Wind Turbines
Unit Plan

Overview

Skills and connections: data collection and analysis, clean energy solutions, engineering design process

Age: 6th grade

Community problem: Inspired by a worldwide lack of access to energy, let alone clean energy, the students set out to investigate what kinds of problems wind turbines solve, and how they could engineer the most efficient turbines.

Student design goals: Students aimed to create and assess prototypes of wind turbines as a large step towards understanding a potential long-term to one of the world's largest problems.

Unit flow

1. Engineers collect qualitative and quantitative data when researching the problem they are trying to solve.
2. Engineers collect information regarding their clients' needs in order to define the criteria and constraints of their design problem.
3. Engineers research existing solutions while brainstorming their own solutions.
4. When selecting materials, engineers reason about how a material's properties will serve the function of the design.
5. Engineers use their criteria and constraints to test the successes and limitations of their prototypes.
6. Engineers use visual representations to design and communicate their solutions.

Lesson Outlines

Lesson 1: Why did William build a wind turbine in The Boy Who Harnessed the Wind?

Description:
Students will read *The Boy Who Harnessed the Wind* and watch a video from the author to identify what problem he was trying to solve and the impact it had on his life.

Objective:

- CO: Students will be able to identify the engineering problem from William's story and describe how that problem impacted his community.
- LO: Students will be able to describe orally and in writing the reasons why William wanted to build a windmill for the community using sentence starters.

Estimated Time: 90 minutes

Concepts/Subconcepts Addressed:
Engineers collect qualitative and quantitative data when researching the problem they are trying to solve and what other solutions already exist.

What Will Students Figure Out:
Engineers identify problems in their community and through research can adapt pre-existing solutions to solve that problem.

Materials/Resources:

- *The Boy Who Harnessed the Wind* picture book
- *The Boy Who Harnessed the Wind Read Aloud* video OR copies of the texts for students: https://www.youtube.com/watch?v=ab-aZ92Vyuc&t=32s
- *William and the Windmill* video: https://www.youtube.com/watch?v=BzlgyDAMupw&t=2s
- Student notebook
- Computers (if not viewing whole group)
- Anchor chart paper

Set Up and Preparation Notes:

- Present map of Africa visible to students
- Share video link(s) with students if necessary
- Copy student notebooks for each student
- Title anchor chart paper: *Problems Electricity Solves*

Procedure and Facilitation Points:

1. Whole Group

Read aloud *The Boy Who Harnessed the Wind*

Before reading:
This book is the true story of William Kamkwamba, a boy from Malawi, Africa (show Malawi on map of Africa). William noticed some problems in his community that he thought he might be able to solve by building a wind turbine which is shown here on the cover (show picture). What do you know about wind turbines? What problems do you predict a wind turbine might help solve in William's community? Our thinking question today is: Why did William build a wind turbine in *The Boy Who Harnessed the Wind*? As we read we're going to pay attention to what problems William is trying to solve by building this wind turbine.

After reading:
We know that his community in Malawi didn't have access to electricity. What did he do to solve that problem? Turn and talk: Why do you think William wanted to bring electricity to his community?

2. Small Group Work

Students will reread the story and watch an interview with William Kamkwamba to explain why William build his wind turbine. Students will work in partners or small groups to take notes and reflect on their reasons in their student notebooks.

3. Whole Group

William built a wind turbine to bring electricity to his community. What problems in his community did you learn about that electricity could solve? Students share and teacher starts a bulleted list of problems on anchor chart.

Lesson 2: Why is not having electricity a problem for people?

Description:
Students will analyze interview evidence of how not having electricity affects people across the world.

Objective:
- CO: Students will be able to prioritize and synthesize information from infographs and interviews using guiding questions.
- LO: Students will be able to explain in writing the impact of limited electricity access using sentence starters: “I think ___ is a problem because ___”

Estimated Time: 45 minutes

Concepts/Subconcepts Addressed:
Engineers collect qualitative and quantitative data when researching the problem they are trying to solve and what other solutions already exist.

What Will Students Figure Out:
- Engineers interview affected people to understand the experience of the problem.

