Demystifying Electricity

An introduction to energy

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Problem:

There is a desperate need for talent in the energy field. We are losing employees in the industry that cannot be replaced quickly enough. Although it only comprises 4% of our GDP [1], it is only through our energy industry that all other domestic industry exists. According to the United States Department of Labor, over 50% of the energy workforce was above 50 years of age in 2004 [1]. Today, 68% of the workforce is comprised of baby boomers [2], meaning that the majority of the workforce is either eligible or approaching eligibility for retirement. The industry estimates that it will be losing half of its workers (more than 500,000 positions) to retirement within 10 years. This, in addition to the new jobs that are being created due to the shift towards renewables and more technologically complex solutions, means that hiring will be above the replacement level [1]. There are not enough graduates in energy-related fields to adequately fill these positions.

Energy demand is increasing around the globe. Moore’s law predicted the exponential growth in the technology sector that we are seeing today. With the increasing amount of electronic devices, there is a corresponding increase in the amount of energy needed to power them. The growth of the middle class in previously underdeveloped areas such as China and India is adding to the demand. The increase in global population is adding to the demand. How do we address this demand without facing the reduction in quality of life that old polluting technologies cause? How do we address this demand with limited traditional energy resources (Coal, oil, natural gas, etc.)? How do we address this demand when we are also dealing with a downward trend in employment in the energy sector?

Abstract:

GridEd aims to develop educational opportunities for learners at all levels, including grade school students, in order to increase energy “literacy” and enrich the candidate pool of energy workers. This is vital due to the demand for highly skilled energy workers, increasing demand for electricity, and decrease in supply of high quality fossil fuel energy sources. The
development of this curriculum was a collaborative effort between industry professionals, research scientists, student assistants, and K12 educators. Once industry specific learning goals were defined, they were aligned with existing standards for K12 energy education and the framework within which this information could feasibly be disseminated within was made clear. We have moved forward to create and revise case and project based learning activities as well as a resource bank that teachers can reference in order to implement this curriculum easily and effectively. An overview of one unit of instruction in addition to sample activities from one lesson in that unit are included in this report. Our next steps include offering professional development to teachers, developing additional relevant material for middle and elementary schools, and tracking students in order to monitor the success of this school-to-career initiative.
Demystifying Electricity

An introduction to energy

Standards:

ENRG-FET-1: Students will describe the history of the energy industry.
a. Describe the history of the United States energy industry/infrastructures.

ENRG-FET-2: Students will analyze the differing processes of generation and distribution of power and energy.
c. Compare the different mechanisms of energy generation and its advantages.
d. Contrast different forms of energy distribution and its advantages.

ENRG-FET-6: Students will develop, through research, an alternative energy system that demonstrates their understanding of a unique, as well as an appropriate, approach to energy and power generation.
a. Provide a research paper that lists innovative alternative energies.
b. Design a system, either via computer model or prototype, which will produce power for a specific need.
c. Submit an engineering notebook which includes a daily journal, spreadsheet, and photos that show the development of this product.
d. Document the need for this product within the community.
e. Present data and prototype, or computer model, to a group of peers and/or school staff/community members.

ENGR-STEM-3. Students will design technological problem solutions using scientific investigation, analysis and interpretation of data, innovation, invention, and fabrication while considering economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability constraints.
a. Demonstrate fundamental principles of design.
b. Design and conduct experiments along with analysis and interpretation of data.
c. Identify and consider realistic constraints relevant to the design of a system, component, or process.

ENGR-STEM-4. Students will apply principles of science, technology, engineering, mathematics, interpersonal communication, and teamwork to the solution of technological problems.
a. Work cooperatively in multi-disciplinary teams.
b. Apply knowledge of mathematics, science, and engineering design.
c. Demonstrate strategies for identifying, formulating, and solving technological problems.
d. Demonstrate techniques, skills, and knowledge necessary to use and maintain technological products and systems.
Objectives and Anticipated learner outcomes

Enduring Understandings:
- Electrical energy is important in modern society, but we must adapt to sustainable sources and systems of production in order to maintain healthy people and a healthy planet.

Essential Questions:
- What is electricity and where does it come from?
- What are the pros and cons of the different methods of energy generation?
- What role do we play in ensuring a sustainable future?

