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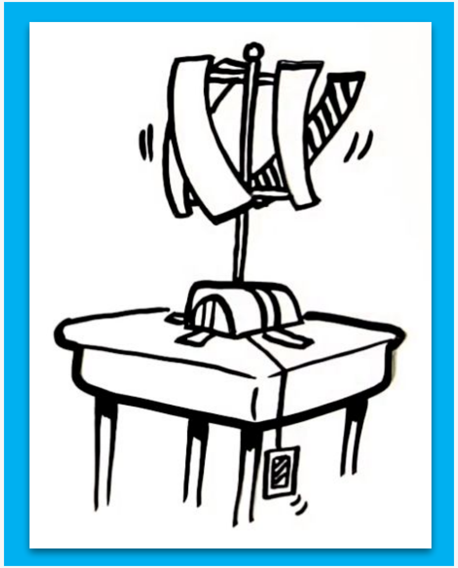
TRY Engineering

Lesson Plan:

Working with Wind Energy



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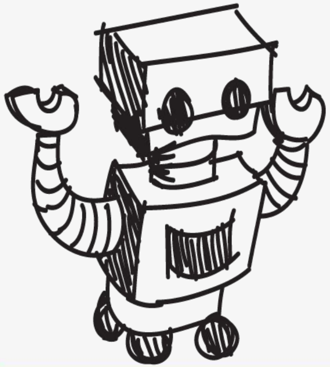
Real-World Application



Wind Turbine: How it works

- The wind hits the blades
- Shaft leads to a gearbox whose output leads to a generator to make electricity
- Usually has 2 or 3 blades

Source: Learn Engineering YouTube Channel

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Wind Resources in your Area?

- Do you have wind farms in your area? How many?
- What is the total operating wind capacity?
- Where is your area on the world list?
- How can you celebrate Global Wind Day?
- Check out the following sites to help you find answers:
    - The Wind Power (thewindpower.net)
    - National Renewable Energy Laboratory (www.nrel.gov/wind)
    - Wind Europe (https://windeurope.org)
    - Danish Wind Industry Association (www.windpower.org)
    - Global Wind Energy Council (www.gwec.net)
    - Global Wind Day (www.globalwindday.org)

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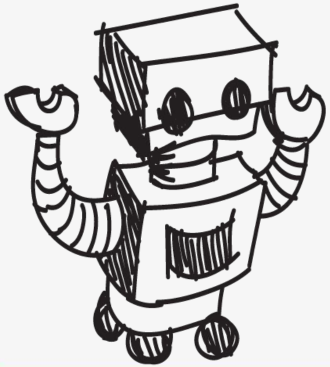
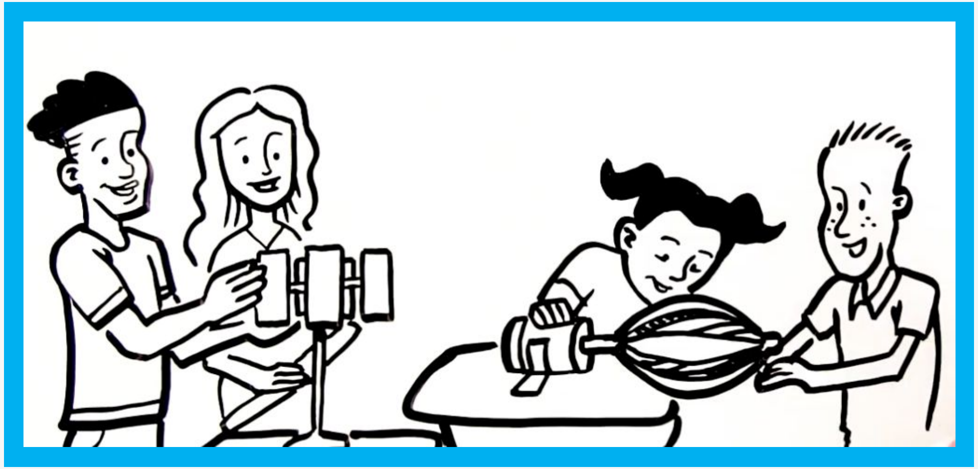
The Design Challenge



The Design Challenge

- You are a team of engineers challenged to design and build an efficient windmill. The design that meets the criteria and is least expensive will be most efficient.