Materials/Resources:
- *Life without Electricity* video: https://www.youtube.com/watch?v=DSCiPFoCAX8
- *Problems Electricity Solves* anchor chart (started in lesson 1)
- Student notebooks
- Computers (if not whole group)

Set Up and Preparation Notes:
- Share access to the video with students if necessary
- Have anchor chart from lesson 1 ready (add paper if necessary)

Procedure and Facilitation Points:

1. Whole Group

At the end of this unit we will be designing our own wind turbines. But before engineers go about building, they do a lot of research. To make sure their design actually solves a problem and helps people, they need to really understand the problem they’ve identified. Who’s affected? How many people are affected? How are they affected? What are some different ways an engineer could research how a problem affects people? (Turn and talk). Write down their ideas on the board and add to them if necessary *(interview people, survey people, look up statistics-results from other people’s surveys, look up other people’s research-results from other people’s interviews/surveys).*

Yesterday we learned about the lack of electricity in William’s community in Malawi, Africa. You identified these problems in the community that not having electricity causes…(refer to yesterday's anchor chart). Today we're interested in learning how big of a problem lacking electricity is in the rest of the world. You're going to be listening to an interview of a family in Northern Africa. Before learning about how not having electricity affects them, watch the beginning of the video to learn a little about what their daily life is like generally.

2. Small Group Work

Students will watch the first part of the video and answer questions #1-2 in their student notebooks.

3. Whole Group

Summarize their descriptions of their daily life and predictions about whether or not they *need* electricity and what problems they might experience without it. Emphasize that researchers use guiding questions to prioritize what information is most important. In our case, the research questions is "what problems does not having electricity cause?" Model how to stop the video after they hear an answer to their question to give them time to write if necessary.

4. Small Group Work

Students will watch the second half of the video stopping it whenever they hear a problem caused by lack of electricity so they can record it in their student notebook and reason about why this would be a problem for them.

5. Whole Group

The class shares the problems they heard and their reasoning about why they're problems. Add these to the chart.

6. Individual Work

Students will reflect on how these problems affect people by answering questions #4-5 independently in their student notebooks.

Lesson 3: Who else around the world doesn't have electricity?

Description:
Students will analyze an interactive map to establish patterns of where electricity access is most limited as well as where the world's electricity comes from.

Objective:
- CO: Students will be able to synthesize information from an inforgraph using text features.
- LO: Students will be able to describe to a partner what information different text features provide using the sentence stem: "The __________ helped me figure out _________."

Estimated Time: 45 minutes

Concepts/Subconcepts Addressed:
Engineers collect qualitative and quantitative data when researching the problem they are trying to solve and what other solutions already exist.

What Will Students Figure Out:
Engineers look to data and experts to understand the scope of a problem.

Materials/Resources:
- Student notebooks
- Computers
- Chart paper

Set Up and Preparation Notes:
- Give students access to the link: https://energyeducation.ca/encyclopedia/Access_to_electricity
- Title chart paper: "How big of a problem is not having electricity"

Procedure and Facilitation Points:

Independent Work:
As a 5 minute warm-up, share the link and have students check out the interactive map on their own so they can explore how it works.

1. Whole Group

Firstly, discuss how this kind of map shares information. What did you notice about this map? What information do you think it shares?

Share with them that this kind of a map is called an infograph and is part of a larger website providing us information about what percentage of the world experiences the problem of no electricity access. We've talked a lot about why having no electricity is a problem so engineers can justify investing a lot of time and money into building solutions, but why might it also be important to know where this is a problem and how many people it affects?

Just like other non-fiction texts, this website uses a lot of text features to share this information with us. Have students spend a few minutes trying to find and identify as many text features as they can. Show and name these as a whole group and discuss what kind of information a given text feature provides.

2. Small Group Work

Instruct students to use the text and various text features to answer the questions in their student notebooks.

3. Whole Group

Share out what patterns or interesting statistics students noticed. Record notes on chart paper.

Lesson 4: How do different places in the world produce electricity and what impact do these energy sources have on the environment?

