
AC 2012-4605: INTEGRATING POWER ENGINEERING INTO MIDDLE AND HIGH SCHOOL MATH CURRICULUMS

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Integrating Power Engineering into Middle and High School Math Curriculums

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Abstract

Electricity is the most popular form of energy because it can be transported with ease at high efficiencies and sensible cost. It is often taken for granted, but when looked at as a single machine, the North American power grid is an incredibly efficient, safe, and robust system.^{1,2} Integration of this topic into K-12 curriculums helps students understand the world they live in, see math applied to real-world problems, and brings a much needed engineering element into the classroom. As part of a NSF Graduate STEM Fellows (K-12) program, 7th grade math students had a graduate electrical engineer visit multiple times a week to integrate power engineering into the classroom. The IMPACT LA (Improving Minority Partnerships and Access through CISE-related Teaching) NSF GK-12 Program works with underrepresented minority students in the East Los Angeles Area.

This paper presents five original or modified classroom activities that have been used in 7th grade pre-algebra. Activities, their engineering connection, the curriculum connection, and impact on students' understanding of engineering will be presented. In the final portions of the paper, pre- and post-survey data will be presented to show the impact that the IMPACT LA program and these activities had on the students.

1. Introduction

K-12 classrooms typically focus on developing student's math, reading, and writing skills, while subjects such as engineering are neglected. Without basic knowledge of engineering and design concepts, high school graduates are less likely to pursue careers in technical fields. Furthermore, many students lose interest in math because curriculums fail to draw connections between abstract math concepts and real-world applications. One such application is the power distribution system that students encounter every day, but probably do not realize its significance or complexity.

Electricity is the most popular form of energy because it can be transported with ease at high efficiencies and sensible cost. It is often taken for granted, but when looked at as a single machine, the North American power grid is an incredibly efficient, safe, and robust system.^{1,2} Integration of this topic into K-12 curriculums helps students understand the world they live in, see math applied to real-world problems, and brings a much needed engineering element into the classroom.

As part of a NSF Graduate STEM Fellows (K-12) program, 7th grade math students had a graduate electrical engineer visit multiple times a week to integrate power engineering into the classroom. The IMPACT LA (Improving Minority Partnerships and Access through CISE-related Teaching) NSF GK-12 Program works with underrepresented minority students in the East Los Angeles Area. Students were exposed to many demonstrations and mini-lectures which explored fundamental concepts of electric transmission systems. Mini-lectures topics ranged from power generation and alternative energy, to the fundamental aspects of the power

transmission system. Demonstrations allowed students to watch a high-voltage capacitor discharge, see a miniature DC power grid in action, and even generate their own power from mini-wind turbines and solar panels. To solidify the knowledge presented, students also conducted several hands-on activities.

This paper presents five original or modified classroom activities that have been used in 7th grade pre-algebra. Activities, their engineering connection, the curriculum connection, and impact on students' understanding of engineering will be presented. Students got a chance to connect their knowledge of working with ratios to the concept of voltage transformation with wall transformers. The transformers were used to raise and lower voltage levels of the electrical wall socket. In another activity students learned about charge storage by demonstrations and interaction with a Van de Graaff generator. The generator makes high-voltage arcs, and students were then able to use some formulas to calculate the energy of the spark.

This paper is organized as follows. Section 2 describes the IMPACT LA Program and its goals. Section 3 introduces the graduate fellow's research in Maximum Power Point Tracking (MPPT) control systems for residential wind turbine generators. Section 4 describes the mathematical concepts the 7th grade pre-algebra students were learning when these activities were conducted and presents a mathematical review of the concepts. Section 5 presents the power engineering classroom activities. Section 6 provides the assessment data of one of the activities while section 7 contains the conclusion and pre- and post-assessment data for the IMPACT LA Program as a whole.

