

**Lesson Title:** Engineering Design Challenge: Windmills

**Author:** Christin McNeil

**Topic:** Engineering Design Process, Alternative Energy: Windmills/Wind Turbines

**Targeted Grade Level:** 5<sup>th</sup> Grade

**Time Needed:** 4 weeks of STEM special or 160 minutes

**Subject Integration:** This lesson intergrates science, engineering, social studies, and ELA.

**Justification:** As the STEM specialist in my elementary school, I have a unit dedicated to the Engineering Design Process. The purpose of this unit is for students to learn about the process, develop an understanding of it's importance, and make connections with how this process integrates into their lives and possible careers of their futures. They will learn about this process in the unit and apply that knowledge to their own Engineering Design project. In an effort to develop 21<sup>st</sup> century learners, it is pivotal that they learn about science concepts that are relevant to their lives and can impact their future. Therefore, as part of the larger unit, this lesson is focused on teaching students about alternative energy and the use of wind farms. Not only is it important for students to understand current issues impacting their world, but also to understand their history. In order to build background knowledge for students, we will briefly learn the history of windmills in America and how their purpose as evolved over time. The picture book version of "The Boy Who Harnessed the Wind" will also be introduced and read to the class. This incorporation of literacy, American history, and World history content will assist in giving students a frame of refernce which will in turn prepare them when the approach the development of their own windmill. Students will then use the knowledge they have gained and apply it to their Engineering Design challenge.

**Standards:** NGSS and PA

**NGSS Performance Expectations**

**3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.**

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
<p><b>Asking Questions and Defining Problems</b> Asking questions and defining problems in 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships. Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.</p>	<p><b>ETS1.A: Defining and Delimiting Engineering Problems</b> <i>Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.</i></p>	<p><b>Influence of Science, Engineering, and Technology on Society and the Natural World</b> <i>People’s needs and wants change over time, as do their demands for new and improved technologies.</i></p>

**PA Science, Technology, and Engineering Standards:**

Science:

**3.4.5.E3** Explain how tools, machines, products, and systems use energy in order to do work.

**3.4.5.D1** Identify ways to improve a design solution.

**3.4.5.B3** Describe how community concerns support or limit technological developments.

**PA Social Studies Academic Standards:**

**7.4.5.A** Describe and explain the effects of the **physical systems** on people within **regions**.

**PA Core ELA Standards:**

**CC.1.2.5.B** Cite textual evidence by quoting accurately from the text to explain what the text says explicitly and make inferences.

**ITEEA Standards**

- Apply the technology and engineering design process.
- Explain how technologies are developed or adapted when individual or societal needs and wants change
- Evaluate designs based on criteria, constraints, and standards.
- Practice successful design skills.

**Measurable Student Learning Objectives:**

Students will be able to:

- Explain the Design Engineering Process and provide examples of where it is found in real life scenarios.
- Analyze informational text and make inferences from their analysis.
- Analyze data and establish connections between wind farms and their impact on the environment.
- Design, build, and test a prototype for a windmill following the Design Engineering Process.
- Communicate the results of their tests and ideas for improvement.

**Nature of STEM:** This lesson incorporates the nature of STEM by the integration of understanding the history, science, and engineering of windmills/wind turbines and their impact on the environment and culture. The lesson begins by an introduction to the history of windmills in America and around the world. It will lead students to an understanding of windmills as a human endeavour and technology that has evolved over time. They will explore the science behind how windmills work as well as their evolution through investigating the answers to questions. Students will then deepen their knowledge and understanding of the Design Engineering Process through the design challenge. They will use the knowledge that they have learned about both the science and history of windmills to design, create, and test their own prototype. Students will be required to work collaboratively with peers in various parts of the lesson. The lesson is an integration of science, technology, engineering, and 21<sup>st</sup> century skills.

**Engaging Context/Phenomena:** The hook for the lesson is intended to grab students attention and raise questions and curiosity about the topic. A picture of the wind farm off the shore of Rhode Island will be displayed for students to view and make observations. The image (pictured below) will raise questions about what is happening here. Most students will know that they are looking at some version of a windmill, some being able to recognize that it is a wind turbine. The class will revisit this image each week. Each revisit, will allow for students to identify what they are seeing and explain the reasoning, science, and even engineering involved with the placement of the wind turbines.



