**Lesson Plan: Using Wind Energy to Solve Power Outage Problem in Puerto Rico**

**Grades**: 9-12

**Time**: 2 weeks / 6 face to face hours

**Concept**: Physical Science and Engineering Design

**Overall Goa**l: Students already have the background on renewable and nonrenewable energy resources. The main goal of this lesson is threefold: 1) It will help students develop a deeper understanding of wind as a nonrenewable resource and pros and cons of using wind power to produce electricity; 2) It will engage students in engineering design challenge to understand the ways engineers think and the processes they engage in while providing solutions; and 3) It will help students make connections between classroom learning experiences and everyday life and recognize ways STEM professionals add to our quality of life.

**Learning Objectives**: Students should be able to,

*Science Content*:

* Explain the use of wind power as a renewable source to supply electricity to a community park, to local communities, and communities around the world
* Explain how wind turbine works -generates electricity
* Measure the DC current in a circuit
* Measure the DC voltage across an electrical component.
* Calculate the power dissipated by a DC motor

*Engineering Practices:*

* Design, build, and refine a wind turbine to increase its efficiency
* Explain how the design of a wind turbine affects the electrical energy produced by it

*Communal Goals:*

* Engineering helps solve large and small problems that we encounter every day, such as developing renewable wind energy technology to supply electricity
* Children and adolescents, like engineers, can improve an existing wind turbine design through the creative process of thinking, building, testing, and refining
* Explain the environmental and societal impact of their wind turbine on the Puerto Ricans’ quality of life
* Explain in what ways their project serves the community
* Explain how working effectively as a team can help engineers and scientists serve a community better

Materials: Internet access, card boards, PVC pipes or ruler, multimeter, handouts, fan with 3 settings, scissors, tapes, toy DC motor, thin electrical wires, wires with alligator clips, rulers.

**Procedures**

**Opening:**

This lesson plan contains four connected activities. Start with pre-assessment using a whole class discussion format. Target each group of learning objectives stated above and take notes on a poster board when necessary. Make these notes available in the class throughout the activity.

**Pre-assessment of the Science Content:** Start the pre-assessment by reviewing what they already know about the renewable and non-renewable energy resources. Students should provide examples (ocean, wind, coal, natural gas) and explain why they can be considered as renewable or non-renewable. Finally, they should be able to explain the pros and cons of renewable and non-renewable energy resources.

Pre-assessment should continue with specific attention on wind as a renewable energy resource. Ask students to share what they know about wind and how it can be used to produce electricity/power for homes, schools, parks, etc. Show an image of various wind turbines (or an image of a horizontal wind turbine as students are mostly familiar with this design) and ask if and what they know about it.

**Pre-assessment of the Engineering Design:** Ask students what engineers do and what their perceptions of how engineers work. Ask probing questions based on students’ responses (e.g., what motivates an engineer to start a project?). Who can be an engineer (Alternatively, how does culture, gender, ethnicity, language, etc. impact who can be an engineer)?

**Pre-Assessment of the Communal Goals:** Ask students their opinion on how scientists and engineers serve the community and share examples. Finally, how they perceive the work of engineers and scientists: Collaborative? Or Solitary? Ask them to provide reasoning.

After pre-assessment, teacher shares all of the learning objectives with students and briefly explains that they will work as small groups of scientists and engineers to provide a solution for the power outage that Puerto Ricans are experiencing since hurricane Maria. To accomplish this goal, they will learn about wind as a renewable energy source, build an efficient wind turbine, identify appropriate location for their wind turbines on the island and communicate their proposal or solution to the Puerto Ricans. Since issues around energy often relates to environmental issues, they will need to consider how they need to communicate their findings to environmentalists as well.

Provide the handouts to the students and ask one or more students to volunteer to read the scenario stating the problem out loud. Teacher then asks probing questions to check what students took away from the text and to focus students’ attention to the next task. These questions include but not limited to the following,

* How did Hurricane Maria affect the life in PR?
* What seems to be biggest problem for the Puerto Ricans?
* What have been done to address the island’s electricity problem in the past? How did the community members and environmentalists react to the previous solution ideas?
* How can you as small groups of engineers and scientists work together to solve Puerto Ricans’ power outage problem? Provide suggestions.
* As the small groups of engineers and scientists, what do you need to know to be able to propose a solution to the islanders?
* Who are your audience? In other words, who do you need to convince to be able to enact on your solution?
* How should you go about presenting your proposals/solutions to receive support for your project?

**PART 1. Wind Power and Wind Turbines**

In the first part of the lesson, students are put in small groups of 3s or 4s. Each group is given a notebook/iPad or a computer to visit the Internet links provided by the teacher to learn about wind power and wind turbines.

