Firefly Wind Wheel-Blade Pitch Investigation Lesson Plan (Grades 3-5)

Objective: Build a small "firefly" using a generator, LED light, and simple craft materials to learn how wind turbines convert moving air into electrical energy.

Time: 65–70 minutes or two shorter sessions (build one day, test/write next).

Grades: 3-5

NGSS Performance Expectations (PEs)

- **3-PS2-4:** Define a simple design problem that can be solved by applying scientific ideas about magnets. *(related: generator inside Firefly uses magnets + motion)*
- **4-PS3-4:** Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
- **4-ESS3-1:** Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
- **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.

Disciplinary Core Ideas (DCIs)

- **PS3.B: Conservation of Energy and Energy Transfer** – Energy can be transferred from place to place by sound, light, heat, and electric currents.
- **PS3.C: Relationship Between Energy and Forces** – When objects collide or interact, energy can be transferred and cause motion.
- **ETS1.A: Defining and Delimiting Engineering Problems** – Possible solutions must be compared to see which best solves the problem under given constraints.

Crosscutting Concepts (CCCs)

- **Cause and Effect** – Tilting blades (cause) changes the brightness of the LED (effect).
- **Energy and Matter** – Energy is transferred from moving air → spinning blades → generator → LED light.
- **Systems and System Models** – The Firefly is a system with parts that interact (blades, shaft, generator, LED).

Science & Engineering Practices (SEPs)

- **Planning and Carrying Out Investigations** – Testing blade tilt angles to see how the LED responds.
- **Analyzing and Interpreting Data** – Recording when the LED lights and its brightness.
- **Constructing Explanations and Designing Solutions** – Explaining why tilt matters and designing a "best" angle.

- **Engaging in Argument from Evidence** – Using data to support which blade tilt worked best.

Overview:

The Firefly Wind Wheel activity introduces students to the concepts of wind energy, mechanical energy, and electrical energy. Students build a small wind turbine that captures kinetic energy from moving air, converts it into mechanical rotation, and then into electrical energy that can power a small LED or other low-power device. This hands-on activity blends **engineering design** and **physical science**. Students experiment with blade pitch, shape, and number to see how these variables affect energy output.

Background:

Wind Energy Basics

- Wind is moving air caused by uneven heating of Earth's surface by the sun.
- Wind turbines harness the **kinetic energy** of wind.
- The moving air pushes against turbine blades, causing them to rotate.

Energy Transformations

- **Kinetic Energy (Wind) → Mechanical Energy (Spinning Blades)**
  - The blades act like airplane wings, using *lift* and *drag* to rotate.
  - Blade pitch (angle) affects how efficiently they capture wind energy.
- **Mechanical Energy → Electrical Energy**
  - The spinning shaft turns a small generator.
  - Magnets spinning past copper coils create an electric current through **electromagnetic induction**.

Energy Transformations

- **Too flat (0° pitch)** – blades don't catch much wind, producing little rotation.
- **Too steep (>30° pitch)** – blades push too much against the wind, slowing rotation.
- **Optimal pitch (10–20°)** – balances lift and drag for efficient spinning.

The Generator

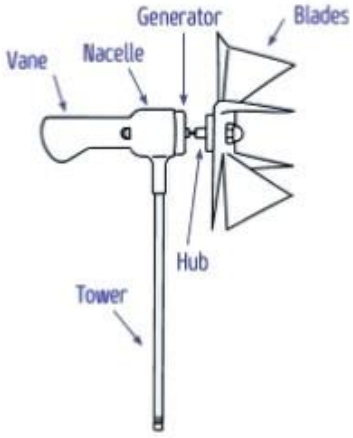
- In the Firefly, a small DC motor acts as a generator.
- When the shaft spins, magnets inside pass by wire coils, producing an electric current that lights the LED.
- This demonstrates **Faraday's Law of Induction** – changing a magnetic field induces an electric current in a conductor.
  - *References:*
    - *NEED Project – Wind Energy Curriculum*
    - *Vernier – Blade Design: Pitch Lab*
    - *ATSE – Wind Energy Teacher Guide*
    - *WindWise Education – Blade Design and Pitch*

Learning Objectives (I CAN STATEMENTS):

- Students will **observe and measure** how blade tilt affects the Firefly turbine's LED.
- Students will **explain energy transfer** from moving air to electrical energy.
- Students will **compare different blade designs** and identify which works best.
- Students will **connect their results to real-world turbines** and renewable energy.