Description:
Students will compare renewable vs. nonrenewable forms of energy to reason about what it means to be renewable and what forms of energy have the greatest harm on the environment. Students will then analyze an interactive map on what forms of electricity different countries use.

Objective:
- CO: Students will be able to compare and contrast renewable and nonrenewable forms of energy and their impact on the environment.
- LO: Students will be able to compare and contrast renewable and nonrenewable forms of energy using technical vocabulary found on their energy cards.
- LO: Students will be able to identify what energy form different countries use and why using the word "because."

Estimated Time: 90 minutes

Concepts/Subconcepts Addressed:
Engineers collect qualitative and quantitative data when researching the problem they are trying to solve and what other solutions already exist.

What Will Students Figure Out:
Engineers research the impact of problems from multiple angles (i.e. human impact vs. environmental impact).

Materials/Resources:
- Student notebooks
- Energy cards (1 set/partner pair or group)
- Chart paper

Set Up and Preparation Notes:
- Print and cut energy cards (enough for every partner pair/group)
- Group sets of cards together with a paperclip or plastic bag
- Title chart paper: Environmental impact of electricity
- Share link with students: https://www.gocompare.com/gas-and-electricity/what-powers-the-world/

Procedure and Facilitation Points:

Day 1

1. Whole Group

First tell students there are many ways of producing electricity and we will be comparing those different ways today. Give students 5 minutes to read all the cards with their partners. When students are done reading, tell them that all energy is either considered renewable or nonrenewable (write words on board as a visual). Point out the R or NR in the corner of their cards.

2. Small Group Work

Instruct the students to sort the cards and compare the two groups. What is similar about all the renewable energies? The nonrenewable energies? What is different? Have them use the venn diagram in their student notebooks to record their ideas.

3. Whole Group

Discuss their ideas about what makes the two groups different and come up with a class definition for the two.

4. Small Group Work

Students will then answer the rest of the questions in their student notebooks from parts 1-2.

Day 2

1. Whole Group

Have students refer to their notes from yesterday and identify which forms of energy harmed the environment and explain how. Record ideas on chart paper and emphasize that non-renewables (except nuclear energy) are also called fossil fuels. We know that a lot of the world has electricity, what forms of energy do you predict are most popular across the world? Share out.

2. Small Group

Share the link with students and give students 5 minutes again to just explore the interactive map. Share out how the map work and model how they can turn on and off the renewable, muclear, and fossil fuel tabs to see some of the "hot spots" for those forms of energy. Have students continue exploring the map in partners and record their noticings in their student notebooks and explain why certain countries are using a given energy source.

3. Whole Group

Share out what they learned and add to the chart. Ask if given everything they've learned if they think designing wind turbines and other renewable energy source technology is worth their time and money. Why? What problems would these designs solve?

4. Individual Work

Optional assessment - Using their notes and the class anchor charts have students write an essay explaining what problems wind turbines could solve (human and environmental).

Lesson 5: What evidence do scientists have that fossil fuels cause global warming?

Description:
Students will perform an experiment on whether or not increased CO2 in the air raises temperature. They will then analyze graphs on carbon dioxide levels and temperature throughout history. Using the experiment and historical data they will make a claim regarding the human impact on climate change.

Objective:
- CO: Students will be able to use evidence to explain how fossil fuels cause global warming.
- LO: Students will be able to explain how fossil fuels cause global warming using casuational language: "When this happens, it causes…"

Estimated Time: 45 minutes

Concepts/Subconcepts Addressed:
Engineers collect qualitative and quantitative data when researching the problem they are trying to solve.

What Will Students Figure Out:
Engineers use math and science to back up their claims when they say something is a problem.

Materials/Resources:
- Student notebooks
- 2 mason jars + lids per group (filled halfway with room temperature water)
- 1 alka-seltzer per group
- 1-2 thermometers per group

Set Up and Preparation Notes:
- Fill mason jars halfway with water
- Open alka-seltzers so they're easily and quickly accessible

Procedure and Facilitation Points:

1. Whole Group

We've been reading and talking a lot about how burning fossil fuels is bad for the environment because it causes global warming. Check that students know what global warming is. Turn and talk: how do you think scientists prove that this is true? Share student ideas. Emphasize that scientists have needed to collect data over many years to prove that the Earth has been getting warmer as more CO2 has been put into the air but also they would need to prove that added CO2 is indeed what is causing temperature to rise. Read through the introduction and procedure for the experiment out loud and discus/record what the different parts of the model will be representing (atmosphere, fossil fuels, oceans). Model how to use the thermometer.

