Alternative Energy Curriculum

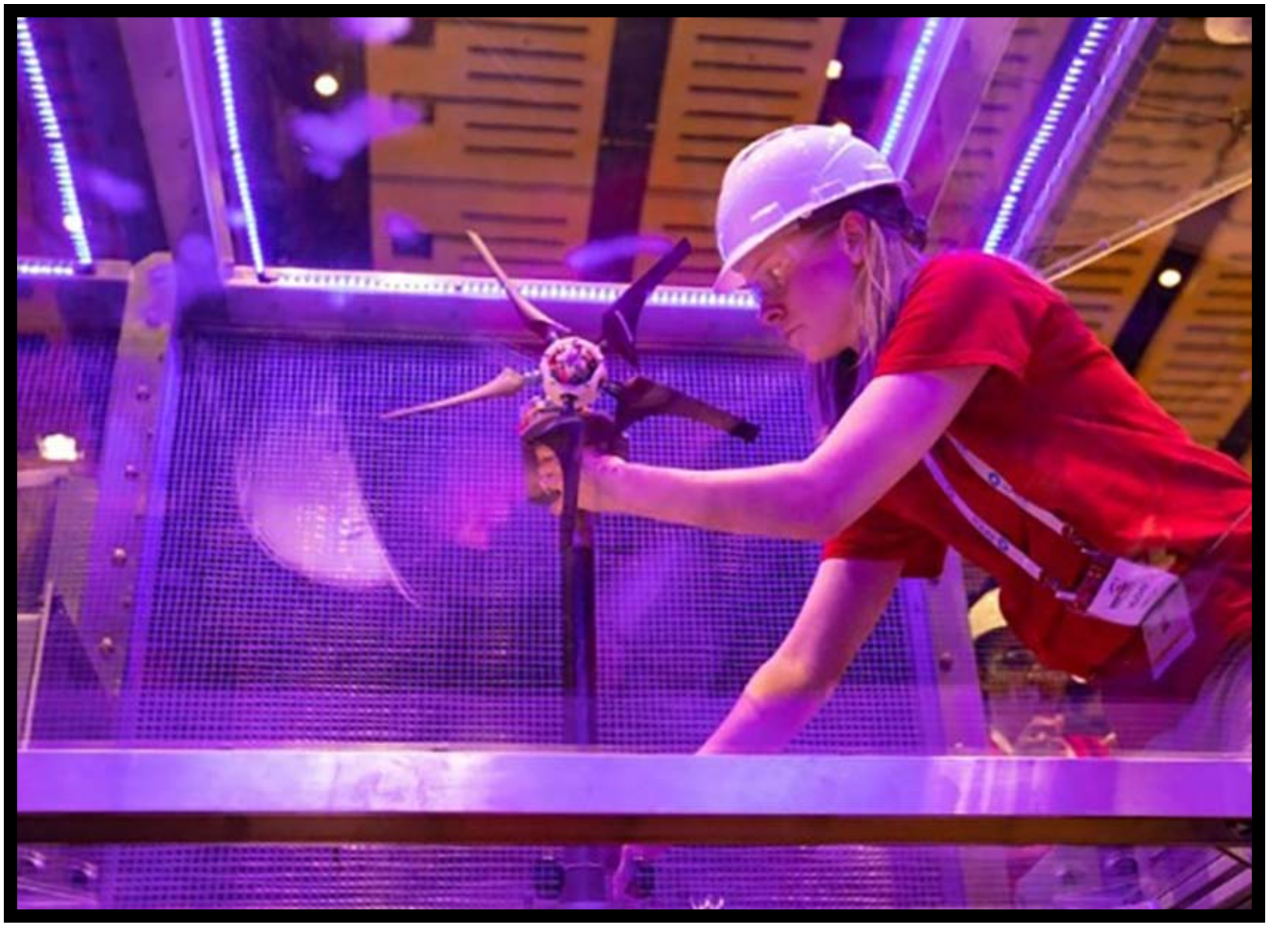


Image Courtesy of NREL

Unit: **Wind Power**
Teaching Time: (5) 60-minute periods
Advanced Planning
Preparation Time: 20 minutes

