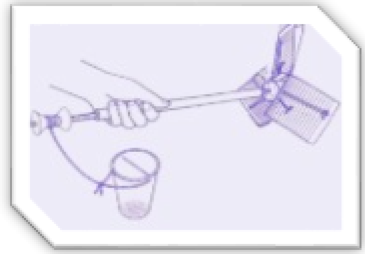
MacGyver Windmills



Description:

In this hands-on engineering challenge, students become "MacGyver engineers" as they design and build their own working windmills from everyday classroom materials. Using the power of wind from a fan, students will explore how blade design, shape, size, and angle affect a windmill's ability to do work, such as lifting a weight. Through building, testing, and redesigning, students learn how wind energy is converted into mechanical energy while practicing problem-solving and the engineering design process. This activity connects science concepts of forces, motion, and energy transfer to real-world renewable energy solutions.

Grade Level: 6th–8th grade (Middle School)

Learning Objectives:

Students will:

1. Design and build a simple windmill using everyday materials.
2. Demonstrate how wind energy can be converted into mechanical energy.
3. Apply the engineering design process: define, design, build, test, improve.
4. Analyze how changing design variables (blade shape, number, angle, material) affects performance.

Record and evaluate experimental data to support design decisions.

Next Generation Science Standards (NGSS):

- **MS-PS2-2**: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces.
- **MS-PS3-5**: Construct, use, and present arguments that when the kinetic energy of an object changes, energy is transferred to or from the object.
- **MS-ETS1-2**: Evaluate competing design solutions using a systematic process.
- **MS-ETS1-3**: Analyze data from tests to determine similarities and differences among design solutions.

Disciplinary Core Ideas (DCIs)

- **PS3.A: Definitions of Energy** – Motion energy is associated with the mass and speed of an object.
- **PS3.B: Conservation of Energy and Energy Transfer** – When the motion energy of an object changes, energy is transferred to or from the object.
- **ETS1.A: Defining and Delimiting Engineering Problems** – The more precisely a design task's criteria and constraints are defined, the more likely the solution will be successful.
- **ETS1.B: Developing Possible Solutions** – A solution needs to be tested and then modified on the basis of the test results.
- **ETS1.C: Optimizing the Design Solution** – Although one design may not perform the best across all tests, identifying the characteristics that improve efficiency is key to optimizing.

Science and Engineering Practices (SEPs)

- **Planning and Carrying Out Investigations** – Students design and test windmills, adjusting variables such as blade shape, size, or number.
- **Analyzing and Interpreting Data** – Students collect and compare performance data from multiple designs.
- **Constructing Explanations and Designing Solutions** – Students explain why some designs performed better and redesign to improve performance.
- **Engaging in Argument from Evidence** – Students support claims about which design works best using test results.

Crosscutting Concepts (CCCs)

- **Cause and Effect** – Changing a design variable (cause) affects the performance of the windmill (effect).
- **Energy and Matter** – Wind energy is transferred into mechanical energy to lift weight.

- **Structure and Function** – Blade design (structure) determines how effectively the windmill captures wind energy (function).
- **Systems and System Models** – The windmill is a system made of interacting parts (blades, hub, shaft, load) that work together to capture and use energy.

Time Length: 60–75 minutes (can extend over 2 class periods if needed)

Prep:

- **Make an example**
  - Use for visual for classroom or use so you are aware of issues your student might have as they approach this challenge

Safety Considerations:

- Use scissors and pins with care.
- Keep hair, jewelry, and fingers away from fan blades.
- Supervise use of small objects to prevent choking hazards.

Materials:

For each group (2–3 students):

- **Blades Options**
  - Index cards
  - Paper
  - Paper plates
  - Scrap cardboard
  - Cardstock
  - Plastic pieces
- **Hub Options**
  - Foam cylinder
  - cork
  - pool noodles cut in ¼ pieces
  - spools
- **Shaft**
  - Skewer
  - Dowel
  - Cardboard tube
  - Plastic straws *(best option-10 mm diameter and 8 1/2″ height)*
- **Lifting Mechanism Options**
  - Small cup
  - Small bucket
  - Washers
  - Pennies
  - Gram weights
  - String
- **Attachments**
  - T-pins or push pins
  - Paper clips
  - Rubber bands
  - Tape
- **Shared materials:**
  - Box fan (20″ × 20″ recommended) bigger classes you may want more than one fan.
  - Rulers or measuring tape
  - Scissors

- Pencils
- Marker

Modifications:

- **Support for struggling learners:**
  - Provide a pre-made template for a basic windmill.
  - Allow focus on testing rather than building complexity.
- **Extension for advanced learners:**
  - Have students test quantitative variables (example: time to lift 50 g weight).
  - Challenge: Can your windmill generate enough torque to lift a larger load?