**Data Integration:** The authentic data source that I found to use for this lesson is the U.S. Wind Turbine Database. The database website is as follows: <https://eerscmap.usgs.gov/uswtodb/>. This data source will be introduced after students have learned about the history of windmills, wind turbines, and wind farms. The viewer component of the website allows you to see a detailed map of the U.S. and the location of every wind farm nationwide. Students use of the data is two fold. First, it will assist in students' understanding of the density of wind turbines nationwide. They will analyze the data, noting in which regions of the use the density is greatest. In addition, they will analyze the map to locate a wind farm that is close to our geographical location. Understanding that there are several wind turbines in our area will help to make the concept more relatable. Once students have analyzed the data and have noted regions where the density of turbines is high, we will discuss the process in selecting a location for a wind farm.

**Differentiation of Instruction:** This lesson can be adjusted in order to meet the unique needs of students in my classes. The following are some possible differentiations that can be made:

- Enabling text to speech application for the Wonderopolis lesson.
- Pre-arranging materials for Design Engineering challenge.
- Allowing additional time for completion of the prototype and one-to-one support throughout the building.
- Enabling accessibility tools on the Chromebooks such as enlarge pointer or text for navigating the U.S. Wind Turbine Database.
- Providing students with specific jobs within their groups to ensure engagement of all students including the more reserved/hesitant students.
- Offering additional resources with greater text complexity for high achieving students and early finishers.

**Real-life Connection:** There are several real-life connections in this lesson. As noted above, the lesson will be part of larger unit teaching students about the Design Engineering Process. Once students have developed an understanding for this Design Engineering process, they will also learn about how it is relevant to many careers in engineering.

Furthermore, alternative energy is a relevant and important concept in today's society. This lesson will assist in students depth of understanding as it relates to this issue and the positive impact that alternative energy sources will have on the environment and their futures.

**Possible Misconceptions:**

Possible misconceptions about engineering:

- There is only one kind of engineering.
- It is too difficult.
- It is a job for males and not females.

Possible misconceptions about windmills/ wind turbines:

- They are loud.
- Wind turbines are dangerous for birds.
- Wind turbines are an unreliable energy source.

**Lesson Procedure:**

5E Model	5E Objectives
<p><b>Engage</b></p> <p>This engage phase of the lesson is meant to grab students' attention and spark curiosity about the phenomena and topic.</p>	<p><b>Procedure:</b> Upon entering the room, students will be seated in the front of the room where we typically begin our class. On the board, the picture(s) of the off-shore wind farm near Rhode Island will be displayed. Students will be asked to make some observations about what they are seeing. This will allow for pre-assessment of students' knowledge of alternative energy and wind turbines.</p> <p>Using Google Classroom, the image and a link to a Jamboard will be provided. Students can post ideas about what they see in the picture. After briefly discussing the ideas, additional discussion questions will be posted and discussed using think-pair-share. A classroom discussion will follow to exchange ideas. Teacher will read aloud the picture book version of "The Boy Who Harnessed the Wind". Students will be asked to listen for evidence from the text that explains how windmills work. Watch video of Willaim Kamkwamba's story.</p> <p>Finally, the teacher will review the Engineering Design Process with students and present them with their design challenge. (attached at the end of lesson).</p> <p><b>Modifications</b> Fidget toys for students who have a tough time sitting still, voice to text and/or visual accessibility features enabled on Chromebook, closed captioning for video.</p> <p><b>Standards Addressed:</b></p> <p><b>3.4.5.E3</b> Explain how tools, machines, products, and systems use energy in order to do work.</p> <p><b>7.4.5.A</b> Describe and explain the effects of the <b>physical systems</b> on people within <b>regions</b>.</p> <p><b>3-5-ETS1-1.</b> Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.</p> <p><b>Formative/Summative Assessments</b> observation, evaluation of Jamboard responses, textual evidences cited from read a loud.</p>