2. Small Group Work

Students will take an initial temperature of each of the jars and will place an alka-seltzer in one before closing the lid on both jars. They'll record the temperatures beneath the model in their student notebooks and then work on analyzing the graph on the next page while they wait the 15 minutes for the jars to heat up (if you have the time to wait 20 minutes-do so). When the time is up they'll unscrew the lids and take the temperature of both jars. Students will record what happened in the results section of their student notebooks.

3. Whole Group

Students will share the results of their experiment and what this proves about the effect of additional carbon dioxide in the atmosphere. They'll also discuss what the results of the data in the graph show about the additional carbon dioxide in the atmosphere over time.

4. Individual Work

Students will then individually explain in the writing their conclusions using evidence from the experiment and the graph's data.

Lesson 6: What do we need to know about our clients needs when designing wind turbines for them? (criteria and constraints)

Description:
Students will be introduced to the design challenge of building a wind turbine to power a small community. They will evaluate their design briefs (as well as calculate how much energy each community member needs) to develop a list of criteria and constraints.

Objective:

- CO: Students will be able to read and calculate the needs of their clients and identify the criteria and constraints of their project.
- LO: Students will be able to pull out important information from a reading passage.

Estimated Time: 45 minutes

Concepts/Subconcepts Addressed:
Engineers collect information regarding their clients' needs in order to define the criteria and constraints of their design problem.

What Will Students Figure Out:
Engineers learn as much about their clients and their needs to understand the criteria and constraints of their challenge.

Materials/Resources:

- Student notebooks
- Sticky notes

Set Up and Preparation Notes:

- Prepare open space in the classroom if necessary
- Prepare a few questions that get at particular parts of criteria and constraints on sticky notes to help the discussion if necessary

Procedure and Facilitation Points:

1. Whole Group

Today you're going to read about the clients for whom you'll be designing a wind turbine. Based on what you know about wind turbines and energy problems, what sorts of questions would you need to ask a client asking you to build something for them. Have students work in pairs to write questions out on sticky notes and walk around to support them. Share out these questions. Then explain that engineers need to ask their clients questions in order to understand the criteria and constraints for the project. The criteria is what things would make a design successful and constraints are limitations. Have students gather their questions into small groups and try to sort them as either a question that helps us understand what will make the wind turbine successful (criteria) or a question that helps us understand what limitations the clients have (constraint). Share out and see if the class agrees.

2. Small Group Work

Students will work in partners/groups to read the client's brief and identify what information is a criteria and what information is a constraint.

3. Whole Group

Review the client's criteria and constraints as a whole class so everyone is on the same page.

Criteria

- Must power all five houses (2,095 amps/sec)
- Would be ideal to be able to power additional houses

Constraints

- Prototype must be made out of paper/plastic cups
- Final design must be made out of metal
- Design cannot have more than 5 blades
- Prototype must be complete before _______ (set a date)
- Final design cannot be wider than 100 feet

Lesson 7: What do blades need to spin?

Description:
Students will study different designs of pinwheels as well as close up pictures of different designs of wind turbines to determine what blades need to spin.

Objective:

- CO: Students will be able to give reasons to explain what they think helps blades catch the wind.
- LO: Students will be able to explain what they think helps blades catch the wind using "because" and specific language regarding the blades' shape and material properties (heavy, light, long, short, narrow, wide, curved, straight, ect.)

Estimated Time: 90 minutes

Concepts/Subconcepts Addressed:
Engineers collect qualitative and quantitative data when researching the problem they are trying to solve and what other solutions already exist.

What Will Students Figure Out:
Engineers research existing solutions to reason about what works and to inspire their own designs.