1. Gather classroom supplies
2. Copy student pages
3. Form student teams

Classroom Materials

- Several Fans
- Construction Materials: assortment of card stock, cardboard, and foam board
- Dowels
- Glue

Team Materials

- (1/ea) Safety Glasses
- Student pages
- Computer with Internet access
- Wind Turbine Kit
- Digital Multimeter
- Ruler
- Calculator
- Scissors or other cutting tools

Prior Knowledge & Skills

- Unit: Fundamentals of Electricity
- Lesson: Solar Race car Challenge
- Lesson: Wind Power Introduction
- Lesson: Initial Turbine Blade Tests
- Lesson: Extreme Wind Power
- Lesson: Calculating Turbine Power

What Students Do

In this challenge, students design, build, and test original blades and turbines. They collect and analyze test data to modify their devices for optimum performance. Students expand upon and apply their experience of testing standard blades and use their knowledge of the diverse approaches to turbine design to conceive their own turbine and blade plans. They study details of traditional and modern blade designs and the principles of airfoils. They consider a range of blade styles from flat to three-dimensional and develop design specifications from which to create their blades using simple and safe materials. Students build and test blades. They collect data regarding their turbine performance. Using this data, they revise their blade and/or turbine design to optimize power production.

Learning Outcomes

As a result of this lesson, students will demonstrate:

- The ability to apply the knowledge and experience gained from initial blade tests to create improved blade designs
- The ability to apply knowledge of modern, conventional, and unique blade and turbine designs to design their own blades and turbine
- Ability to apply aerodynamic and scientific principles of airfoils to the design and construction of blades
- How to design, build, and test blades and turbines
- The use of data analysis to modify blade and turbine design features
- The ability to collect and analyze data of turbine performance
- The ability to optimize blades and turbines to improve performance

Implementing the Lesson

Introduce

In this challenge, students design, build, and test blades and turbines. They collect and analyze data to modify their conceptions for maximum performance. This challenge combines the experience and knowledge gained from all previous lessons in the unit.

1. Explain to students that they have gained the experience and knowledge that enables them to design, build, and test their own blades and turbines.
2. Remind them that in previous lessons they tested standard blades measuring power output relative to number and pitch of the blades. They have learned about unique turbines and solutions for capturing the energy of wind. Also, they have used mathematics to predict theoretical and actual power produced by turbines.
3. Show students the available materials and tools. As a class, briefly discuss both construction methods and blade design. Students will learn specifics as part of the lesson.
4. Explain that in this lesson, students will learn about the structure and function of three-dimensional blades and how to craft unique blades out of simple materials.
5. **Encourage creative thinking**. Invite students to consider additional materials they might be able to find to meet the needs of unique designs.

If you have taught this lesson before, share examples of work by previous students.

6. Review safety procedures. Remind students that they need to design blades that use safe and simple materials.
7. Form teams and direct students to the start of the lesson.

Facilitate

This lesson consists of background information regarding modern blade design, directions for blade construction, and instructions and support for testing and modifying blades and turbines.

Design

Encourage students to produce thoughtful designs. They should justify the dimensions and shape of their blades based upon knowledge and experience. Encourage them to keep it simple and to use light, strong, easily manipulated materials.

- **Use Data**: Encourage students to review the data they collected comparing blade number and pitch to performance. This data should help them decide on the number of blades to construct and an initial pitch at which to test their blades.
- **Keep it Simple:** The time required to build elaborate blades will decrease the time allotted to testing blades. Therefore, encourage students to keep their designs simple and practicable. Students need time to test and modify their designs, too.
- **Materials**: Weight vs. Strength. Encourage students to avoid needless weight. Lightweight, well-built blades work better. Even the professionals need to compromise between strength and weight.