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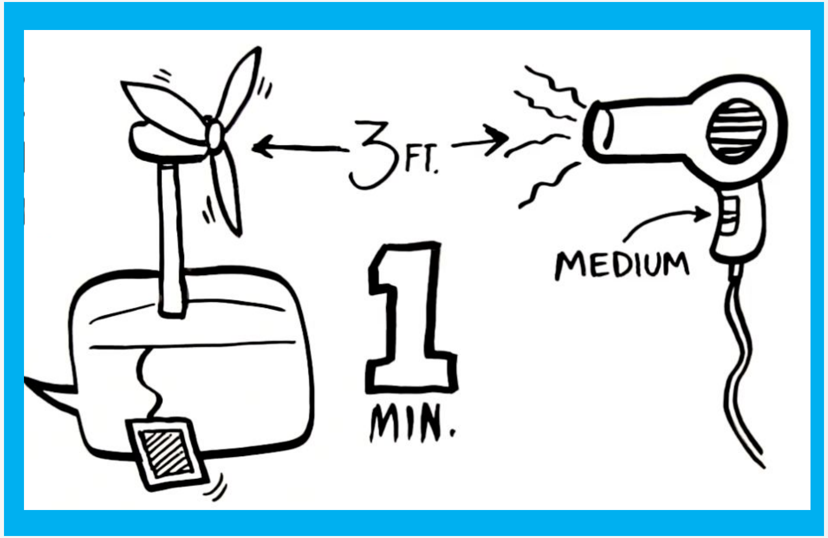
Defining the Challenge: Criteria

Criteria

- Must have a rotor shaft around which to wind-up the given weight (tea bag)
- Must be freestanding (no human interaction)
- Weight (tea bag) to be lifted 6 in. in 1 minute or less
- Blow dryer minimum of 3 feet away from turbine and on medium speed
- Stay within your $5.00 budget



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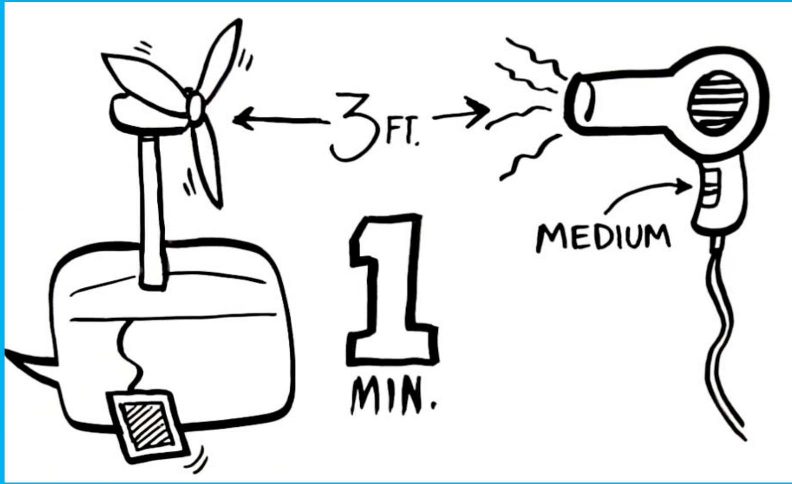
Defining the Challenge: Constraints

Constraints

- Maximum time to wind-up weight is 1 minute
- You must buy your materials – you can trade and return materials



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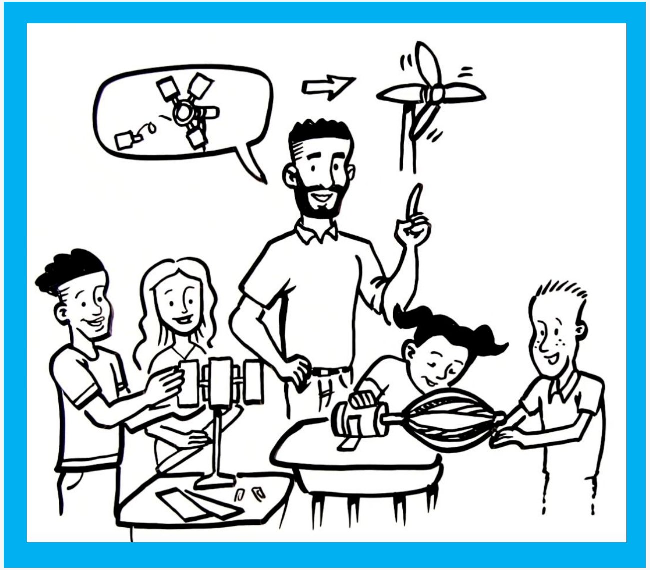
Materials