Materials (per group):

- Firefly kits can be checked out for 20 students (in groups of 3-4).
- Template page
- Firefly template (or pre-cut circle)
- Scissors
- Push pin, small Philips, or small nail
- Pencil with eraser
- Tape
- Nacelle with generator and LED
- Acorn Hex Nut
- Screw Hub
- Fan (for testing)



Firefly Lesson Plan:

Show Phenomenon & Spark Curiosity (5 minutes)

Teacher Actions:

- Begin with a short demo: hold up a pre-built Firefly and blow on it with a fan until the LED lights up. — the "bug" lights up
- Ask guiding questions:
  - "What do you notice?"
  - "Where do you think the light is coming from?"
  - "What's making it spin?"
- Relate it to real-life wind turbines and renewable energy sources.
- For extra engagement, dim the lights so the LED glow is more visible.

Question to set up CER:

Teacher Script:

- *Your job is to figure out what blade pitch will make your Firefly light up the brightest. We'll be changing the tilt angle of the blades and recording the LED brightness in a data table. Then you'll use your data to make a claim and explain why it worked*

- Tell students that they are going to be able to explore their claim by making their own firefly as a group.

Introduce Key Vocabulary (5 minutes)

Teacher Script:

- *First, we need to learn some vocabulary to help us make better claims.*

Key Words & Quick Definitions:

- **Blade** – The flat part that catches the wind.
- **Wind** – Moving air that pushes the blades.
- **Spin** – To turn around quickly in a circle.
- **Light** – Something we can see when energy powers it.
- **Electricity** – Energy that can power lights and devices.

Teacher Tip: *Write the words on the board or chart paper, leaving space to add student-friendly examples or pictures.*

Teacher Actions:

- Hand out Student Data Sheets
  - Have each student write their claim, draw and label their firefly design before you pass out the materials to the group.
- Hand out materials to each group or work as a class. (groups of 3-4 students work best)
- Walk students through each step slowly, checking for understanding.
  - See directions below-this is also on the student data sheets
  - Give each group a copy of the direction sheet
- Encourage students to note how the blades are positioned before testing.

Build the Firefly with the Class (35-40minutes):

Step-by-Step Instructions for Students

- There are many options for templates. Since the focus is on pitch, I would make sure they all have the same design for now.
- For an extension, you can have them fix the pitch and change the design.
- Remember to enforce the rule: Change only 1 variable at a time.

Step 1 – Cut Out the Firefly Circle

- Cut along the solid outer shape of the Firefly template.

Step 2 – Cut Along the Inner Lines

- Carefully cut along each line toward the center, stopping at the inner circle mark.
- These cuts will form the turbine blades.

Step 3 – Fold the Blades

- Gently fold each blade forward along the line (like bending a door open).
- The arrow symbol in the corner of each section indicates which corner to fold inward
- Keep all blades bent in the same direction.
    - **Observation Prompt:** "Notice the angle (pitch) of your blades — we'll test how this affects the light later."

Step 4 – Assembled pieces 

- The generator and LED should already be in your nacelles
- You may want to add a piece of tape across the generator to keep it in place.
- Each nacelle should have a #2 pencil to put in the bottom of the nacelle piece to hold while the blades are turning.

Step 5-Attach the Firefly to the Generator Shaft 

- Use the screw hub point to push through the center of the blades. Slide the hole over the screw hub
- Twist the acorn hex nut onto the screw hub, to secure your blades to the screw hub
- If you removed the screw hub from the rotor of the generator to attach your blades, you would need to reattach it by pushing it gently back on the rotor.

Step 6 – Prepare for Testing

- Hold the Firefly (holding on to the pencil) in front of the fan without blocking the blades.
- Make sure the fan speed is the same for all tests.

Step 7 – Test Different Blade Angles

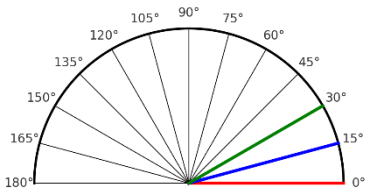
- Record brightness results for each.

