AC 2012-3160: EXCHANGE: MOUSE-WHEEL GENERATOR

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Exchange: Mouse Wheel Generator

Through the Bechtel K-5 Educational Excellence Initiative, the Colorado School of Mines is working with kindergarten through fifth grade (K-5) teachers to increase their competence and confidence in mathematical and scientific content, in the use of manipulatives and technology, and in the integration of reading instruction in mathematics and science content delivery (see: <http://mcs.mines.edu/Research/bechtel/new>). This is being accomplished by offering cohorts of K-5 teachers two, two-week summer workshops on a college campus, over successive summers, in mathematics and science with an energy and renewable energy emphasis. Each cohort consists of a teaching team representing all grade levels, K-5, within a given elementary school. These workshops are taught by university professors and researchers from a national laboratory.

Implementation of workshop activities in the elementary classroom during the academic year is not left to chance; rather, graduate students directly assist the participating teachers for up to fifteen hours per week, throughout the academic year, in implementing the discovery-based learning activities in the K-5 classrooms. These same graduate students are also responsible for 1) arranging visits by prominent individuals to the K-5 classroom, 2) researching additional mathematical and scientific classroom topics, and 3) arranging elementary school campus tours. Since mathematics and science comprise, on average, forty-five minutes of an elementary school day, one graduate student supports multiple classrooms.

As has been argued elsewhere^{5,6,7}, there is a growing interest among engineers and teachers in the development and design of lesson plans that introduce renewable energy and energy generation to pre-college students. This paper outlines lesson plans that are designed for grades 2-4 and can be easily modified up to eighth grade. Each of these plans focuses on a renewable energy concept from an engineering perspective. These lesson plan segments include instructions, worksheet printouts, and recommended classroom materials. Each of these segments has been pilot tested in a second grade classroom.

Participating Student Population

Three second grade classrooms participated in this investigation. Two of these classes were located in a science, technology, engineering and mathematics (STEM) magnet school. The magnet school curriculum incorporates “Science, engineering and technology each school day in addition to the other core content areas of literacy, mathematics and social studies”³. The third classroom was drawn from a low-income, public elementary school. CSAP results for third grade: 33% proficiency in reading, 8% in writing, 46% math. In comparison, the state averages are 73% reading, 51% writing, 70% math⁴. The STEM school scores are unavailable as it is a new school. There were approximately 25 students per class and the same graduate student assisted all of the classrooms. Two different instructors taught the two courses in the STEM magnet school; a different instructor taught in the public elementary school. All teachers were female.

Assessment: Pretest/ Post-test

The pre and posttest, displayed in Appendix A, was administered to the participating students immediately before instruction, with the posttest done within a few hours after the lesson due to

scheduling. This was used to gauge student knowledge, but does not reflect attitude. Poor performance of the pretests was anticipated, as the students were unlikely to have had prior exposure to the presented concepts. The average pretest score for the sampled classes was 20, whereas the posttest was 64 (standard deviation ~20 points for both). Most critical was the understanding of power being generated by generators and not simply existing by flipping a switch, which is reflected in question 2. This targeted question of power generation was answered as a 2:1 ratio of flipping a switch vs. a generator spinning. After the lesson, only 18% selected flipping a switch is “what makes electricity” (23% motor, 40% generator). The only negative is some of the students were confused with the motor and generator terminology. Lesson modification for various levels is given in the conclusion.

Lesson Plans

The sections that follow briefly describe the three sections of the lesson: mouse-wheel generator, blackbox generator, and motor/generator implemented in the second grade classroom. Complete lesson plans are provided in the appendix of this document. Each of these lessons are designed to be completed in sequence, across a three day period, or over an extended lab period.

A. Mouse-wheel generator

In this lesson plan, an electric motor, which can be found in many electrical devices, is attached to a mouse wheel using a small plastic tube. This is then attached to the drive, and outputs to a low-power LED light. The instructor uses different attachments to mimic a waterwheel, a wind turbine, and steam power and demonstrates that a turning motion generates the electricity necessary to light the LED. The mouse-wheel can also be powered with a small hand crank or a running rodent (note consistent power generation requires constant quick rotation).

