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| **Title** | Using model generators to explore alternative energy |
| **Introduction** | Where does electricity come from? For many students, the answer is obvious: “an outlet!” However, when they are asked to trace the route to the outlet back further, some students will follow the electric lines back to a power plant, and there the trail often goes cold. When comparing and assessing alternative energies, it can be difficult to get students to move beyond the obvious, largely because they don’t really understand how power is generated.  In this lesson, students experiment with model generators to answer the question, “Where does electricity come from?” They then apply that knowledge by viewing and reading case studies about innovations in power generation. The students identify what energy source is turning the generator and what aspect of generation is being improved in each innovation. |
| **Curriculum Alignment** | North Carolina New Essential Standards:  High School Earth & Environmental Science:  EEn.2.8.1: Evaluate alternative energy technologies for use in North Carolina  8th Grade Science:  8.P.2.1: Explain the environmental consequences of the various methods of obtaining, transforming, and distributing energy. |
| **Learning Outcomes** | Students will be able to describe how electricity is generated and identify possible sources of energy to turn generators.  Students will identify the parts of a generator and suggest modifications to existing designs that would make generators produce more electricity.  Students will evaluate scientists’ innovations and identify the technical aspects that help improve electrical generation. |
| **Time Required and Location** | Making the generators: 90 minutes  Lesson: 90 minutes  Due to time and materials constraints, I would not recommend that each class make generators. Ideally, a school Science Club or Science Olympiad team might take on the actual construction in one of their meetings. If this is not an option, building the generators could be a task for a class that is ahead in pacing, or an activity to fill in an extra block of time (with a homeroom, for example). |
| **Materials Needed** | Building the generators:Each Generator:  * 4 - 1x2x5cm [ceramic](http://amasci.com/coilgen/rsmagnet.html) magnet: [Edu. Inv M-700](http://www.teachersource.com/ElectricityAndMagnetism/Magnets/CeramicMagnets.aspx) or [R Shk #64-1877](http://www.radioshack.com/product/index.jsp?productId=2102689), or [HFT](http://www.harborfreight.com/cpi/ctaf/displayitem.taf?itemnumber=97504&Submit=Go), or [CMS](http://www.magnetsrc.com/ceramic_ferrite_block_magnet.htm) * 1 - #30 Magnet wire 200ft, [Rad. Shack 278-1345](http://www.radioshack.com/product/index.jsp?productId=2036277), or cheaper from [other stores](http://amasci.com/coilgen/generator_3.html#onewire) (if you get the multi-pack from Radio Shack, use all three types, and make wire thickness one of the variables your students investigate) * 1 - Miniature Lamp, 1.5V 25mA Rad. Sh. #[272-1139](http://www.radioshack.com/product/index.jsp?productId=2102813) * 1 - Cardboard strip, 8cm x 30.4cm (or notched popsicle sticks and wood glue, or plastic drinking straws and a single-hole punch) * 1 - Large nail, 8cm long or more * Small pieces of cardboard or washers to help space the magnets around the nail   General Tools:   * Scissors for cutting cardboard/popsicle sticks/straws, and stripping the insulating coating from the ends of the wire * Tape to hold wire down and magnets together * A ruler * Wood glue (for popsicle stick frame generator) * Plastic drinking straws and a single-hole punch (for the straw frame generator)   Classroom Activity: Multimeters; one per group (optional; students may use qualitative terms such as easy to light, difficult to light, does not light at all if these are not available. If you are not using multimeters, make sure students only test variables that show a strong difference (speed of turning, gauge of wire, number of coils)Alligator clips; two per group (for use with the multimeter)Handheld whiteboard or large piece of paper: one per groupDry-erase or regular marker: one per groupCopies of energy innovation articles: one per studentScience notebook/paper to record observations and results: one per student **Technology resources**   * Computer with projector to show TED talk (optional) |
| **Safety** | Make sure students are careful with electricity. |
| **Facilitator Preparations** | Build GeneratorsSchedule a meeting with an after school club to build the generators. Decide if they will all be the same design, or if you will allow students to design their own. The cardboard model is the most basic, but the cardboard insulates the wires from the magnetic field. Both the popsicle stick and the straw design have less problems with insulation, but take a little longer to construct. The popsicle stick design requires some time for glue to dry, and may work best if the project is spread between two meetings. The straw design does not require any time to dry, but is not as sturdy as to popsicle stick design.Click on the picture of each design for building instructions; the links will provide both diagrams and written directions on how to construct the generators.  Or, if you have the funds, purchase a kit from a source such as http://www.miniscience.com/projects/KITWG/index.html |