- Required
  - Tea bags (with string)
  - Hair dryer
- Optional (on the Table of Possibilities)
  - Craft sticks
  - Bendable wire
  - String
  - Paperclips
  - Rubber bands
  - Toothpicks
  - Aluminum foil
  - Plastic sheets
  - Wood dowels
  - Cardboard
  - Binder clips
  - Paper fasteners
  - Clothespins
  - Tea bags



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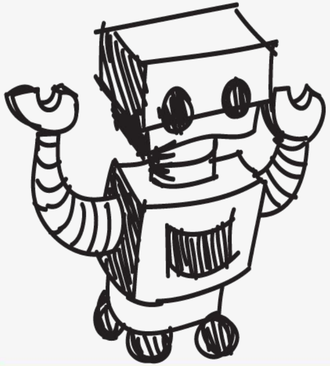
The Budget

You must purchase your materials. Each team gets $5.00 to spend.

- Blade Shape & Body of Windmill
  - Craft sticks: $.25
  - Bendable wire $.25
  - Wood dowels/sticks $.25
  - Cardboard Stip$.10
  - Toothpicks $.10
- Cover the blade
  - Aluminum foil Sheet $.25
  - Plastic sheets $.25
- Connectors
  - String $.10
  - Paperclips $.05
  - Rubber bands $.05
  - Binder clips $.05
  - Paper fasteners $.05
  - Clothespins $.05

Remember you can trade with teams, if materials are out. You can also return and exchange any materials not used.

Engineering Design Process



The Engineering Design Process

Learn about the engineering design process (EDP). The process engineers use to solve problems.

Source: TeachEngineering YouTube Channel

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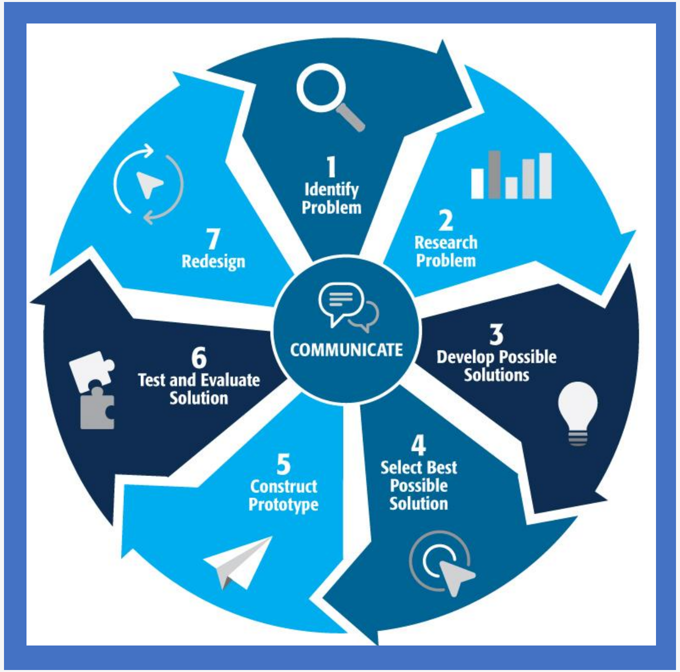
Engineering Design Process

- Divide into teams of two (or up to 4 max)
- Review the challenge and criteria & constraints
- Brainstorm possible solutions (sketch while you brainstorm!)
- Choose best solution and build a prototype
- Test then redesign until solution is optimized
- Reflect as a team and debrief as a class



