**Understanding By Design – Backwards Design Process**

(Developed by Grant Wiggins and Jay McTighe, 2002)

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| **Stage 1 – Desired Results** | |
| **Content Standard(s):**  **National Science Education Standards, Physical Science 9-12 http://www.nap.edu/catalog/4962.html**  Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators. Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators.  Abilities of Technological Design | |
| **Understanding (s)/goals**  Students will understand that:   * Motors and generators can be simple devices that work on a set of related principles. | **Essential Question(s):**   * How is electricity generated? * How can a wind turbine be designed for optimal electrical output? |
| **Student objectives (outcomes):**  Students will be able to:   * Identify the major components in a generator and explain the function of each. * Collect and evaluate the effect of at least two (2) variables on wind turbine electrical output. * Use scientific data to guide the design process. | |
| **Stage 2 – Assessment Evidence** | |
| **Performance Task(s):**   * Given access to appropriate materials, build a simple generator from scratch. * Build a wind turbine that meets baseline performance criteria (such as at least 1.0 V, unloaded, at a specified wind speed or fan setting) | **Other Evidence:**  Create a journal that chronicles the design process and documents at least two (2) required “bench tests”. |
| **Stage 3 – Learning Plan** | |

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| **Learning Activities:**  **Lesson #1: Exploring a Generator**  *In this lesson students will develop a conceptual understanding of how a generator works (a logical precursor to building a wind turbine generator). Myriad approaches to this learning goal can be made, one of which is detailed here.*  Students are shown the procedure for measuring electrical potential (“voltage”) in the DC millivolt range via voltmeter (analog or DMM), voltage sensor (i.e. Vernier, PASCO, etc.), or other method (for this reason a simple bulb circuit as a voltage detector would not be appropriate). A battery cell might be used as the object to be tested.  Once students are comfortable with this standard for evaluating the presence of electric potential, students are then asked to see if they can find a way to create a device which produces enough electric potential to be measured. They are supplied with magnets and magnet wire. It might be appropriate to display one of the DC motor/generators (with the cover removed which will show the armature winding and permanent magnet) to be used in the wind turbine at this time if students need some “inspiration” to get started.  The teacher might also provide a method of improving on the electrical output from the most basic designs. Some ideas are:   * Provide a film canister cylinder in order for students to wrap multiple turns of wire as the armature coil. * Pre drill a small hole in the canister to accommodate a bamboo skewer “rotor shaft” to be inserted through the canister and rotated through the magnetic field at higher rates. * Provide a stronger magnetic field. Powerful neodymium rare Earth magnets can be clamped in place at a distance slightly greater than the diameter of the film can.   The ultimate learning goal is only that students observe that the necessary conditions for electromagnetic induction are:   1. A magnetic field 2. A conductor 3. Relative motion between the two.   **Lessons #2-5: Introduction to the Wind Turbine Contest**  *In this lesson students will be introduced to the DC hobby motor, which will be used as a generator when attached to the turbine rotor and blades. The students should have a strong conceptual understanding for how the device will work as a generator from the previous lesson. The introductory discussion sets the stage for three to four subsequent class blocks.*  Students will observe a pre-assembled working model of a wind turbine using the KidWind™ ([www.kidwind.org](http://www.kidwind.org)) crimping hub, Mabuchi™motor, PVC stand, wooden dowels and fan blades. Although a school-wide competition is encouraged, each student will be evaluated on their individual journal and not on the electrical output of their generator. It is important to establish this in the introductory discussion so that the focus is on developing a design process that is data-driven and deterministic. In practice this is often difficult for students to do and many are prone to whimsical design (selection of variables) and fatalistic outcomes based on observations of other wind turbines, hunches, and gut-feelings. One of the primary goals of the project is for students to use data to determine their variable selection (optimization).  Handout:  Your journal will be a record of the design process for your team’s wind turbine. It will communicate your ideas and what your have considered, tested, and adjusted prior to the competition. The document will be turned in as a hard copy for evaluation (for a group grade), so it is important that you share and maintain the document throughout the design process.  A. **Formatting Requirements**   * The journal should be either a spiral notebook, three-ring binder, or binder-clipped papers. * It must have a cover that has all of your group member’s names neatly printed on it. * The top of each page should be a date entry. Always start each new date entry on a fresh page. * An entry should be a brief description of what your group did on that day. * All sketches, test results, graphs, or other documentation should be added to the design journal in its proper chronological location.   B. **Essential Questions / Variables**  *What will be the shape of your blades?*  *How many blades will your team make? Are two blades better than three? Why not five or six?*  *What material will your team use to fashion the blades?*  *What angle will the blades be placed against the wind?*  Your team will need to answer all of these questions in order to be successful. In order to be competitive and get the best grade you can on this project, you will have to avoid blind decision-making. Each choice should only be made after research, data collection (testing) and analysis. Your journal will document this design process.  C. **Content Requirements**   * Your team must select at least two of the variables to test as part of your design process. Of course the more the better, but two will meet the minimum requirements. * For each of the independent variables, your team should design an experiment that evaluates that variable against the dependant variable: output voltage (produced by the generator). *The larger the output, the “better” the design.* * A minimum of five (5) test points need to be completed for each experiment. For example if you are testing the number of blades, you will need to test 2, 3, 4, 5, and 6 blades (5 different points). * Each test should include an appropriate hypothesis, procedure, data analysis, and conclusion.   **D. Grading**  Exemplary (A)   * Evidence of daily work is present with each entry describing meaningful progress by the entire group. * All entries are clearly dated and each date begins on a new page. * Cover page has all group names * The group makes quality sketches of different ideas to be considered and there is strong evidence of research and planning in the design process. * At least two experiments have been completed. Results (data) are organized and well presented and completely guides the design process.   Competent (B)   * Evidence of daily work is present with most entries describing meaningful progress made by the entire group. * Most entries are clearly dated and begin on a new page. * Cover page has all group names * The group attempts sketches of different ideas and there is some evidence of research and planning in the design process. * At least two experiments have been completed. Results (data) are organized and presented and basically guide the design process.   Needs Improvement (C)   * Evidence of daily work is mostly present with some entries describing meaningful progress by the entire group. * Some entries are dated but gaps exist in the record of group progress. * Cover page has all group names * The group makes some attempt at making sketches of different ideas but there is limited evidence of research and planning in the design process. * At least two experiments have been completed. Results (data) are loosely organized but are only modestly connected to the ongoing design process.   Incomplete (D)  **The Competition Rules**  *On competition day:*   1. Your turbine will be placed 1.0 meter from a standard box fan set at medium speed. 2. Once the turbine reaches steady state, the output will be measured by a voltmeter and recorded. 3. The *average* reading over a 30-second measurement interval will be the official reading. 4. If a team’s turbine fails to perform at expected levels, the team will be given time to make adjustments to the turbine (if remaining class time permits) for up to one additional re-test. 5. If a team does not test their turbine within the assigned class, that team forfeits their chance in the competition.   *Materials:*   1. A standard crimping hub will be used to connect the blades to the generator. 2. Only the supplied generator can be used. 3. No additional stored energy (other than the kinetic energy of the wind to be captured by the turbine) can be used. For example, no stored elastic energy (rubber bands, etc.), electrical energy (batteries, etc.), or other can assist or improve the rotation of the turbine in any way. 4. The blades of the turbine can be of any length, shape and of any material. 5. Up to 10 blades may be used. 6. The blades must not extend forward more than 5 cm from the plane of the crimping hub (so that they get closer to the box fan).   **Lesson #6: A Deeper Analysis of Turbine Design**  *In this lesson students will upload their data into iSense. A comparative analysis with data from other students will answer some questions about turbine design characteristics. The data oftentimes asks new questions about design principles that were unforeseen before comparison. These additional questions can simply be asked or evaluated further in subsequent lessons. The visualization tools built into iSense make this type of real and meaningful analysis accessible to students and are likely to improve student engagement.*  Before the lesson the teacher should set up an experiment in iSense.   1. Login or Register to iSense 2. Click “Create Experiment” 3. Fill in “Basic Info” fields. Click on Setup Data Fields. Follow the prompts for data collection fields. Common fields would be:    1. What is this measuring? *Voltage* Type? *Electric Potential* Units? *Volts*    2. What is this measuring? *Time* Type? *Time* Units? *Seconds* 4. Click on Create Experiment.   Students should collect a single 30-second data set on low, medium, and high speeds (10-seconds each, starting at steady state in low speed) on with the box fan located 1.0 meter from the wind turbine. This can be done during a previous lesson in order to save time.  Each student should upload their data into iSense:   1. Go to <http://isenseproject.org> and login using the username and password that your teacher has provided for you. 2. Click on *experiments* and find your school’s wind turbine experiment 3. Click on *contribute*. 4. Fill in the required data fields. Name is important because it is how everyone else will identify your data; use first name and last initial for you and your partner(s). Under Session Type, choose Data File. 5. Navigate to the data file that you selected. If you are using LoggerPro and a Vernier voltage sensor to collect your data, you must first export the data in CSV format:    1. Open the file in LoggerPro    2. Choose File > Export As > InspireData (CSV)    3. Save the CSV file somewhere so that you can then use it as your iSense data file upload. 6. Click on *Create Session*. 7. Go back to the experiment page (you should now be able to see your session data under this experiment) and click on *add image* in your data set and upload a picture of your turbine.   Students will then compare their data with the data from other wind turbines. This is a good opportunity to extend the activity beyond the classroom and compare data from other classrooms and perhaps even other schools.  Use iSense to evaluate three (3) different data sets from any class at Windham High School. Place the three sets of data on the same graph and then paste the image into a word document (use screen shot: command+shift+4).   1. Go to [www.isenseproject.org](http://www.isenseproject.org) 2. Login using your username and password 3. Click on experiments and find our wind turbine experiment 4. Select at least three data sets (checkbox) from the available student groups. One of them may or may not be your group’s. 5. Click on the visualize button 6. Click on the timeline tab 7. Select "side-by-side" comparison using the drop down menu on the right 8. Click "reload" 9. You can hover over the graph to get actual data point values.   An example of iSENSE student work comparison:  Macintosh HD:Users:patrickkaplo:Desktop:Screen shot 2011-08-15 at 8.56.33 PM.png  Students can then be prompted to answer questions or journal about this comparative analysis. Some questions might be:  *Why are the graphs shaped the way that they are (like plateaus)? What is the maximum voltage for each turbine at each fan speed? What does the data seem to say about the three different turbine designs?*  *Is the most efficient turbine at high speed also the most efficient turbine at low speed? What does this tell you about how turbines might be selected at different locations?  What questions might remain unanswered about the data?* |
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