them together. Teams should conduct three 10-second trials. Students should record the results of each trial on the handout. You should record each set of trials for all teams on the board. Help the class calculate the average number of revolutions for each team's windmill, and record those averages on the board. Have the class identify the winning design (the design that produced the largest average number of revolutions in 10 seconds).

9. Students should regroup and conduct a second round of designing and building. Students will have seen the winning design from the first part of the competition, but this is OK. In the real world, engineers often use existing designs for inspiration. Remind them that since the winning team will also be improving its design, it does not make sense to simply copy the winning design from the previous round. Have the students keep their original windmill as a reference. This means that they should build a new shaft for the windmill. Students may need additional materials for the blades. Have the students sketch the final design of the second round of construction on the handout.

10. Once all teams have completed their revised designs, repeat the contest. Have the class again identify the winning design. If possible, use a digital camera to take photographs of the winning designs.

11. **b}l{8¡{+Ln t¢t ¥**: Review the results of the two contests with the students. Present the winning designs. Ask the class to analyze them for similarities and differences. How many blades did the winning design have in each round? What material was used? Were the blades wide or narrow? Was the second-place team's design close to that of the first-place team? Draw a Venn diagram on the board to summarize the differences between the first- and second-place windmills. Ask the students to describe how they decided what to change in their second design.

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One major problem with the large scale use of wind turbines is that the wind doesn't always blow in the same direction. For an extension activity, students can design a windmill that best captures wind coming from all directions. They should use a procedure similar to that used in the main activity. However, when students test their designs, they should move the fan several times so that the wind comes from four different directions. The best solution usually involves putting a wind vane on the back of the fan and loosening it from the base so that it can spin.

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In this activity we simplify the production of wind power by taking out the components of a modern windmill that would generate electricity. In a real wind turbine, the force of moving wind pushes the blades of the turbine. The moving blades cause a rotor to turn. This rotor, in turn, powers an electric generator, which converts mechanical energy into electrical energy.

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Wind turbines are most commonly used in three types of places: on the coastline, on hilltops, and in open plains areas. All three areas are similar in that they have relatively few obstructions blocking the wind. For wind power to be economically viable, the average wind needs to exceed 8–10 m/s. Denmark, which is a small coastal nation, receives much of its power from wind turbines. The United States has ample supplies of coastline, mountain tops, and high plains. However, many of the non-coastal areas are far from the people who would need to use the electricity. To use this electricity would require the building of expensive long-distance power lines.

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Modern wind turbines generally look very different from the small handheld pinwheels one might get at a parade, or even the older windmills that were made famous in Holland. Those windmills generally have four or more large blades. Modern wind turbines can have as few as one blade, although most have two or three narrow blades.

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Fossil fuels and other forms of combustible fuels have been used for most of human history to provide energy for heat, and more recently to generate electricity. In the past 150 years, the burning of fossil fuels has increased the amount of carbon dioxide in the atmosphere, which most scientists agree is causing Earth's surface temperature to increase. Therefore, methods of generating electricity that generate no carbon dioxide are in increasing demand. Because windmills rely only on wind to function, they produce no air pollution or carbon dioxide. Recent advances in design and materials have allowed engineers to create wind turbines that can generate electricity at a cost that is competitive with burning fossil fuels.

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b tyo+ ¡}mtyp: a machine that converts wind energy into electrical energy

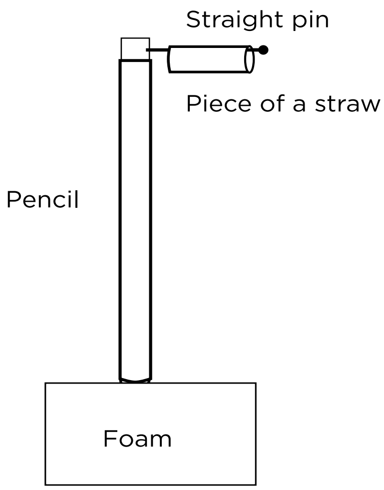
Op~tr y+{}znp~~: a series of steps that engineers use to design product

TEACHER HANDOUT
BLOWIN' IN THE WIND

Ylxp ______________________ **Ol p** ______________

Follow the directions below to build a base for your windmill.

1. Cut a coffee stirrer about 0.5 centimeters shorter than the length of the straight pin.
2. Place the pin through the hole in the piece of stirrer and push the pin into the pencil eraser. The pin should be mostly inside the coffee stirrer, and the stirrer should be able to spin freely around the pin.
3. Attach aluminum or cardboard blades to the stirrer using tape or glue.



What kind of limitations did you have on your design?

[I only had certain materials available. It also had to be able to stand up to the wind caused by the fan.]

How did you decide which design to use?

[I remembered the picture of the windmill that the teacher showed us at the beginning of class, and used a similar design.]

Sketch your original design below.

How did you change this design after the first test?

[The blades on the first one were not large enough to capture the wind and spin the wheel quickly, so we made the blades larger.]

Sketch your second design below.

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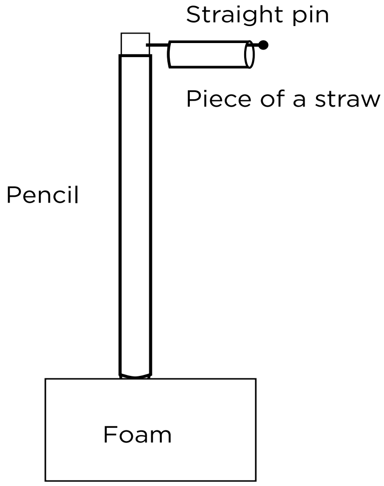

What kind of limitations did you have on your design?

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How did you change this design after the first test?

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