* Video: http://www.pbs.org/video/nova-wind-power/
* https://www.awea.org/wind-power-101
* http://www.pbs.org/now/science/wind.html
* https://www.energy.gov/eere/wind/how-do-wind-turbines-work
* Cost comparison: http://www.pbs.org/now/science/wind2.html#costs
* Wind turbine works: https://www.youtube.com/watch?v=EYYHfMCw-FI&t=1s

 As they gather information, they are encouraged to think about these questions:

* Why would global community need to come up with alternatives to fossil fuels?
* What are the benefits of wind power as an alternative energy resource?
* What drawbacks do you see?
* In what ways can power production be compared to a crop?
* In what ways can using wind power can help with economy?
* What is a wind turbine? What does it do?
* What are the parts of a wind turbine? What is the function of each?

Once the online investigations are completed, groups prepare their brief statements for the raised questions. They then share their perspectives with other groups. Teacher follows the patterns in students’ statements and notes the highlights on a poster board, which s/he makes it available in the classroom throughout the lesson.

**PART 2. Building, Testing, Evaluating and Refining a Wind Turbine**

Teacher presents the engineering design framework: Define (Attend to precision of criteria and constraints and considerations likely to limit viable solutions); Develop Solutions (Combine parts of different solutions to create new solutions); and Optimize (Use systematic processes to iteratively test and refine a solution).



Directly copied from Appendix I. Engineering Design in *NGSS* (p. 5).

Teacher emphasizes that constructing a wind turbine is not sufficient enough to be successful based on this framework. Students must identify the problem that they are to solve, understand the limitations they may face during the process, test the effectiveness of their model, and refine it until it is considered efficient in producing energy. Students discuss what it means for wind turbine to be “efficient.” They review the provided materials and determine the value they read on the voltmeter will indicate how much electricity their wind turbine produces. The higher the value they read on the voltmeter, the more the amount of electricity they produce, and the more efficient the wind turbine is. Tell students that the group that designs the most efficient wind turbine will be awarded. Since each group receive the same materials, the wind turbine that produces the highest voltage should win the design competition.

Next, groups build their wind turbines by using the provided instruction on the handout: <https://www1.eere.energy.gov/education/pdfs/wind_basicpvcwindturbine.pdf> (pages 3-6). Upon completion, they should test how their wind turbines work and how much energy is produced.

Then they should experiment with variables, such as **length, width, weight, numbers, and/or angles of blades**, to determine the most efficient design. In this phase students will engage in testing, redesigning, re-testing, and refining activities until they are satisfied with their final design. Each group’s wind turbine will be tested by placing them 20 cm from an artificial wind source, such as a fan, and measure the voltage produced for 30 seconds. Each turbine will go through at least three trials so that an average voltage can be calculated. The design that produces the greatest number of average volts win the design challenge.

**Part 3. Determining the Best Location for the Wind Turbines**

Now that each group has a wind turbine, they need to investigate and make a decision as to where on the island the turbines should be located. To understand this, students will be engaged in another investigation in which they will answer the question, *How do scientists and engineers decide where to place the wind turbines?* Through a structured inquiry activity, students will determine the effect of the 1) distance between the fan and the wind turbine, and 2) wind speed (fan setting) on the voltage generated by their wind turbine. Students will use the Claims-Evidence-Reasoning (CAR) framework to report their findings. They will discover that more energy is generated when the fan is closest to the wind turbine, which then indicates that the wind turbines should be placed in windy areas or in locations with guaranteed wind.

Upon this completion of this investigation, students will be provided with online maps revealing the average yearly and seasonal wind resource estimates for Puerto Rico (<http://rredc.nrel.gov/wind/pubs/atlas/maps.html#2-6>). These maps are very helpful in locating the regions on the island where the wind is very reliable, and thus make it easier for students to provide suggestions for locations. To provide students with opportunities to develop scientific explanations, they will use CAR framework to propose a location for their wind turbines on the island.

CLAIM: What is your suggested location(s)?

EVIDENCE: What evidence/data from the maps did you gather to answer this question?

REASONING: How does your evidence support your claim?

**PART 4. Presentation to the Community**

Now that students have a wind turbine that has been tested and refined for efficiency and have developed an understanding of its advantages and disadvantages and where it should be located, it is time for the groups to prepare a presentation to propose their project to the island community and environmentalists. Students should use a visual media (e.g., posters, PowerPoint, Prezi, etc.) to communicate their project. Groups should be encouraged to revisit the work they completed in previous parts (e.g., pros and cons of using wind power and wind turbines to produce energy) as they develop their argument as to how their project will help the community in short-term and long-term. Each group makes their presentations one by one while the rest of the students pretend to be the community members and environmentalists to assess the effectiveness of the project and the presentation. Audiences are encouraged to provide constructive feedback to the presenters. Once the presentations are done, teacher should bring students together as whole class to review what they learned from various aspects of the lesson.

**Whole Group (In-Class) Discussion to Address Communal Goals**

Teacher should address the communal goal learning objectives presented at the beginning of the lesson via these questions:

* In what ways did you as a team of scientists and engineers work together to serve the people of Puerto Rico?
* What are the environmental and societal impact of your wind turbine on the Puerto Ricans’ quality of life?
* What are some societal considerations that engineers would make in designing and constructing wind turbines?