- **Limiting Materials**: Placing limits on the quantity of available materials encourages students to work within design specifications.
- **Decrease Drag**: Shorter blades, with narrower tips than roots, and smoother blade surfaces create less drag.
- **Blade Length**: Extremely long blades may increase drag depending upon their design and construction. If students find long blades ineffective, suggest that they shorten the length. Remind them to record their modifications and retest the blade/turbine.

Build

The PowerPoint presentation provides detailed support and instructions for constructing unique blades.

- Encourage students to build blades from light, safe, and easily modified materials.
- Students should proceed to building upon your review of their design documents.
- If special equipment or materials are required, the instructor needs to facilitate use especially with respect to safety.
- Remind students to work carefully and safely.
- Encourage students to stick to their original plans or document any modifications to their design as they construct the blades.

Test

Remind students to collect, record, and analyze data for several tests before they make any modifications in their designs. They need to justify any redesign of their blades on test data.

- **Data**: A sample data table is provided. Students with spreadsheet experience should be encouraged to use the software.
- **Results**: Daily, or as time permits, have teams share the results of their tests with peers. A frank and open discussion about challenges and solutions to blade design, construction, and testing may provide solutions to the challenges encountered.

Several simple experiments they should do before they make blade modifications include:

- **Pitch**: Students should select the initial pitch of their blades based upon the data resulting from the lesson, *Initial Turbine Blade Tests*. Remind them that their blades may function best at a slightly different pitch than was optimum for the standard blade. Have students adjust the pitch slightly to either side of their initial setting and compare performance.
- **Blade Number:** Based upon data from the lesson, *Initial Turbine Blade Tests* students should recognize that a turbine functions best with between 2-4 blades. If they start with 4 blades, they can quickly test 3 and 2 blade turbines and compare performance.
- **Fan Speed:** If students find their blades do not perform well, have them increase or decrease the speed of the fan.
- **Fan Distance:** Have students move the turbine toward or away from the fan and record performance.

Evaluate

The design process is iterative. Changes to blade design should result from data collection and analysis. Have students justify modifications they intend to make based upon their data. Depending upon your situation, the level and detail of documentation you require may vary from completely rethinking blade design and creating new drawings to making notes regarding minor changes undertaken to as students optimize turbine performance.

Summarize & Reflect

Each day, provide teams time to organize, summarize, and reflect upon their work. Have teams present their work at various points in the process and discuss challenges and successes. Peers should be encouraged to support other teams and provide constructive criticism and solutions.

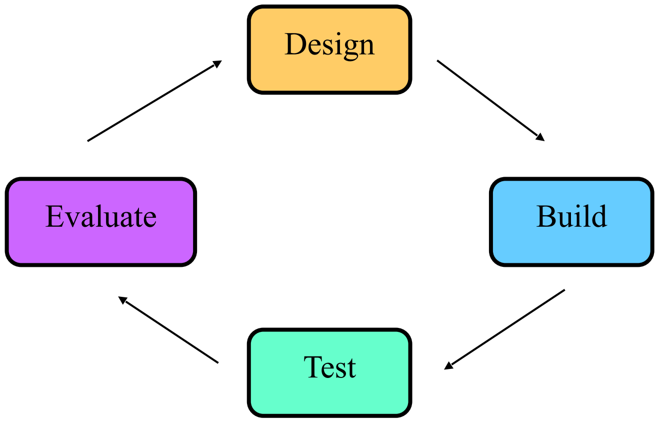
Final Turbine Presentations

Depending upon preference, this may be a basic or elaborate event. Suggestions include:

- Have teams create a poster of their turbine that includes examples of their work at each phase of the design process: design, build, test, evaluate.
- Have teams demonstrate their turbines and record the performance of each for all teams to see.
- Have teams present their work to the class, demonstrating their turbine and reviewing the process that led to their final product.

Invite local engineers, especially if you have access to individuals with experience in wind power or blade design, to a panel discussion where students present their work and are critiqued by professionals.