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Productive Failure

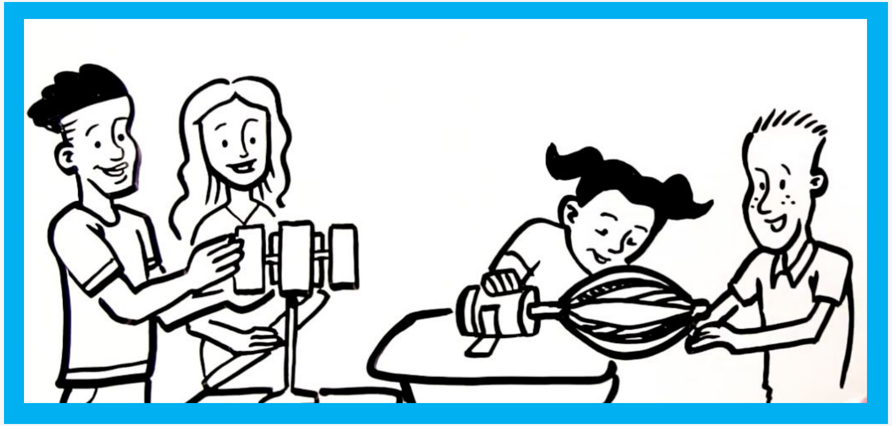
- The engineering design process involves productive failure: test, fail, redesign. Iterate again and again until you have the best possible solution.
- It is important to document iterations to keep track of each redesign. Use the engineering notebook to sketch ideas, document iterations and any measurement and/or calculations.

- It's also important to showcase the fact that there can be multiple solutions to the same problem. There's no one "right" solution.

Consider...

Before you get started brainstorming...consider the following...

- Number of blades
- Shape of the blades
- Strength of the blades
- Direction the windmill sits: can be vertical or horizontal
- Efficiency and not spending all your money

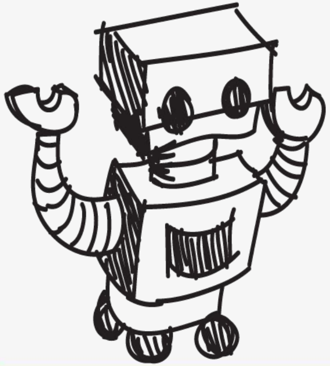


Optional: Calculate Efficiency

- Efficiency of design will depend on more than cost.
  - Cost of materials
  - Speed (rotations per minute)
  - Power (time to wind weight)
  - Measure of Efficiency = (Cost of materials) / (time [sec] to lift weight)

Engineers will be working in this field for years to come to determine the optimal shape, weight, and materials to generate energy most efficiently!

Dig Deeper



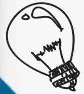
Vocabulary

- Engineers: Inventors and problem-solvers of the world. Twenty-five major specialties are recognized in engineering (see infographic).
- Engineering Habits of Mind (EHM): Six unique ways that engineers think.
- Engineering Design Process: Process engineers use to solve problems.
- Criteria: Conditions that the design must satisfy like its overall size, etc.
- Constraints: Limitations with material, time, size of team, etc.
- Prototype: A working model of your solution to be tested.
- Iteration: Test & redesign is one iteration. Repeat (multiple iterations).
- Wind Energy: Wind power or wind energy is the use of wind to provide

Continued on next page

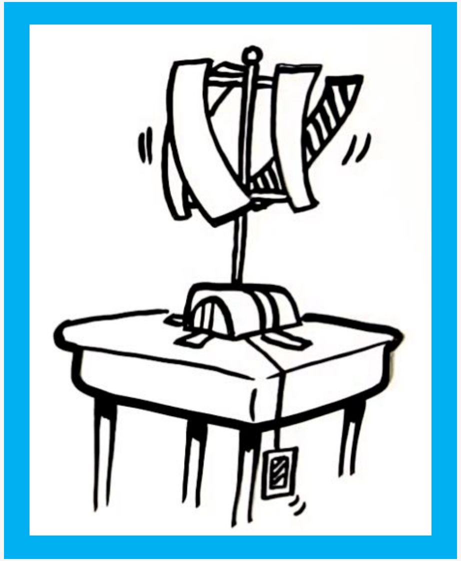
Vocabulary

- the mechanical power through wind turbines to turn electric generators and traditionally to do other work, like milling or pumping.
- Wind Turbine: Is a wind energy converter - a device that converts the wind's kinetic energy into electrical energy.
- Aerodynamic Efficiency: A measure that assesses a design to generate aerodynamic forces for efficient flight parameters.
- Tip speed ratio: Is the ratio between the tangential speed of the tip of a blade and the actual speed of the wind.
- Renewable energy: Wind power or energy is the use of wind to provide the mechanical power through wind turbines to turn electric generators and to do other work, like milling or pumping.