**Out-of-Class Reflection to Address Communal Goals**

The following questions will make students focus on the two aspects of communal goals:

* Explain what other ways engineering and engineers help humanity and communities every day? Give examples.
* In what ways did you work like engineers in the Wind Power activity? In the light of your in-class experience, who can be an engineer?
* Explain how working effectively as a team can help engineers and scientists serve a community better.
* How did today’s lesson affect the way you think about who scientists and engineers are, how they work, and what they do?

**Part 1. Rubric/Checklist**

3-Excellent, 2-Satisfactory, 1-Needs Improvement

Understanding of the content: \_\_\_\_\_\_

Quality of the answer : \_\_\_\_\_\_

Group Work : \_\_\_\_\_\_

**Part 2 Rubric**

|  |  |  |  |
| --- | --- | --- | --- |
| Criteria | Excellent(3) | Satisfactory(2) | Need Improvement(1) |
| Variables  | All variables were correctly identified. | Most of the variables were correctly identified. | Few of the variables were correctly identified. |
| Investigation | All variables were manipulated or controlled accurately. Data collection was reliable. | Variables were manipulated or controlled accurately most of the time. Data collection was reliable. | Variables were manipulated or controlled incorrectly most of the time. Data collection was not reliable.  |
| Conclusion | Conclusion was well-articulated and explained how the most efficient design was determined. | Conclusion explained the final design as the efficient design but how it was selected wasn’t explained. | Conclusion did not clearly explain how the most efficient design was determined. |
| Group Work | Group members worked together effectively. | Group members worked well together but some had more responsibilities than others. | Group members weren’t well-prepared to present together or were distracted during the investigation. |

Part 3 Rubric

|  |  |  |  |
| --- | --- | --- | --- |
| Criteria | Excellent(3) | Satisfactory(2) | Need Improvement(1) |
| Investigations | All variables were manipulated or controlled accurately. Data collection was reliable. | Variables were manipulated or controlled accurately most of the time. Data collection was reliable. | Variables were manipulated or controlled incorrectly most of the time. Data collection was not reliable.  |
| Conclusion | Conclusions were well-articulated and final answer was justified with the findings.  | Conclusions were based on the investigations, but final answer wasn’t clearly tied to the findings. | Conclusions were not well-stated and/or the final answer wasn’t based on the findings.  |
| Group Work | Group members worked together effectively. | Group members worked well together but some had more responsibilities than others. | Group members weren’t well-prepared to present together or were distracted during the investigation. |

Part 4 Rubric

|  |  |  |  |
| --- | --- | --- | --- |
| Criteria | Excellent(3) | Satisfactory(2) | Needs Improvement(1) |
| Strength of the Proposal | All arguments were supported by evidence gathered from the online and experimental investigations.  | Arguments were mostly supported by the findings and the online investigations. | The arguments were not clearly supported by the online and/or experimental investigations.  |
| Clarity | Information provided and the proposal was very clear for stakeholders to make a decision. | Information provided and/or the proposal was somewhat clear for stakeholders to make a decision.  | Neither Information provided nor the proposal was clear enough for stakeholders to make a decision.  |
| Use of Visual Media | The visual media was effectively used to present the ideas clearly and effectively. It was engaging and interactive. | The visual media used had interesting images, diagrams, charts, etc. but wasn’t engaging enough.  | The visual media was not engaging nor was it interactive.  |
| Group Work | Group members worked together effectively to present their proposal. | Group members worked well together but some had more responsibilities than others. | Group members weren’t well-prepared to present together or were distracted during the presentation.  |
| Enthusiasm | Group members were very enthusiastic about their ideas and presented with great energy. | Group members were enthusiastic about the ideas but the presentation lacked energy. | Group members did not show any enthusiasm toward their presentation. |

Communal Goal Reflection Rubric

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| --- | --- | --- | --- |
|  | Excellent(3) | Satisfactory(2) | Needs Improvement(1) |
| Quality and Clarity of Prosociality Aspect  | Student developed informed understanding about how STEM fields and professionals help others. ANDStudent made clear connections by providing examples from the lesson and/or real life.  | Student recognized how STEM fields and professionals help others. ANDStudent made connections that were too vague or not articulated strongly enough.  | Student did not recognize how STEM fields and professionals help others. ORStudent did not make any connections between communal goals and the lesson.  |
| Quality and Clarity of Collaboration Aspect | Student developed informed understanding that STEM is a collaborative endeavor. ANDStudent made clear connections by providing examples from the lesson and/or real life.  | Student recognized that STEM is a collaborative endeavor. ANDStudent made connections to lesson or real life that were too vague or not articulated strongly enough.  | Student did not recognize collaborative nature of STEM. ORStudent did not make any connections between communal goals and the lesson or real life.  |