2. IMPACT LA Program Information

The IMPACT LA Program partners graduate teaching fellows with middle and high school math and science teachers in the Los Angeles Unified School District (LAUSD), primarily in Local District #5. The program is centered at California State University, Los Angeles (CSULA), and is part of the national NSF Graduate STEM Fellows in K-12 Education (GK-12) Program, which provides fellowships and training for graduate students in science, technology, engineering, and mathematics (STEM).^{3,4} The graduate student fellows serve as visiting scientists or engineers who work closely with their partner teachers to engage middle and high school students in science and engineering demonstrations, presentations, and activities related to the fellows' research.

The two primary goals of the IMPACT LA Program are to 1) change teachers, students, and parents' perceptions of engineers and encourage K-12 students to explore engineering and research careers, and 2) to enhance the communication and research skills of graduate fellows.⁶ To achieve these goals, during workshops teachers participate in a wide range of research experiences designed by fellows to introduce and update teachers to their research areas. Graduate fellows conduct Master's thesis research in Computer Science, Computer/Electrical Engineering, Bioinformatics, Biomedical Engineering, Mechanical Engineering, Civil Engineering, Biology, Chemistry, Physics, and Math. CSULA faculty train fellows through a preparation course and workshops in order to improve communication, collaboration, and teaching skills. Furthermore, a strong partnership between CSULA, LAUSD, local industry, and

minority serving organizations such as Great Minds in STEM and MESA has been established in order to achieve program goals.

At the time these demonstrations and activities were performed, the program consisted of eight fellows, conducting research in Electrical Engineering, Civil Engineering, Chemistry, Computer Science, Biology, and Biochemistry. A total of eight teachers are in the program and are partnered with an individual fellows. In the IMPACT LA Program, fellows are required to spend 10 hours per week in the classroom conducting presentations, activities, and demonstrations related to their research, science and engineering. Fellows are partnered with teachers throughout the entire school year. Currently, one fellow is partnered with one high school math teacher, while the rest are placed in middle school math and science classes. This paper focuses on the research of one of these middle school fellows and how his research was infused into pre-algebra curriculum through hands on activities and demonstrations. The activities were conducted over two years working with two different 7th grade math teachers at XX and YY school.

In addition to providing in-class hands-on activities, fellows along with their partner teachers are required to write and publish four lesson plans, conforming to the TeachEngineering.org guidelines.⁵ Care is taken when writing lesson plans to include sufficient information for teachers including connections to engineering/science, background information for teachers about both the subject matter and the engineering/science research-related concepts, cost, materials, etc. This is done in an effort to maintain these valuable activities so that any teacher can re-use them and adapt them to their specific needs. As a result, when the fellow is no longer available, their partner math teachers and other teachers can take advantage of these valuable lesson plans. Lesson plans, worksheets, and demonstrations are posted on the program website (impactla.calstatela.edu) and selected lessons will be submitted to TeachEngineering.org.

3. Fellow Research Overview

The goal of the IMPACT LA NSF GK-12 program is to have the graduate fellows serve as visiting scientists and engineers bringing their research into the classroom through demonstrations, presentations, lectures, and hands-on activities. By the end of the year, both the students and the teacher will have a good understanding of both the research topic and how the research can be conducted. The master's research related to the activities presented in this paper is titled "Improving Efficiency of Residential Wind Turbines by Developing a Control Algorithm for an Adaptive, Power-sensing, pulse-width-modulation (PWM) Controller." A brief overview of this research is provided to set the stage for the activities presented in Section 5 and to provide K-12 educators with an introduction to a real-world research problem in power engineering.

As the demand for energy rises and resources continue to dwindle, the need for clean, renewable energy sources continue to rise. Power is still primarily generated by burning fossil fuels such as coal and natural gas, but there continues to be more interest in developing infrastructure for generation by solar, wind, and geothermal. Wind energy is a popular renewable source, but there still exists many hurdles in implementing this technology. Wind speed is

variable; therefore the efficient use of this source is a primary concern. One proposed solution is to increase the captured energy by developing wind turbines for residential application. An adaptive control system that responds to the changes in wind-speed in order to operate at maximum efficiency is needed. Research on this topic involves developing a Maximum Power Point Tracking (MPPT) algorithm for a digital control system which will keep the wind turbine in its most efficient state all the time.