Optimal Blade Design: Tip Speed Ratio

- Blades come in many shapes and sizes, and there is continuing research into which design is best. It turns out that the optimal design really depends on the application, or where and how the blade will be used.
- Designers look at the "tip speed ratio" that determines efficiency. This is the ratio between the speed of the wind and the speed the blade tip. High efficiency 3-blade-turbines have tip speed/wind speed ratios of between 6 and 7.

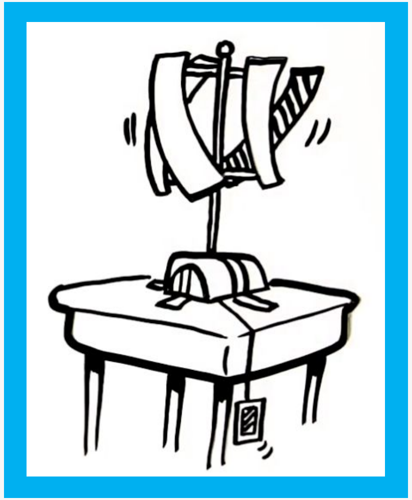


Optimal Blade Design: Aerodynamic Efficiency

- Most wind turbines use either two or three blades.
- Research indicates that as more blades are added, there is a increase in aerodynamic efficiency, but this efficiency decreases dramatically with each added blade.
- For example, increasing the number of blades from one to two can yield a six percent increase in aerodynamic efficiency, but increasing the blade count from two to three yields only an extra three percent in efficiency.

Optimal Blade Design: Materials

- Early windmills were made of wood with canvas sails. These deteriorated over time and required care – but they represent the materials readily available.
- More recently, older mechanical turbine blades were made out of heavy steel, but now many are made using fiberglass and other synthetic materials that offer strength at lower weights.



- Manufacturers also use epoxy-based composites and carbon fibers have also been identified as a cost-effective method to further reduce weight and increase stiffness. Smaller blades can be made from light metals such as aluminum.

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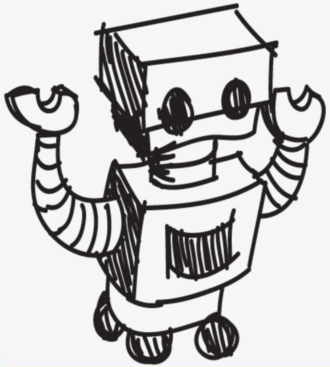
Engineering Fields



What is Engineering?

Source: *TeachEngineering YouTube Channel*

Learn about engineering and how engineers are creative problem solvers and innovators who work to make the world a better place.

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Related Engineering Fields

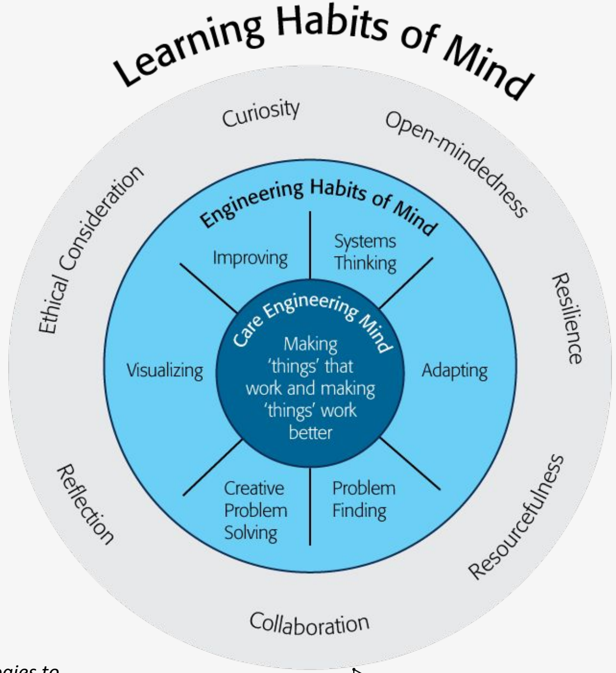
There are many different types of engineering fields that are involved with wind energy. Here are just some of the related engineering fields.

- [Mechanical Engineering]
- [Electrical Engineering]
- [Computer Engineering]
- [Software Engineering]

Download the Engineering Fields Infographic
How will **YOU** change the world?