Through this activity, students learn how different energies, renewable and nonrenewable, are implemented. Detailed instructions for construction are available in Appendix B. It is recommended that lower level students [grades 2-4] try to spin the motor stem to turn on the light manually. This gives them a concrete idea of how much rotational force is required just to light a small bulb.

B. Blackbox Generator

In order to better understand power generation, a coloring sheet was developed that describes how generators work. This worksheet is contained in Appendix C and was completed by the students following the mouse wheel demonstration. A major emphasis of this lesson plan is understanding that a conductor turning in a magnetic field generates electricity.

Electron flow is what we call electricity, and a generator can be paralleled to a pump pushing standing water in a loop where the flow of electrons is equivalent to the flow of water. This is an approximate visualization that is easily relatable to actuality at a basic level because electrons do not flow at the speed of light; it is the bulk motion, not an individual electron that generates electricity instantaneously¹. Instruction began with a class brainstorming session concerning methods for

generating energy. Students came up with renewable (solar, biomass, wind, hydro, geothermal) and nonrenewable (nuclear, fossil fuels, coal) energy forms, which were listed on a class whiteboard. Negating solar, all of these resources are used in approximately the same way to generate power: a fluid is forced over turbines to generate a continuous rotational motion. This rotation turns a generator (composed of wire and magnets) that makes electricity. Specifics of this technology involve electromagnetic fields, however the basic idea illustrated with a demonstration of a generator in operation is sufficient for student comprehension.

C. Motor/Generator

In small groups (2-4), students built the simple motor displayed in Figure 1. Another option would be for the instructor to build the motor while the students observe.

Figure 1 : Simple Electric Motor

This simple electric motor is pretty typical and can also be bought in a kit ². The economical version uses the following:

1. battery
2. magnet
3. 2 safety pins
4. thin electrical wire
5. electrical tape

Steps to build:

1. Coil the wire 20+ times in a tight circle. It must be small enough to spin when attached to the safety pins without hitting the battery or magnet. Allow an inch on either side of the coil.
2. Cut the insulation or sand (on magnet wire) the ends of the wire to create a circuit.
3. Tape the safety pins to the battery ends as shown in Figure 1.
4. Slide the coil into the safety pin end circles and place the magnet in the center of the battery.
5. Gently spin the coil to get it started (overcome friction and inertial energy); it will continue on

its own.

6. Note: this shorts the battery, so keeping it running for more than 2 minutes can heat up the battery.

The comparison for the students to make is:

generator: magnets + wire + motion = power

motor: magnets + wire + power = motion

Have the students write these equations, draw their motor like the generator worksheet, and brainstorm what types of things that are driven by motors.

Conclusions and Recommendations

Innovation can only be reached with a solid platform of comprehension. While there is a multitude of renewable energy lessons available^{8,9}, they often neglect to discuss how the source interfaces with any type of power generation. In order to fully understand how to use renewable energy sources or brainstorm unique ways of power generation, the generator must be introduced at least in a basic manner. While second graders struggled with memorizing some of the vocabulary and concepts of electricity flow, an introductory understanding for this technology was successful. At this age group, it is critical to complete handouts and activities as a class first, particularly if reading is an issue. This lesson group would be optimal for slightly more advanced students [recommended 4th +] but is proven even at a lower level to be beneficial and effective at conveying the main concepts. An additional lesson to demonstrate how gas expands when heated is also recommended to bolster the gas turbine comprehension.

To modify lessons based on grade level, simply take out some of the hands-on construction of the generator or motor. It is seen that at the younger ages, the coordination and precision is lacking to be able to make the models within the tolerances that they require. Another strategy is to cut open an electric motor [pull the end off to expose the wire, cylindrical magnet, and drive shaft] and use that as a manipulative rather than building your own. This method worked well for the lower-level kids within the 2nd grade classes.

