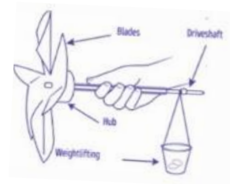
Mini Windmill Challenge (Grades 3-5)

Description: Students will use simple materials to build their own Mini Windmills. They will learn how wind can spin blades, how pitch angle affects motion, and how rotational energy can be transferred to lift weights. Through testing and redesign, students will explore the engineering design process and apply science concepts of energy transfer.



Grade Level: 3–5

Objectives:
By the end of this lesson, students will be able to:

- Identify the fundamental parts of a windmill (blades, hub, drive shaft, drivetrain).
- Describe how wind energy can be converted into mechanical energy.
- Apply the scientific method to test and adjust variables (blade pitch, blade number, materials).
- Construct a functioning windmill that spins and lifts weight.
- Explain how changes in blade design affect performance.

Next Generation Science Standards (NGSS)
Disciplinary Core Ideas

- 3-PS2.A: Forces and Motion
- 3-PS2.B: Types of Interactions
- 4-PS3.A: Definitions of Energy
- 4-PS3.B: Conservation of Energy and Energy Transfer
- 4-PS3.C: Relationship Between Energy and Force
- 5-PS3.D: Energy in Everyday Life
- 3-5-ETS1.A: Defining and Delimiting Engineering Problems

Crosscutting Concepts

- Patterns
- Cause and Effect
- Energy and Matter

Science and Engineering Practices

- Planning and Carrying Out Investigations
- Constructing Explanations
- Analyzing and Interpreting Data
- Asking Questions and Defining Problems

Time Required: 45–60 minutes

Teacher Preparation (30 minutes):

- Build one Mini Windmill yourself before class.
- Prepare "kits" for each group.
- Pre-punch holes in cups and pre-cut string.

ENERGY EDUCATION RESOURCE from the Kansas Corporation Commission and K-State Engineering Extension. Made possible by a grant from the U.S. Department of Energy. Document last revised 9/9/2025.

- Set up fans around the room for testing stations.

Materials: Each group will need:

- Paper plate
- Foam cylinder (hub)
- Skewer (drive shaft)
- Straw (bearing)
- Duct tape
- String (2 feet)
- Paper cup (pre-punched with 2 holes)
- Washer (weight)
- **Classroom shared materials**:
    - Rulers
    - Scissors
    - Pencils
    - Box fan (20”x20”)
    - Alternative blade materials (cardstock, cardboard, paper cups, etc.)

Differentiation & Modifications:

For Younger or Struggling Learners:

- Pre-cut and pre-fold plates to simplify construction.
- Provide step-by-step visuals or illustrated guides.
- Pair students with supportive peers for collaborative building.
- Use larger, sturdier materials (thicker straws, skewers) for easier handling.

For Advanced Learners / Extensions:

- Challenge students to test multiple blade materials (cardstock, cardboard, cups).
- Ask students to measure how high or how fast their windmill lifts the cup.
- Graph results (washers lifted vs. blade pitch).
- Explore powering another task (e.g., spinning an LED).

For Limited Time / Space:

- Pre-assemble parts of the windmill to save time.
- Use rotations at fan stations to manage space.
- Limit weight tests to one or two washers if time is short.

Alternative Setups:

- If box fans aren’t available, use handheld fans, hair dryers on cool, or natural outdoor wind.
- Adapt testing area by marking safe zones and spacing groups apart.

Lesson Procedure

Step 1 – Engage (10 minutes)

- Class Discussion

- Ask prompting questions:
  - Have you seen something spin in the wind?
  - How do windmills work?
  - Can wind do work?
- Demonstrate with the "hand out the car window" example to show how tilt angle affects movement.
  - *What if we move our hand flat, like it is cutting through the wind?*
  - *What happens if we tilt our hand, thumb pointing upward?*
  - *What happens if we tilt our hand thumb pointing downward?*
  - *Now our hand is out, fingers together, like we are making a wall. What happens to our hand?*
    - *Link to PowerPoint with pictures*

Step 2 – Explore (10 minutes)

- Show your completed Mini Windmill model.
- Demonstrate how blades spin and lift a cup with washers.
- Highlight the importance of blade pitch (tilt angle).

Step 3 – Build (20 minutes)

- Guide students through step-by-step building of the windmill:
  1. **Fold Plate** – Fold in half, then the other way, to make 4 equal sections and find the center.
  2. **Attach Hub** – Place tape roll on the center (back side). Stick foam cylinder on the tape.
  3. **Secure Skewer** – Turn over the plate and skewer the plate to the foam cylinder. If plate is not secure, add tape to the skewer to secure it in place.
  4. **Build Drive train** – Slide straw over skewer. Hold onto straw and spin plate — it should turn freely.
  5. **Attach String** – Tie one end to skewer and secure. Tie the other end to paper cup.
  6. **Make Blades** – Cut along fold lines, on plate, almost to the center.
  7. **Bend Blades** – Angle blades so they catch the wind.

Step 4 – Test & Redesign (15 minutes)

- Students test windmills in front of a fan at a marked distance.
- Record how many washers are lifted.
- Encourage redesign and multiple test cycles (at least 3).
  - *Ask:* What changes helped your windmill spin better or lift more?

Step 5 – Reflect & Share (10 minutes)

- Discuss results.
- Ask:
  - Who got their windmill to spin?
  - Who lifted one washer? Two? Three or more?
  - What design changes worked best?
- Celebrate creativity and problem-solving.