Knowledge from this Unit:
Students will be able to:
- Explain variables related to the induction of EMF
- Be aware of and follow safety procedures in the prototyping workshop and classroom
- Design and improve a simple electric generator
- Describe and understand mathematical relationship between energy, work, and power.
- Properly cite resources in a research paper format
- Explain the evolution of electrical technologies and the utility industry
- Explain the current global energy mix and how it related to current trends in energy and sustainability

Skills from this Unit:
Students will:
- Follow written instructions
- Communicate effectively
- Analyze and solve problems using the engineering design method.
- Use writing, science, and mathematics in the context of engineering design

Overview of plans:

• **LESSON 1: introduction to voltage**

1. Review Essential Questions. Whole class discussion: *What is electricity and where does it come from?*

2. Divide students into four groups of equal size, and distribute the Shaky-Gen handout. Have students move to tables equipped with all the materials needed to complete the building activity.

3. Have a whole group discussion on what happened and why. Present lecture on faraday's law and check practice questions as well as journaling.

4. Give students handouts for two assignments: inventor presentation (homework) and long term generator project.
Assessment/Rubrics:
see handouts (attached on back end of document)

Materials & Supplies:
see handouts (attached on back end of document)

• LESSON 2: history of electricity

1. Have students come up to introduce their inventor to the class in chronological order
2. Round table discussion on the history of electricity and relevance of these inventors. What would life be like had it not been for that particular invention or innovation?
3. Students walk down the timeline and note accomplishments and facts about the different inventors in their notebooks.

• LESSON 3: energy work and power

*lesson adapted from the Energy Action Technology supplemental teaching resources guide provided by Georgia Power [3]

1. What is energy? Quick notes on energy laws (along with slides printout for students)
2. Discuss and demonstrate several changes in energy.
   a. Burning candle
   b. Connect battery to a light
   c. Solar cell to motor
   d. Vinegar and baking soda
   e. Blow up a balloon and release it
   f. Wind up a toy and let it go.
3. Students should think/pair/share for each demonstration of energy transformation.
4. Introduce students to the forms of energy via graphic organizer
5. Introduce students to transformations of energy using an additional graphic organizer
6. Have students build a simple DC motor and investigate variables.
7. Extension: Have students deconstruct motors from various household appliances and compare and contrast with the motors that they built and share results with class.

Day II
1. Lecture on energy laws and efficiency
2. Have students calculate efficiency and transformations of energy
3. Give students the rollercoaster energy hand out sheet and materials to create a rollercoaster from paper towel rolls. Students calculate the KE and PE.

Day III
1. Lecture on power
2. Have students calculate power on student worksheet
3. Have students design wind turbine blades from common household materials such as paper plates, foam cups, popsicle sticks and paper, etc.
4. Test turbines on how effectively they can raise a cup of marbles from floor to table.
5. Calculate mechanical power.

**Day IV**
1. Attach turbines blades to DC motor to produce EMF and discuss electrical power.
2. Students look up and define vocabulary associated with discussion (handout)

**LESSON 4: power generation and utilities**

1. Students complete presentations on different generator types and generator of their choosing
2. Lecture on basic turbine generated electricity systems and the role of utilities

**Day II**
1. Field trip to power plant.

**Day III**
1. Students complete safety lecture and practical

**Day IV**
2. Students begin building their generator prototypes. After the completion of other units of study, with built in working time for generators, students will present on their successes and failures regarding their generator prototypes. This is a long term project based learning assignment.

**Summary:**
GridEd is a collaborative educational initiative between universities, industry stakeholders, and the Electric Power Research Institute. The objective of GridEd is to train the next generation of power engineers. An integral part of this is early outreach to K-12 educational institutions. Not only does K-12 energy education help build energy conscious citizens capable of making informed decisions, it also serves to build an understanding of and interest in the various fields that comprise the energy industry. By admitting students with an existing understanding of the challenges faced by and complexities of the energy industry into degree programs, we are increasing the number and quality of our future energy workers, the quality of our energy, and the quality of our lives.

GridEd has developed goals and objectives for learning through collaboration between the energy industry, K12 institutions, and university partners. Case based and project based learning
resources are being developed, focusing on energy industry specific skills, practical application of knowledge, critical thinking, and collaborative work. These objectives and activities are being chosen and created to align with state and national standards for ease of use by teachers. Through creation and revision of curriculum resources, dialog with partners, development of engaging opportunities in energy education and exploration of work based learning opportunities; the principal goal of this work is to increase participation in energy related fields of study at all levels of education, thus enriching the candidate pool of high skilled energy workers.