Background Information



Design Process
Briefly summarized, the engineering design process consists of a cycle that leads to the development of a product or system. In this case, we will condense the steps to: design, build, test, evaluate and (re)design. The process repeats until the design specifications are met or constraints such as time or money bring the effort to an end.

Design
Students often begin their work with very creative designs and high performance expectations. If the turbine does not perform as expected, it is all too easy for students to change performance goals. Encourage students to identify realistic performance expectations and to manage variables to meet the goals. Keep designs simple. Hold students to account for their specifications once testing begins. Set limitations on the quantity materials students use to encourage realistic designs and appropriate material use.

Build
Encourage students to follow their design specifications. These were thoughtfully created and provide the basis for building and testing the blades and turbine. Encourage use of lightweight and easily manipulated or modified materials. The PowerPoint for this lesson provides detailed instructions.

Test
In this phase, encourage students to perform several simple tests before they make any modifications to their blades. Tests they should conduct include changing blade number or pitch, fan speed, and distance from turbine to fan distance.

Remind students to test a single variable at a time, to collect and record their data, and to analyze the data before they modify their blades. If none of the simple tests suggested leads to improved turbine performance, then blade design should be reconsidered.

Evaluate

Based upon the data collected, students may, and probably will, modify their designs. Encourage students to analyze their data and justify changes to their designs based upon objective information.

Optimizing Performance

In engineering design challenges, students often trend toward optimizing the performance of the device or system by simultaneously manipulating multiple variables. This is a natural outcome of working with several interconnected variables. Yet, it remains important for students to understand the discrete effects of individual variables. Thus, in the tests recommended above, students should be reminded to hold all but one variable constant. If you observe students optimizing, probe their understanding of the effect of changing several variables at the same time. Do they know which variable or variables are responsible for any changes in performance? Refer them to their data to help them understand the importance of using objective observation to inform design modification.

Ultimate Turbine Blade Design
Design Specifications

Goal: Set design specifications for your blades and the turbine
Directions: Complete the table

Performance Goals: be specific; refer to Initial Wind Turbine Blade Test data	Materials for Blade & Turbine	Tools

Sketch of One Blade	Sketch of Complete Turbine

Ultimate Turbine Blade Design
Design Drawing

Goal: Make very specific drawings of each part of the blade and turbine
Directions: Use graph paper, a pencil and a ruler to draw a very specific drawing of the vehicle.
Include:

- Blade Length
- Blade Width at various points along the long axis
- Blade Thickness if 3-dimensional
- Twists or Curves in the blade
- Art: Add any artwork
- Label all parts and include measurements

Our 1st Ultimate Blade!

Ultimate Turbine Blade Design

Goal: Test and analyze the performance of your turbine. Identify design modifications to improve turbine performance.
Directions:

- Assemble and test your turbine.
- Run the fan at different levels—low, medium, and high. Observe the turbine to make certain that it is running to your satisfaction. Make any necessary adjustments to your blades so that the turbine runs smoothly.

Simple Tests
BEFORE you decide to modify the blades perform several simple tests of your turbine.
Experimental design:

- Change only ONE variable. Keep all other variables constant.
- Create a new data table for each experiment.
- Connect the turbine to a load and the digital multimeter.
- Collect and record data, voltage and current, for each test.
- Calculate the output power of your turbine in Watts.
- After all these simple experiments, do you need to modify your blade? If so, why and how will you modify the blade?

Test the following variables:

- Number of blades on the turbine
- Pitch of the blades
- Fan setting: low, medium, high
- Distance from Fan to Turbine

Ultimate Turbine Blade Design

Sample Data Table

Name Partner(s)	Date	Design Version	Formulas Current = Amps = milliamps x 1000 Power = Volts x Amps	
Pitch of Blade (Degrees)		Distance from Fan to Turbine (m)		Fan Setting (circle one) Low Medium High
Test Number	Volts (v)	Current (milliamps)	Current (Amps)	Power (Watts) P = V x C
1				
2				
3				
4				
5				

Observations & Comments: Based upon the above results, use this space to make observations of the performance of the turbine AND recommend design modifications.