Background Information

Wind is a form of **kinetic energy** (the energy of moving air). A wind turbine captures that kinetic energy with its **blades**, which are angled (pitched) to catch the wind. When air pushes on the blades, it creates **rotational motion**. This motion is transferred through a **shaft** inside the turbine to perform useful work, such as generating electricity or lifting weight.
The design of the blades is critical. If blades are flat, they may just block air without spinning. By tilting them at an angle, the wind flows unevenly across the surfaces, creating a force that turns the blades. This is similar to how airplane wings generate lift.

In real wind turbines:

- **Blades** are usually made of strong, lightweight materials like fiberglass or carbon fiber.
- The **hub** connects the blades to the **main shaft**.
- The **shaft** transfers energy to a generator, which converts the motion into **electrical energy**.
- The amount of power a turbine generates depends on blade size, pitch angle, wind speed, and air density.

For students, the mini windmill demonstrates these same principles in a hands-on way:

- The **blades** are made from a folded paper plate.
- The **shaft** is represented by a wooden skewer.
- The **hub** is made from foam.
- Instead of producing electricity, the model turbine lifts a small cup with washers to show that wind energy can be converted into useful work.

This activity connects to real-world renewable energy discussions. Wind energy is one of the fastest-growing sources of electricity in the U.S. and Kansas ranks among the top states for installed wind capacity. Wind power reduces dependence on fossil fuels and lowers greenhouse gas emissions.

Works Cited

- U.S. Department of Energy. (n.d.). *How do wind turbines work?* Office of Energy Efficiency & Renewable Energy. https://www.energy.gov/eere/wind/how-do-wind-turbines-work
- U.S. Department of Energy. (n.d.). *How a wind turbine works (text version).* Office of Energy Efficiency & Renewable Energy. https://www.energy.gov/eere/wind/how-wind-turbine-works-text-version
- Savree. (n.d.). *Wind turbines explained.* https://savree.com/en/encyclopedia/wind-turbines-explained
- U.S. Energy Information Administration. (2023). *Kansas state profile and energy estimates.* https://www.eia.gov/state/?sid=KS
- U.S. Energy Information Administration. (2023). *Kansas: State energy analysis.* https://www.eia.gov/state/analysis.php?sid=KS
- Wikipedia contributors. (2022, December). *Wind power in Kansas.* In *Wikipedia*. https://en.wikipedia.org/wiki/Wind_power_in_Kansas

- Wikipedia contributors. (2021, October). *Cimarron Bend Wind Farm.* In *Wikipedia*. https://en.wikipedia.org/wiki/Cimarron_Bend_Wind_Farm
- Maguire, K. (2024, October 31). *Key U.S. wind power trends and metrics to track.* Reuters. https://www.reuters.com/business/energy/key-us-wind-power-trends-metrics-track-maguire-2024-10-31

Vocabulary

- **Blade pitch** – tilt or angle of the blades.
- **Drive shaft** – axle that transfers motion (skewer).
- **Bearing** – allows axle to spin with less friction (straw).
- **Hub** – central part connecting blades to the shaft.
- **Rotor** – spinning section made of hub + blades.
- **Force** – a push or pull.
- **Friction** – resistance that slows motion.

Assessment

- Informal observation during testing/redesign.
- Student explanations during reflection.
- Success criteria: Windmill spins and lifts at least one washer.

Extension Ideas

- Experiment with different blade materials or shapes.
- Measure how far/fast the cup lifts.
- Relate to real-world wind turbines and renewable energy.

Additional Resources: KidWind Activities

Teacher Key

Part 1: Predict- (*Answers will vary.*)

- Students should predict that the windmill will spin in front of the fan and lift the cup.
- Most will guess 1–2 washers, though some may predict more.

Part 2: Build

- Students' drawings should include these labeled parts:
    - **Blades** (folded paper plate sections)
    - **Hub** (foam cylinder)
    - **Drive Shaft** (skewer)
    - **String** (attached to shaft and cup)
    - **Cup** (holds washers/weight)

Part 3: Test

Example Data Table (*answers will vary by group*):

Trial	Did it spin?	How many washers lifted?	What did you change?
1	Yes	1	Adjusted blade tilt
2	Yes	2	Folded blades more steeply
3	Yes	3	Tried new material (cardstock)

Key expectation: *Students should see improvement after adjusting blade pitch or number of blades.*

Part 4: Reflect

1. Did your windmill spin? → Expected answer: Yes.
2. Did it lift weight? → Yes, at least 1 washer.
3. What design changes helped? → Adjusting pitch angle, folding blades more, or using sturdier material.
4. Why does tilt (pitch) matter? → The angle allows blades to catch moving air instead of blocking it, creating rotational movement.

Vocabulary (Answer Key)

1. **Blade Pitch** → A. The tilt or angle of the blades.
2. **Drive Shaft** → B. The stick (skewer) that makes the cup go up and down.
3. **Bearing** → E. The straw that helps the skewer spin smoothly.
4. **Hub** → C. The part in the middle that connects blades to the shaft.
5. **Force** → D. A push or pull.

Correct order: **1–A, 2–B, 3–E, 4–C, 5–D**

Part 5: Connection to the Real World

Expected student answers:

- Real wind turbines use blades and hubs like our model, but they generate electricity instead of lifting weight.
- Wind power is renewable, clean, and reduces pollution from fossil fuels.

ENERGY EDUCATION RESOURCE from the Kansas Corporation Commission and K-State Engineering Extension. Made possible by a grant from the U.S. Department of Energy. Document last revised 9/9/2025.