Bibliography:


**Shaky-Gen Activity**

Adapted from instructables.com

**Materials:**

- Film canister
- Laminated wire (5200 cm)
- LED light bulb
- Light cardboard
- Wire cutters
- Scissors
- Sandpaper
- Strong magnet
- Soldering iron
- Solder
- Electrical tape

**Safety precautions:**

*Rare earth magnets are incredibly strong and can pinch if they are not handled carefully. Do not try to snap them together from more than an inch apart. They also may shatter into tiny fragments, as they are very fragile, which can cause eye damage as well as loss of materials.*

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**Procedure:**

1. Cut out light cardboard guides and tape them to the ends of the film canister. They should be about 10 cm in diameter with a hole cut out of the center the size of the canister so that the canister can slide inside.
2. Tape the cardboard guides about a cm from each end.
3. Leaving about 8 cm of wire free (you can tape it to the cardboard guide in order to prevent it from getting caught during your winding), wind the wire as evenly and close together as you can. Be patient. You will be making approximately 1000 turns of wire. Work with your team to do this in the most efficient way possible.
4. When you are done, tape down the wire leaving the last 8 cm or so free. Tape that wire next to the other lead wire, but not touching.
5. Use sandpaper to scrape off the enamel on the ends of the wire (about 1 cm worth)
6. Using the soldering iron, solder the ends of the wire to the LED light ends so that each wire is connected to one of the leads to the bulb. Make sure that these leads do not touch each other. You can secure this bulb to the film canister with electrical tape in a way that makes sense to you.
7. Insert the rare earth magnets into the film canister. Replace the top.
8. Shake the film canister.

**Questions (please record in your engineering notebooks)**

1. What difficulties did you run into as a team, and how did you work together to move beyond them?
2. What did you observe when you shook the canister?
3. Give an explanation for what you think is happening here. Explain your reasoning. Do not worry about being “wrong”.

Be sure to record your procedures and observations at every step of this process. Keeping detailed working notes in your engineering notebook is a standard in this class, a useful way to review and improve our designs, as well as a necessary way to communicate your knowledge and understanding to others (including your instructor). Please be explicitly detailed, including labeled sketches, measurements, conversations and agreements with teammates and others, ideas, questions, and notes on how you could improve the process.
Lecture and practice: Faraday's Law and electromagnetic induction

Electromagnetism and Faraday's law: demystifying electricity

Michael Faraday
- English bookbinder, chemist, and later physicist
- Curious about the relationship between electricity and magnetism
- Already knew that electric current could produce a magnetic field. He asked, "Can a magnetic field produce electric current?"
- Discovered electromagnetic induction
- Invented the electric motor

Faraday's law, simplified.
- EMF, or Voltage, is equal to the change in magnetic flux divided by the change in time.
- Magnetic flux \( \Phi \) is equal to \( B \) (magnetic field measured in Teslas) multiplied by \( A \) (area through which field passes).
- Voltage is also proportional to the number of turns of wire in a coil (N)
- Final (simplified) equation: \( \varepsilon = N \cdot \frac{\Delta (A*B)}{\Delta t} \)

Shaky generator recap/discussion.
- What did you observe?
- How can you explain it?
- Can we measure how well it worked?
- How can we make it work better?

EMF
- Electromotive force (emf) is a measurement of the energy that causes current to flow through a circuit. It can also be defined as the potential difference or change of electric potential energy between two points in a circuit. Electromotive force is also known as voltage, and it is measured in volts.

Faradays law
\[
\Phi_B = \int \int \Phi B(r, t) \cdot dA ,
\]

- How can we induce EMF?
- What are the variables?
- How can we manipulate those variables to increase EMF?
Practice

Scenario 1:
There is a coil of 100 turns. The magnet measures a strength of 0.1 Tesla and takes 0.1 seconds to move through the coil.

Scenario 2:
There is a coil of 200 turns. The magnet measures 1.1 Tesla and takes 1.5 seconds to move through the coil.

The coils both have the same shape and size. The area through which the magnetic field passes in both scenarios is 1 meter square. Calculate to find which coil has a higher induced emf (voltage).

Journaling:

- What could we do to increase the voltage of our shaky generators? Explain your reasoning referencing Faraday's Law.

Mid term project: design a generator

See handout.
Electric generator design: Quarter one project (with sample timeline)

Final build due ___October 2nd._

High school engineering/energy

Objective: students will research, build, and modify a turbine based generator with the goal of increasing power output through modifications.