Test & Compare Blade Pitch (15 minutes):
Test & Compare: flat blades → tilted blades → more tilt.

Teacher Actions:

- Use a fan set at the same speed for all tests.
- Students need to build a Firefly Wind Wheel with flat blades. Test in the fan.
- Students will bend blades slightly. Test again.
- Students will bend blades more. Test again.
- Students will record their results in the Evidence chart.

Teacher Tip:
For younger students, describe pitch as "how much the blades are turned like a door that's slightly open."



Write CER (Claim–Evidence–Reasoning) (10 minutes)

Student Task:

- **Claim:** Which blade tilt made the Firefly's LED glow the brightest?
- **Evidence:** Fill in a simple results table, for example:

Blade Tilt	Did it Glow? (Yes/No)	How Bright (Dim/Bright)
Flat		
Slight		
More Tilt		

- **Reasoning:** Explain why the chosen tilt worked best. Encourage them to connect to what they know about wind catching the blades to make them spin faster, which spins the generator more quickly to make more electricity.

Teacher Support for Reasoning:

- More tilt = more aerodynamic lift, allowing blades to spin faster.
- Faster spinning = more mechanical energy transferred to the generator.
- Generator spins faster = more electrical energy for the LED.

Extension Ideas for Teachers:

- **Math Connection:** Count blade rotations for each test and compare data.
- **Art Connection:** Have students decorate their blades, then retest to see if decorations affect performance.

Real-World Connection: Show a short video clip of real wind turbines in Kansas and discuss how engineers test blade shapes and a

- **Reasoning:** *Explain why the chosen tilt worked best. Encourage them to connect to what they know about wind catching the blades to make them spin faster, which spins the generator more quickly to make more electricity.*

Teacher Answer Key: CER Activity: Firefly Wind Wheel

Question: What makes the firefly light up more — flat blades or tilted blades?

Claim: What do you think makes the firefly glow brighter?

Possible Answers:

- **Student 1:** I claim that **tilted blades make the firefly glow brighter** because **they catch more wind and spin faster than flat blades**.
- **Student 2:** I think that **the firefly lights up more with tilted blades** because **the tilt helps the wind push the blades more strongly**.
- **Student 3:** My claim is **that the tilted blades work better** because **the Firefly glowed brighter when we tested them compared to flat blades**.
- **Student 4:** I believe that **tilting the blades is the best design** because **it helps the generator spin faster and make more electricity**.
- **Student 5:** In my opinion **the tilted blades are better** because **they made the LED brighter during our test**.

Evidence: What did you see in your test?

- We tested the Firefly Wind Wheel with **flat blades**. It glowed **yes, but dim**.
- We tested the Firefly Wind Wheel with **slightly tilted blades**. It glowed **yes, brighter**.
- We tested the Firefly Wind Wheel with **more tilt**. It glowed **yes, very bright**.

Observation Chart

Blade Tilt	Did it Glow? (Yes/No)	How Bright (Dim/Bright)
Flat	Yes (could be no)	dim
Slight	yes	bright
More Tilt	yes	Very bring

Reasoning: Why did it happen that way?

Tilting the blades helps because **it allows the blades to catch more wind**.
This happened since **angled blades create more lift from the moving air**.
The tilted blades caught more wind, which **made the Firefly spin faster**.
The faster the Firefly spins, the more **electricity the generator produces**.
This makes sense because **more electricity flowing into the LED makes it glow brighter**.

Reflection – Example Student Drawing

Blades shown tilted at an angle (like a pinwheel) with arrows for airflow.

Real-World Connection – Teacher Note

Students should connect their results to how **real wind turbines** also have carefully angled blades to catch the most wind. Too flat = no spin. Too much tilt = sometimes drag. Engineers test designs to find the best balance.

Question:
How do the tilted blades on real wind turbines help them make electricity, and why can't the blades be too flat or too tilted?

A. The tilted blades catch the wind and spin the turbine. If the blades are too flat, the turbine won't spin well, and if they are too tilted, they can slow down from too much drag. ✅

B. The tilted blades are only for decoration, so it doesn't matter how they are shaped.

C. Flat blades make the most electricity because the wind hits them straight on.

D. The more tilted, the better — the turbine will always spin faster with extra tilt.