Wind turbine generators have different operating parameters related to the wind speed and the rotational speed of the generator to produce the maximum power. For every different wind speed, there is an optimum rotational speed for power generation. This rotational speed changes as the wind speed changes. To take advantage of this, the control system must make the appropriate changes as the variable wind speed changes. There are several ways to accomplish this. The generator can be tested to find the rotational speed for each wind speed. This can be a lengthy and expensive process, as many different wind speeds must be tested in an air-tunnel while the rotational speed must be tuned to find the best operating speed. Another approach is to have a control algorithm which adapts to changing wind speed and finds the maximum power point on its own for each speed.

This research focuses on developing an algorithm for MPPT using power sensors. The sensors will detect power output, and then incrementally change rotational speed up or down until the maximum power point is found. It will make these changes quickly so that it can keep up with the rate of change of wind speed. This algorithm will use a digital microprocessor to make decisions based on the detected power output and then will enact its changes in generator rotational speed using a pulse-width-modulation (PWM) controller. A PWM controller works as an on/off switch for the generator. Applying small changes to the ratios of “on” and “off” states is an effective way to change the generator speed.

4. Background Mathematical Concepts

The hands-on activities presented in this paper reinforce some mathematical concepts covered in pre-algebra including negative and positive numbers, ratios, order of operations, and using formulas to calculate physical quantities. A quick review of these concepts is provided.

a. Ratios

Number Transformations

In mathematics, there are several ways to transform a constant, c , to a higher or lower value. Addition and subtraction can be employed to raise or lower the number ($c + n$, $c - n$) where n is the selected number to change c). Multiplication and division can be used as well ($c \cdot n$, $c \div n$). Another way is to use ratios (changing c by a ratio of $n:1$ or $1:n$). For instance it is desired to change the constant c to a value 4 times greater than its original value; it would be expressed in a ratio $1:4$. If it is desired to change c to a value 4 times less than its original value, the ratio would be $4:1$. Using these concepts the constant, c , can be transformed to any desired value.

Order of Operations

A basic, but essential mathematical concept is order of operations. Without a standard which dictates what order to perform the mathematical operations there could be a great many solutions to a mathematical problem when in actuality, only one exact solution is intended. For example, there could be some confusion as the solution of the following problem.

Problem: Evaluate the following arithmetic expression:

$$5 + 4 \times 3$$

Solution:

Solution 1	Student 2
$5 + 4 \times 3$	$5 + 4 \times 3$
$= 9 \times 3$	$= 5 + 12$
$= 27$	$= 17$

Solutions 1 and 2 interpreted the problem differently, resulting in two different answers. Solution 1 performed the operation of addition first, then multiplication; whereas Solution 2 performed multiplication first, then addition. When performing arithmetic operations there can be only one correct answer. There needs to be a set of rules in order to avoid this kind of confusion. Mathematicians have devised a standard order of operations for calculations involving more than one arithmetic operation.

Rule 1: First perform any calculations inside parentheses.

Rule 2: Next perform all multiplications and divisions, working from left to right.

Rule 3: Lastly, perform all additions and subtractions, working from left to right.

The above problem was solved correctly by Solution 2 since it followed Rules 2 and 3.

5. Activities

a. Batteries: Positive and Negative Numbers

Engineers build transmission systems to deliver power to houses and businesses. Customers of the power company need specific voltage ranges to run their devices and machines. Power engineers use their knowledge of circuits to deliver the correct voltage to the customers at the end of the power line. When powering a portable electronic device, the engineers use batteries to power the device.

Many students struggle when first introduced to the idea of negative numbers. Some students have trouble seeing the real-world connection to negative numbers. Voltage is the

measure of electric potential: the difference in electrical charge between two points in a circuit expressed in volts. Batteries are power sources and their electrical power is often quantified in terms of their voltages. When batteries are connected in a line, or in *series*, the voltage of each battery is added to the others. Figure 1 shows two batteries connected in series. When a battery is placed in this line backwards (with respect to the others) its voltage becomes negative. So battery voltages, just like numbers can be positive and negative. Thus, batteries can be arranged to be added and subtracted from one another with resulting positive or negative voltage sums.