This project is expected to be constructed during the time that we cover essential concepts related to the generation of electricity in class. These concepts include Faraday's law, electromagnetic induction, energy types, power systems and components, renewable and non-renewable energy sources, efficiency, etc.

Generators must be built from readily accessible materials. If a student is having a difficult time acquiring materials that he needs, it is expected that he will consult the instructor during office hours for assistance in finding a solution through sourcing or substitution, and that this will be done in a timely manner (i.e. not a week before this long-term project is due).

Part 1: research. Due _____Aug 17th____________

Students will create a presentation detailing the following:

- Pros and cons of at least five different DIY generator types
- Explanation of choice for their generator
- Explanation of the design and how it functions
- List of all materials needed to construct the generator and sourcing information
- List of potential solutions that can be applied to offset limitations of chosen generator
- Amount of voltage expected from the generator compared with the amount of voltage needed to charge device.
  *research process must be documented in notebook.

Suggested sources include

Need.org
Kidwind.org
http://www.scraptopower.co.uk/home

Part 2: prototype. Due ___Sept 18th__________

Students will build a working prototype of the generator

- Must document process in notebook through writing/thumbnails/photos
- Drawings and legends must have scale noted.
- Prototype must use appropriate technology to serve the intended function (producing voltage to charge a device)
- Prototype must be neatly constructed.
- Articulate and well planned presentation describing all parts of the generator as well as a discussion of shortcomings of generator (what are your failures, and what did you learn from them?)
Part 3: final build. Due __________ October 2nd

- Articulate and well planned presentation describing all parts of the generator as well as a
discussion of modifications of generator (what was improved and what were the effects of that
improvement.)
- Must have higher voltage output over original design.
- Aesthetically pleasing and neatly constructed.

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  d. Demonstrate techniques, skills, and knowledge necessary to use and maintain technological products
and systems
History of electricity - Inventors and their contribution to energy science.

Tasks
1. Choose a person you are interested in.
2. Write out the things you know about this person. List at least 10 things you would like to know about this person and how their work impacted electrical technology.
3. Research the inventor and the invention using at least one paper resource.
4. Gather the information that you have collected from your sources to create a presentation poster on the inventor's life and their work/inventions. We will assemble all posters into a timeline.
5. Alongside the presentation, you will write a speech as if you were the inventor. Whether you choose to dress in costume is up to you, but it will be considered “extra effort”. Your speech should be no longer than 5 minutes and must be turned into your instructor on the day of the presentation.

Inventors for timeline of electricity presentations:

- Ancient Greeks
- William Gilbert
- Pieter van Musschenbroek
- Benjamin Franklin
- Charles Coulomb
- Alessandro Volta
- Hans Christian Oersted
- Andre-Marie Ampere
- Michael Faraday
- Joseph Henry
- James Clerk Maxwell
- Heinrich Hertz
- J. J. Thomson
- Albert Einstein
- Samuel F. B. Morse (Telegraph)
- Guglielmo Marconi (Wireless telegraph)
- Thomas Edison (Electric lights)
- Nikola Tesla (A.C. generators, motors)
- John Bardeen and Walter Brattain
- Jack Kilby and Robert Noyce
- Gordon E. Moore
## Standards based grading rubric:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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| 4 - Advanced |  • Student consistently reached beyond established goals  
  • Consistently transfers, applies, and expands skills Independently.  
  • Routinely applies problem-solving and critical-thinking skills across are as of the curriculum  
  • Consistently shows originality, creativity, and intuitive thinking beyond standard expectations |
| 3 - Proficient |  • Often goes beyond established goals for achievement and contributions  
  • Frequently transfers, applies, and expands skills  
  • Often shows originality, creativity, and intuitive thinking beyond standard expectations  
  • Generally applies problem-solving and critical-thinking skills across areas of the curriculum |
| 2 - Basic |  • Meets expected goals for achievement and contributions  
  • Transfers skills with teacher direction  
  • Applies problem-solving and critical-thinking skills across areas of the curriculum with teacher direction  
  • Demonstrates some originality, creativity, and intuitive thinking in completing tasks |
| 1 - Below Basic |  • Has difficulty/does not meet established grade-level goals for achievement and expectations  
  • Seldom understands, transfers, or applies skills  
  • Rarely applies problem-solving and critical-thinking skills across areas of the curriculum  
  • Infrequently shows originality, creativity, or intuitive thinking skills in completing tasks |

Adapted from Sullivan County Department of Education Guidelines for Scoring Using Standards Based Grading Rubric [4]