	<p><b>Resources</b></p> <p><a href="#">Week 1: 5<sup>th</sup> Grade Enginneering: Windmill Challenge Google Slide</a></p> <p>Kamkwamba, W., &amp; Mealer, B. (2012). <i>The Boy Who Harnessed the Wind</i>. Dial Books for Young Readers.</p> <p><a href="#">Moving Windmills: The William Kamkwamba Story</a></p>
<p><b>Explore</b></p> <p>Now that students' are engaged in the topic, they will have the opportunity to explore and learn more, building their own understanding and background knowledge prior to the Engineering Design Project.</p>	<p><b>Procedure:</b> Again, the wind farm phenomena will be presented to students. Look at additional pictures of wind powered machines and make observations. Students will hop back into the Jamboard from the previous class. A new slide will be added and students will again add what they see in the picture. This time, they will be more successfully in identifying and explaining what is happening in the picture. (Naming the wind turbines and their purpose)</p> <p>As a class we will review the Desing Engineering Process and discuss the importance of conducting further research before they generate a plan to create a windmill prototype.</p> <p>Sharing via Google Classroom, students will access the Wonderopolis lesson: What is a Wind Farm?. They will conduct their research in partners by reading the text, watching the videos, and viewing the images on the lesson. This will empower them to build their knowledge as they begin to think about how they are going to prototype their own windmill for the engineering challenge.</p> <p>After students have had sufficient time to complete their research, they will be asked to access the link to The US Wind Turbine Data base. With the knowledge they have just learned, they will navigate the "viewer" feature on the map to explore the geographical locations of all wind farms across the US. Each group will be challenged to locate a wind farm in our region. Questions that students will respond to while viewing the map are as follows:</p> <ul style="list-style-type: none"> <li>• What geographical location has the highest density of wind fams in the US?</li> <li>• How would you explain the reason for this?</li> </ul>

	<ul style="list-style-type: none"> <li>• Once you have located a wind farm in our region, think about how it can positively/negatively impact the people in region.</li> </ul> <p><b>Modifications:</b> Enabling text to speech or visual accessibility features for completion of the research. Use of Immersive Reader on Wonderopolis website. Enabling closed captioning for the videos. For early finishers, the teacher will attach additional, more in-depth research for students to explore.</p> <p><b>Standards Addressed</b></p> <p><b>3.4.5.E3</b> Explain how tools, machines, products, and systems use energy in order to do work.</p> <p><b>ITEEA:</b> Explain how technologies are developed or adapted when individual or societal needs and wants change.</p> <p><b>7.4.5.A</b> Describe and explain the effects of the <b>physical systems</b> on people within <b>regions</b>.</p> <p><b>Formative/Summative Assessments</b> Observation, Jamboard responses, engagement with research material, and successful location of a wind farm in our region.</p> <p><b>Resources</b></p> <p><a href="#">Wonderopolis Lesson: What is a Wind Farm?</a></p> <p><a href="#">Additional Research for Early Finishers</a></p> <p><a href="#">The US Wind Turbine Database</a></p>
<p><b><u>Explain</u></b></p> <p>In this phase, students will have the opportunity to make</p>	<p><b>Procedure:</b> At the start of class, the phenomena will once again be displayed and students will respond on a slide on the class Jamboard. Students will now be identify it as a wind farm, explain the purpose, and the reason for the geographical location of wind farms.</p> <p>As a class, we will revisit the Engineering Design Process challenge as well as the materials and constraints for the challenge. The class will also briefly discuss the importance of torque, aerodynamic, efficiency, and torque.</p>

<p>sense of all they have learned about windmills and wind farms in the US. They will now use this background knowledge to make a plan for their Design Engineering challenge.</p>	<p>Students will be divided into groups of 2 or 3 and they will use all of the knowledge that they have learned about windmills to begin designing their prototype. They will use the Google slide shared in their Google Classroom to collaborate as a group to complete the planning guide. This will include brainstorming solutions and choosing one of those designs. Once they have selected the design, teams will decide which materials they will use and sketch their design.</p> <p>Planning guides will be collected at the end of class to be redistributed at the start of the next class.</p> <p><b>Modifications</b> Providing students with specific jobs within their groups to ensure engagement of all students including the more reserved/hesitant students. Extended planning time. Assistance in facilitating the communication in groups as needed.</p> <p><b>Standards Addressed</b></p> <p><b>3-5-ETS1-1.</b> Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.</p> <p><b>ITEEA:</b> Practice successful design skills.</p> <p><b>ITEEA:</b> Apply the technology and engineering design process.</p> <p><b>Formative/Summative Assessments</b> Jamboard responses, completion of planning guides</p> <p><b>Resources</b></p> <p><a href="#">Windmill Prototyping</a></p> <p>Engineering Design Challenge Planning Page: Anderson, M. (n.d.). <i>Design A Windmill</i>. teacherspayteachers. <a href="https://www.teacherspayteachers.com/Product/STEM-Activity-Windmill-STEM-Challenge-3179080">https://www.teacherspayteachers.com/Product/STEM-Activity-Windmill-STEM-Challenge-3179080</a></p>
--	--