Materials/Resources:

- Student notebooks
- Projection of side by side turbines for beginning discussions (found in appendix)
- Close-up photos of different wind turbine blades (found in appendix)
- Different style pinwheels (varying number of blades, size, ect)
- 1-3 fans (depending on how many centers you want)

Set Up and Preparation Notes:

- Set up center areas with pictures in center 1 and a fan and variety of pinwheels in center two
- Project side by side wind turbines for beginning discussions

Procedure and Facilitation Points:

1. Whole Group

Begin each day of this two day lesson with a discussion around which of two different wind turbines students think will catch the wind and spin better. Give them some independent time to reflect and then open it up to the class for discussion. There's no right or wrong answer as we're not testing these but students should practice giving reasons based on the properties of the blades for their idea. Encourage students to build off of each others' ideas.

2. Small Group Work

Center 1 - Students will examine the number of blades, material, and shape of different wind turbines and record their noticings. (It is not essential all students complete all 8). In the last 3-5 minutes instruct them to answer the questions at the bottom of the center work in their student notebook where they'll record commonalities and their current working theory on what makes blades catch the wind better.

Center 2 - In center two every student should select a pinwheel to start and record what they notice about the blades' material, number of blades, and shape. When everyone's ready turn on the fan so they can test how well that particular pinwheel spins and give it a rating. They'll then trade pinwheels so that they have one that is different from the first and will repeat this process until time runs out. In the last 3-5 minutes instruct them to answer the questions at the bottom of the center work in their student notebook where they'll record commonalities and their current working theory on what makes blades catch the wind better.

Lesson 8: What design features (size, weight, shape) do you want to test? What materials will work best for your design?

Description:
Students will work with partner teams to brainstorm and draw their designs. They will then investigate the available materials and reason about which material will best suit their design function.

Objective:
- CO: Students will be able to give reasons for why they think a particular material would help their design catch the wind the best.
- LO: Students will be able to describe the properties of each cup using specific language (heavy, light, long, short, narrow, wide, flexible, inflexible, ect.)
- LO: Students will be able to explain what they think helps blades catch the wind using "because."

Estimated Time: 45 minutes

Concepts/Subconcepts Addressed:
- When selecting materials, engineers reason about how a material's properties will serve the function of the design.
- Engineers use visual representations to design and communicate their solutions.

What Will Students Figure Out:
Engineers choose their materials based on which properties will best suit their design.

Materials/Resources:
- Student notebooks
- A variety of cups (differing in height, width, weight, material, ect)
    - A sample of each available cup material for each engineering team

Set Up and Preparation Notes:
- Group together the cups each design team will be investigating
- Label each cup material 1-6 so students can take notes on them
- Make picture of wind turbines and pinwheels from lesson 7 visible for inspiration

Procedure and Facilitation Points:

1. Whole Group

Get students into engineering teams (recommended 2 students/team, no more than 3). Inform them that they will be investigating the available materials for their wind turbines to better understand their properties and then brainstorming different blade designs for their wind turbines.

2. Small Group Work

In their engineering teams students will feel each cup and describe its properties. They'll record their ideas in their student notebooks where they'll then brainstorm as many wind turbine ideas. It may be helpful to have the wind turbines and pinwheels students had be exploring earlier easily visible for inspiration. Students will able be sharing their reasoning about why a given design will catch the wind as well as why a given material would best support that design.

3. Whole Group

Groups will share one of their designs and reasoning either with another group or with the whole class time permitting.

Lesson 9: How can we test different design features (size, weight, shape) to make the most efficient wind turbine possible?

Description:
Students will build and test their prototypes. After testing they'll adjust the features or materials of their design to determine the most efficient design features.

Objective:

- CO: Students will be able to use evidence from testing to explain what design features help catch the wind.
- LO: Students will be able to explain what they think helps blades catch the wind using "because" and specific language regarding the blades' shape and material properties (heavy, light, long, short, narrow, wide, curved, straight, ect.)

Estimated Time: 120 minutes

Concepts/Subconcepts Addressed:

- Engineers use visual representations to design and communicate their solutions.
- Engineers use their criteria and constraints to test the successes and limitations of their prototypes.