| **Activities** | **Explore:**  Model how to spin the axel to make the generator light the bulb. Each person in each group should practice.  Demonstrate how to use multimeter; use AC 2V setting, as the voltages are extremely low. This measurement works best when the probes are attached to the wire with alligator clips. By nature, the output of the generators will be highly variable. For each test, the groups should record the highest voltage observed under the conditions being tested. Explain that not every generator will (necessarily) produce a measureable current.  Rotate the models through the groups, so that each group sees each model. While testing, students record observations of how well various models work in an I Notice/I wonder chart.  As a class, share observations and discuss factors necessary for a successful generator.  Students may observe the voltage necessary to light the bulb (0.5 V to light dimly, 1.0 V to light brightly), that the thinner wire appears to work better, that open-framed models work better, that all models have spinning magnets coiled in wire. They may wonder what would happen if the coil had been wrapped in the lengthwise direction (across the openings of the box—it would not work), or how many coils are required for the generator to work, or why the magnets are taped together (so they align and spin w/o hitting the sides of the box).  **Model System**  Using their observations of characteristics of a successful generator, each group should choose one variable to investigate further:  -*speed of turning (slow, medium, fast)*  *-thickness (gauge) of wire (thin, medium, and thick-correspond to red, green, and copper colors respectively, if you used Radio Shack wire)*  *-number of coils*  *-type of case (cardboard vs. popsicle stick or cardboard vs. straw)*  *-strength of magnets (they will need to remove the outer two magnets to test this: 2 vs. 4 magnets)*  *-space between the magnets and the wire*  *-having spacers to keep the magnet properly aligned*  If you are pressed for time, only test the turning speed of the axel, and graph the results as a class.  Each group will investigate their variable, and make a graph of variable vs. mV on chart paper or large whiteboard or laminated white poster. Each group will offer a possible explanation for the relationship they graphed (it may be helpful to have computers or texts on hand for the students to use for reference).  The students will then take a gallery walk and observe the results from each group. Each student should have three green tabs, two yellow tabs, and one red tab. Students will place the green tabs next to explanations they agree with, yellow tabs next to explanations they don’t understand, and the red tab next to an explanation they disagree with.  **Content Wrap-Up**  Discuss the feedback from the gallery walk. Give students the opportunity to pose and answer questions about the data assembled. As the students discuss their results, encourage them to support their claims with evidence from their data.  Class discussion questions:  -What is electrical current?  *Moving electrons*  -Which part of the mechanism provides the electrons for the current?  *The wire*  -What part of the mechanism moves the electrons, thus generating a current?  *Spinning magnets; just as a magnet can move a paper clip across a desk without touching it, the magnet moves the electrons in the wire with its magnetic field.*  -Where does the energy that creates the electricity come from?  *Manual rotation of the axel*  Few generators are manually rotated like our models. Most have a turbine attached to the axel. (Show the class a turbine attached to the axel of the generator). However, the speed of rotation is still the key factor that determines how much electricity is generated.  What could make the turbine spin?  *-wind*  *-rivers*  *-ocean currents*  *-tides*  *-heat/steam (from nuclear reactions or burning coal, wood, trash, manure)*  Explain that better generators don’t need to turn as fast, and so can generate current with slower moving energy sources, like tides and currents. Rank the sources of energy from fastest to slowest: *steam, rivers, wind, ocean currents, tides*.  **Guided Practice**  Ask students:  Choose one model generator you worked with, and describe it.  How would you modify it to make it produce more electricity?  Watch [Saul Griffith’s TED talk](http://www.ted.com/talks/lang/eng/saul_griffith_on_kites_as_the_future_of_renewable_energy.html) (5 minutes), and discuss his innovations:  What source of energy is this generator using?  *Wind*  Did Saul Griffith change the generator or the turbine?  *The turbine*  How did he change the turbine to increase the amount of electricity produced?  *He made the generator turn faster by moving the kite through a wider arc than a turbine blade*  Divide students into groups, have them read [energy articles](file:///C:\Documents%20and%20Settings\mpmisura\Local%20Settings\Temp\EnergyArticles.docx), and decide what source of energy is turning the generators, and what innovation is increasing the amount of electricity produced. |
| **Assessment** | Informal assessment:   * Students’ graphs and explanation of the variable they examined * Oral or written responses describing the source of energy and innovation used in the guided practice energy articles   Formal assessment:   1. What part of a generator creates electricity?   *The spinning magnet*   1. Which part of the generator provides electrons which are moved by a magnetic field?   *The wire*   1. What does a turbine do?   *It translates linear motion into rotational motion/it spins the magnets*   1. What sources of energy can turn a turbine?   *Wind, water, humans, steam (from nuclear, coal, biomass)* |
| **Critical Vocabulary** | Turbine: a device that rotates as a fluid (steam, gas, air, or liquid) flows through  Generator: a device that uses the motion of a magnetic field to create electricity |
| **References** | William Beaty’s how to build a generator: <http://www.amasci.com/amateur/coilgen.html> KidWind page on how to use a multimeter: [learn.kidwind.org/sites/default/files/**poweroutput**.pdf](file:///C:\Documents%20and%20Settings\mpmisura\Local%20Settings\Temp\learn.kidwind.org\sites\default\files\poweroutput.pdf) Saul Griffith’s TED Talk: <http://www.ted.com/talks/lang/eng/saul_griffith_on_kites_as_the_future_of_renewable_energy.html>Energy innovation articles:Generators in prayer wheels: <http://inventorspot.com/articles/innovative_electricity_generator_powered_prayer_27251>Magnetic levitation wind turbine: <http://inhabitat.com/super-powered-magnetic-wind-turbine-maglev/>Innovative design for residential power generation: <http://www.sciencedaily.com/releases/2006/08/060822173021.htm>Capturing energy from slow-moving currents: <http://www.alternative-energy-news.info/renewable-energy-from-slow-water-currents/> |
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