<p><b><u>Elaborate</u></b></p> <p>In this phase, students will apply their knowledge of the Engineering Design Process and wind turbines to create their prototype of a windmill that can spin freely.</p>	<p><b>Procedure:</b> Planning guides will be redistributed to groups. They will spend the majority of the class period building and testing their prototypes.</p> <p>They will collect materials needed for their design. Once assembled, they will test the windmill using a fan. If the windmill spins freely, they will work on improving efficiency. If the windmill does not spin freely, they will discuss possible improvements. Throughout the class period, each group will complete up to 4 trials. The teacher will be facilitating the process, but this is designed to be almost entirely student centered.</p> <p>When finished, the engineers will be asked to reflect on their prototypes, make recommendations for improvement and share those ideas with their peers. The last stage of the planning guide requires students to make improvements for their design. When the challenge is complete, students will work collaboratively with group to discuss what worked and what did not as well as ideas for improvement.</p> <p>Students will access the Jamboard one final time to share their ideas of improvement. This will be followed by a brief class discussion. Finally, the class will be asked to look back on the progression of knowledge on the Jamboard slides to celebrate how much they have learned.</p> <p><b>Modifications</b> Providing students with specific jobs within their groups to ensure engagement of all students including the more reserved/hesitant students. Extended building time. Assistance in facilitating the communication in groups as needed</p> <p><b>Standards Addressed</b></p> <p><b>3-5-ETS1-1.</b> Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.</p> <p><b>3.4.5.D1</b> Identify ways to improve a design solution.</p> <p><b>ITEEA:</b> Evaluate designs based on criteria, constraints, and standards.</p>

	<p><b>ITEEA:</b> Practice successful design skills</p> <p><b>Formative/Summative Assessments</b> observation, completion of challenge</p> <p><b>Resources</b></p> <p>Engineering Design Rubric</p> <p>Anderson, M. (n.d.). <i>Design A Windmill</i>. teacherspayteachers.  <a href="https://www.teacherspayteachers.com/Product/STEM-Activity-Windmill-STEM-Challenge-3179080">https://www.teacherspayteachers.com/Product/STEM-Activity-Windmill-STEM-Challenge-3179080</a></p>
<p><b>Evaluate</b></p> <p>This phase will take place throughout all 4 weeks and will allow both students and the teacher to determine acquisition and application of knowledge.</p>	<p><b>Procedure:</b> The teacher will evaluate students formatively throughout the course of the 4 weeks, adjust instruction as needed. As a summative evaluation, a performance rubric will be used.</p> <p>Through observation and discussion responses based on higher level questions, the teacher will determine students understanding and application of concepts taught over the 4 week period.</p> <p><b>Modifications</b> Extended time for completion of creating, testing, improving, and sharing phase.</p> <p><b>Formative/Summative Assessments</b> Engineering Design Performance Rubric</p> <p><b>Resources</b></p> <p>Engineering Design Rubric</p> <p>Anderson, M. (n.d.). <i>Design A Windmill</i>. teacherspayteachers.  <a href="https://www.teacherspayteachers.com/Product/STEM-Activity-Windmill-STEM-Challenge-3179080">https://www.teacherspayteachers.com/Product/STEM-Activity-Windmill-STEM-Challenge-3179080</a></p>

**Teacher Background:** The teacher must have a deep understanding of this history of windmills and their evolution, wind energy, wind turbines, wind farms, and the Engineering Design Process. The following can be used to build that knowledge:

[History of Windmills](#)

[The Evolution of Wind Turbines](#)

[Why do wind turbines have 3 blades?](#)

[The US Wind Turbine Database](#)

[Save on Energy](#)

[Engineering Design Process](#)

[Several additional videos on wind turbines](#)

**\*\*All resources are linked within the lesson and therefore not attached to the end of the lesson**