References

1. R. Bertran, "How fast does electricity travel?" Radio and Electric School, 2010. <<http://www.radioelectronicschool.net/files/downloads/howfast.pdf>>.
2. "Magnet Motor Kit." MiniScience.com, December 14, 2011. <http://www.miniscience.com/projects/Magnet_Motor_kit/index.html>.
3. STEM Magnet Lab School Parent and District Handbook. December 11, 2011 <<http://stem.adams12.org>>.
4. Stats and Test Results – Tennyson Knolls Elementary School. Great Schoools.org, December 14, 2011. <<http://www.greatschools.org/colorado/>>

5. NEED National Energy Education Development Project. December 15, 2011. <<http://www.need.org/>>.
6. Energy Kids. U.S. Energy Information Administration, December 15, 2011. <<http://www.eia.gov/kids/>>.
7. PECO Energizing Education Program, December 15, 2011. <<http://www.need.org/peco>>.
8. Educational Resources. National Renewable Energy Lab. Alliance for Sustainable Energy LLC, August 29, 2011. <http://www.nrel.gov/education/educational_resources.html>.
9. Renewable Energy Lesson Plans - Infinite Power.org, Texas State Energy Conservation Office, 2005. <<http://www.infinitepower.org/lessonplans.htm>>.

Appendix

Appendix A: Student Pre/Post Test

Test – Generator Lesson

NAME: _____

DATE: _____

1. Circle the **renewable** energy sources:

Nuclear

Geothermal

Hydro (Water)

Fossil Fuels / Coal

2. What makes electricity? [Pick 1]
- a. Spinning a motor
 - b. Spinning a generator
 - c. Flipping a switch
 - d. Atoms

3. Write the words in the correct place on the generator picture:

Magnet **Wire** **Electrons**

4. Draw a picture of a turbine on the back of this paper.

Appendix B: Build Instructions

This project uses a wind turbine kit from Pitsco [reference here], but can easily be recreated, as will be explained below. The critical pieces from the kit are:

1. small motor (found in most small appliances or at electronics stores)
2. low power LED light (electronics stores)
3. wire (strip the ends of a twist tie)

There are 2 attachments to the motor:

1. Wind Turbine [wind power]
2. Turbine for air/water [water or steam driven – ie hydro, geothermal, biofuels, fossil fuels, nuclear]
3. Mousewheel

To build the wind turbine:

You can use existing pinwheels, or glue pencils in a reinforced circular center and use paper as the blades. The important part is to have a straight attachment to the motor shaft, like the inside of an ink pen tube cut to $\sim 1/4''$. Glue this piece firmly to the exact center of the turbine and push it onto the motor.

To build the turbine [water and air]:

Using Figure 2 as a guide,

1. Cut the top off of a 2 liter bottle.
2. Cut $1-1/2''$ tall strips from around the bottle. Cut these every $1''$ to make $1 \times 1.5''$ rectangles.
3. Drill a small hole in the *center* of the cap just large enough for the pen tube.
4. Hot glue the rectangles around the top (part 1) at a slight angle (Figure 2).
5. Hot glue around the pen tube and let dry as straight as possible (Figure 3).

To use, hold perpendicular to a water or air stream when attached to the motor and light.

Visually this is a waterwheel, but real hydro or steam powered turbines are multiple stages of this turbine shape encased tightly in a cylindrical pressure vessel. Steam turbines in particular (because air is a compressible fluid) can be 40 feet long with 20 stages of turbine blades.

Figure 2: Generator Bottle Schematic

General LED notes:

LED's are *diodes*, meaning they only work one direction. If the circuit doesn't work, even if you spin the motor very quickly, try flipping the LED leads.

LED's also cannot handle a large current, like a D cell battery. Your motor will spin when hooked up to the battery, but remove the light prior to this demonstration. If the LED keeps burning out, the current may be too high; add a small resistor in series to decrease the current (voltage will be the same).

Figure 3: Plastic Bottle Turbine Detail Images

Appendix C: Generator Worksheet

NAME: _____ DATE: _____

1. Color the :

wire Black

Magnet – South Red

Magnet – North Blue

electrons Yellow

drive shaft Grey

2. Color the renewable energy circles [dashed] Green

3. Color the nonrenewable energy circles [solid] Brown

4. Cut out the energy source circles and glue them on either the renewable or nonrenewable source.