What Will Students Figure Out:
Engineers have to redesign several times to determine what design will best meet their criteria given their constraints.

Materials/Resources:

- Student notebooks
- Wine corks (2-3 times the number of engineering teams is recommended so they can experiment with a different number of blades if desired and can replace a cork whose hole is is too wide due to extensive testing if necessary)
- Craft sticks
- 1-2 fans set up
- 1-2 multimeters
- 1-2 low resistant motors
- A large array of diverse cups students can use for building
- Scissors
- Masking tape
- rulers

Set Up and Preparation Notes:

- Hot glue craft sticks to wine corks for the foundation of the blades
- Set up testing centers (1 fan + 1 multimeter + 1 low-resistance motor per center)

Procedure and Facilitation Points:

Day 1

1. Whole Group

Have students share theories they currently have on what type of blade will catch the wind and how they might test that. Have each group choose a design from their brainstorming that would help them t (i.e. do more or fewer blades go faster? Does a smaller or bigger curve go faster? Does a heavier or lighter blade go faster with a small curve?)

Then demonstrate how to cut the bottom of the cup out and if they don't want the natural curve of the cup's lip, how to also cut that out. Then give instructions on what information they have to record in their student notebooks before testing and how to use the multimeter and motor when testing (insert motor into wine cork, and hold each end of the multimeter to each end of the motor). Set the multimeter to 200 ohms (see picture).

Day 2 (beginning or ending depending on how much testing happened on the first day)

Have two groups share out a design they're working on. Select groups that have some good thinking behind it but don't necessarily spin fantastically. Also select groups depending on what you think kids need support with:

- Testing a theory (same shape, different material; same shape, different size; ect)
- Attending to more than one design feature (i.e. not all "light" designs will spin)

Have the rest of the class first look at the design and make predictions about how well it might spin and why they think that. Then have the engineers show them how it works with the fan and explain why they think it moves the way it does. Open it back up to the class to add on and give advise.

Day 3 - Just build.

1. Small Group Work

Engineering teams will build a prototype (1 per team), test it, and then make adjustments based on the feedback from their evidence. Some guiding questions include: What theory are you testing right now? Why do you think it will spin better? What change can you make to see if it'll go faster?

Lesson 10: Did you meet your criteria under the given constraints? How can you communicate your final design to the client?

Description:
Students will make a scale drawing of their prototype and determine how much energy the full scale wind turbine would produce. They will then communicate the successes and limitations of their designs to their client.

Objective:

- CO: Students will be able to calculate whether or not they've met their criteria and communicate their design to the clients.
- LO: Students will be able to describe the properties of their design using specific language (long, short, wide, narrow, curve, rectangular, heavy, light, ect).

Estimated Time: 45 minutes

Concepts/Subconcepts Addressed:

- Engineers use visual representations to design and communicate their solutions.
- Engineers use their criteria and constraints to test the successes and limitations of their prototypes.

What Will Students Figure Out:

Engineers reflect on what they have learned from the tests of their prototypes and evaluate how well they'll met their criteria and constraints.

Materials/Resources:

- Student notebooks
- Colored pencils
- rulers

Set Up and Preparation Notes:

- Provide a word bank of descriptive words on the board to support students in describing their design
- Make a scale drawing of yourself on the board

Procedure and Facilitation Points:

1. Whole Group

Ask engineering groups to review their testing data and select the wind turbine design that produced the most electricity. Tell them they're going to be making a scale drawing of their design and calculating how many times bigger your design would be if it were 100 feet wide and how many amps it could produce. Do an example of the division together using a drawing of yourself. "I am ___ times bigger than this drawing of me."

2. Small Group Work

In their student notebooks engineering teams will calculate how many times bigger their prototype would be at full scale of 100 feet (width of best design is recorded in testing chart), how many amps their full scale model would produce, and how many houses it could power. They'll then check off how well they met the constraints and criteria of the project and follow the letter template to communicate their design to their clients. Teacher should circulate supporting students on how to describe their design.

3. Whole Group

Engineers will share their letters or part of their letters either with the class or another group depending on time.