Engineering Habits of Mind (EHM)

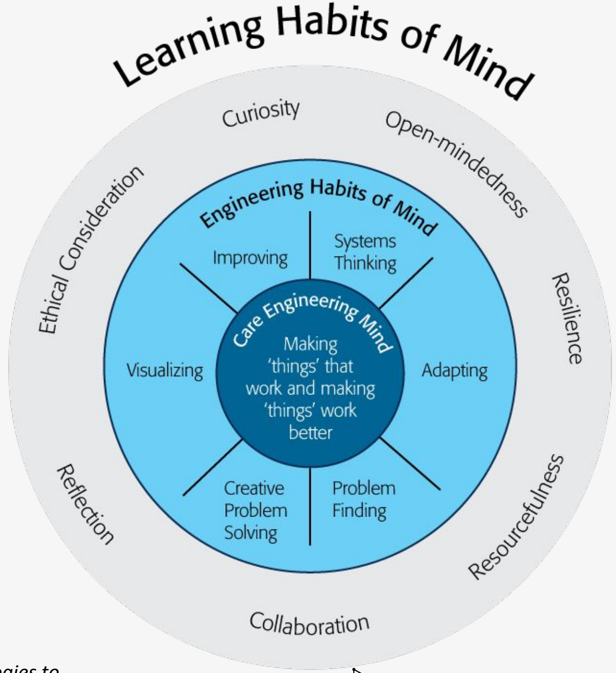
- EHM is about how engineers think everyday. The core of the engineering mind is about making things that work and making them work better.
  - Systems thinking: Seeing whole systems and parts and how they connect.
  - Problem-finding: identifying and defining a problem.
  - Visualising: manipulating materials and sketching. Mental rehearsal of practical design solutions



Source: B. Lucas and J. Hanson, Thinking Like an Engineer: Using Engineering Habits of Mind and Signature Pedagogies to Redesign Engineering Education. (International Journal of Engineering Pedagogy, Vol 6, No. 2 (2016): https://online-journals.org/index.php/i-jep/article/view/5366)

Engineering Habits of Mind (EHM)

- Improving: Persistently trying to make things better by experimenting, designing, sketching, and prototyping
- Creative problem-solving: generating ideas and solutions with others with many iterations.
- Adapting: Testing, analysing, reflecting, & rethinking



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Greatest Engineering Achievements of 20th Century

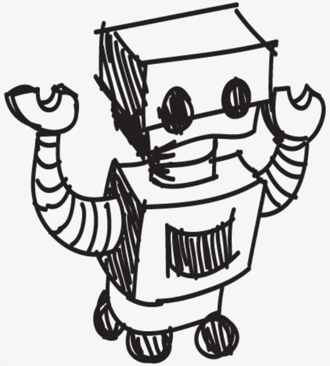
- Electrification
- Automobile
- Airplane
- Water Supply and Distribution
- Electronics
- Radio and Television
- Agricultural Mechanization
- Computers
- Telephone
- Air Conditioning and Refrigeration
- Highways
- Spacecraft
- Internet
- Imaging
- Household Appliances
- Health Technologies
- Petroleum/Petrochemical Technologies
- Laser and Fiber Optics
- Nuclear Technologies
- High-performance Material

Source: http://www.greatachievements.org/

Do you know any Engineers?

- How many engineers do you know? Your teammates? Your class?
- What do they do? What engineering degrees do they have?
- What items in your classroom and your school did engineers help design?
- Check out the NAE Grand Challenges for Engineering to help you learn more about how engineers make the world a better place:
  - NAE Grand Challenge for Engineering

Reflect & Debrief



Reflection

- Did you succeed in creating a windmill that met all the criteria/ constraints?
- Did you need to revise your original design or request additional materials?
- How many iterations did you need?
- Did you negotiate any material trades with other teams? How did it go?

- If you could have had access to materials that were different than those provided, what would your team have requested? Why?

Continued on next page

Reflection

- How would you redesign next time?
- How did the most "efficient" design differ from your own?
- What drawbacks does a wind turbine have as a reliable source of energy?
- What technologies exist that might compensate for these drawbacks?
- What advantages does the windmill have as a renewable source of energy?

For more engineering lesson plans and resources like games, engineering careers, and STEM opportunities visit IEEE's TryEngineering.org

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