Safety Considerations:

- Use scissors and pins with care.
- Keep hair, jewelry, and fingers away from fan blades.
- Supervise use of small objects to prevent choking hazards.

Procedure:

1. Engage (5–10 minutes)

- Ask students: *What are some ways humans have used wind energy in the past? How do wind turbines work today?*
- Show pictures/videos of windmills and turbines.
- Introduce challenge:
  - *"You are engineers! Build a windmill that lifts the most weight using only the materials provided."*

2. Explore – Build Phase (15–20 minutes)

- Students sketch and plan their design.
- Build first version of windmill using index cards, hub, shaft, and lifting mechanism.

3. Test Phase (10 minutes)

- Place windmill in front of a fan.
- Use string and cup to test lifting ability (weight lifted, or how high it goes in a set time)
- Record data.

4. Improve – Redesign (15 minutes)

- Students modify **one variable** (blade number, angle, material, etc.).
- Re-test, compare results, record new data.

5. Explain & Share (10–15 minutes)

- Groups present their designs, data, and improvements.
- Class discusses:
- *Which designs worked best? Why? What scientific principles explain the results?*

Teacher Notes

- **Shaft & Bearing**: Use a straw as a sleeve for the shaft (skewer/dowel). This allows the shaft to spin freely and keeps hands out of the way.
- **Blades**:
  - Fold or curve index cards to help them catch more wind.
  - Encourage testing different shapes (rectangles, triangles, curves).
  - Remind students to space blades evenly for balance.
- **Hub**: Foam cylinders, corks, or bottle caps work well. Use tape or T-pins to attach blades securely.
- **String & Load Cup**: Tie string around the shaft so the blades wind it up to lift the cup. Keep the string straight for smooth lifting.

- **Fan Testing**: Keep the fan at the same distance for each group. Remind students to keep fingers, hair, and paper away from the fan blades.
- **Choose Consistent Ability Test**: Decide ahead of time whether students will test **weight lifted** or **height lifted** so that all groups measure performance in the same way.
- **Set Consistent Starting Points**: If lifting weight, decide how high it must be lifted off the ground. If lifting height, decide the starting point for the cup/string. This keeps results fair and comparable across the class.
- **Troubleshooting**:
    - If it won't spin → check for friction (shaft rubbing against tape or cardboard).
    - If it spins but won't lift → reduce weight or adjust blade number.
    - If it spins slowly → test steeper blade angles or lighter materials.
- **Encourage Iteration**: Remind students to change *one variable at a time* (blade shape, number, or angle) so they can compare results fairly.

Real-World Connection:

- Modern turbines use the same principles, but with optimized blade design and materials.
- Wind energy provides clean, renewable electricity—important for sustainability and reducing fossil fuel dependence.

Assessment

- **Formative:** Teacher circulates, asks guiding questions, checks data tables.
- **Summative:**
    - Students complete a lab sheet with:
        - Sketch of final windmill design
        - Data table (trial 1 vs. trial 2)
        - Short written reflection: *Which design was most effective and why?*

Background Information:

Wind turbines capture the kinetic energy of moving air and convert it into mechanical or electrical energy. In early history, windmills were used for grinding grain or pumping water. Today, turbines convert wind into electricity. Blade design (shape, size, angle, material) plays a major role in performance. Students will experience these principles hands-on through testing and redesign.

- KidWind. *MacGyver Windmills Activity.* KidWind Project, 2025, https://kidwind.org/activity/macgyver-windmills/.
- U.S. Department of Energy. *How Do Wind Turbines Work?* Office of Energy Efficiency & Renewable Energy, 2023, https://www.energy.gov/eere/wind/how-do-wind-turbines-work.
- National Geographic Society. "Wind Power." *National Geographic Resource Library*, 20 July 2022, https://education.nationalgeographic.org/resource/wind-power/

Vocabulary / Key Concepts:

- **Blade** — Surface that captures the force of the wind
- **Hub** — Center where blades connect
- **Shaft** — Rotating rod transferring energy
- **Mechanical Energy** — Motion energy of parts doing work
- **Variable** — A factor that can change in an experiment (e.g., blade angle)
- **Optimization** — Improving a design to maximize efficiency