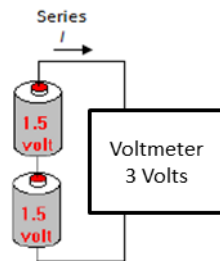


Figure 1: Diagram of two 1.5 Volt batteries connected in series

In this activity students were given 1.5 Volt batteries and then given many different arrangements of batteries and asked to compute the expected output. Then to verify their calculations, students use a multimeter (an electrical tool for measuring many different electrical quantities) to measure the voltage of their arrangement. Figure 2 shows the voltage being measured from two batteries connected in forward position.

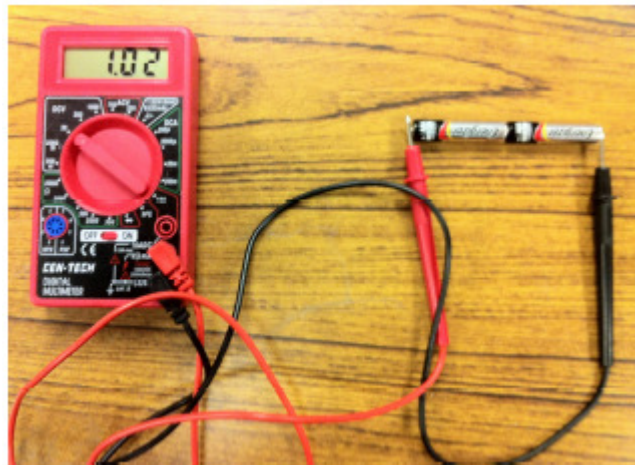


Figure 2: Multimeter measurement of voltage output from two batteries connected in series (these were used batteries, so their voltage has dropped well below 1.5 Volts each).

The following is an example of how the proposed activity works.

Example: 2 forward, 1 backward as shown in figure 3.



Figure 3: Diagram of batteries arranged 2 forward, 1 backward.

This results in a total voltage of + 1 Volt.

b. Computing Percent Change Using Electric Resistance

Power engineers build transmission systems which sends electricity from their generating systems to their customers. When dealing with small circuits and devices, of the wires is often negligible compared to the resistance of the load on the circuit, but when modeling large systems like power transmission lines, the resistance is measured per unit length. Knowing the resistance on a particular length of transmission line will allow the power engineers to make many useful predictions, including the resistive power losses on the line.

This activity deals with computing percent changes. A fun way for students to improve their skills in this area is to measure the electric resistance of their pencil lead. All materials have a certain amount of resistance. In a given conductor, the resistance increases as the length increases. The resistance of the conductor will also decrease as the cross-sectional area of the conductor increases. Electric resistance is a measure of opposition to electric current and the unit of measurement is called an Ohm (abbreviated as Ω). Current is the flow of electric charge through a conductor. Something with low resistance like metal makes a good conductor and usually has a resistivity on the order of 10^{-8} Ohm-meters (abbreviated $\Omega \cdot m$). An Ohm-meter is a measurement engineers use to define resistance with respect to length. This is why copper wire is often used for electrical connections. The same copper wire is usually surrounded by rubber or plastic, which has very high resistance (around 10^{16} Ωm). This high resistance keeps the electric current from flowing out when the wire comes into contact with another conductor. It also keeps other electromagnetic signals from interfering with the electric signal within the wire.

In this activity students will measure the resistance of a “wire” created by drawing a thick line with a pencil on an index card. Two probes will be spaced at different lengths apart on pencil lead. Resistance should vary directly with the length between the probes. The students will see this when they measure different lengths and compare them by calculating percent change. The formula for calculating percent change is:

$$\% \text{ Change} = [(New - Old) \div Old] \times 100\%$$

Where “New” is the newer measurement and “Old” is the reference measurement. The students will be measuring the resistance at a reference length (1”) and then comparing it with the resistance at other lengths (2”, 3”, 4”, 5”). Figure 4 shows a diagram of the flash card that will be used to make measurements. Again the students will use multimeters in order to make their measurements.

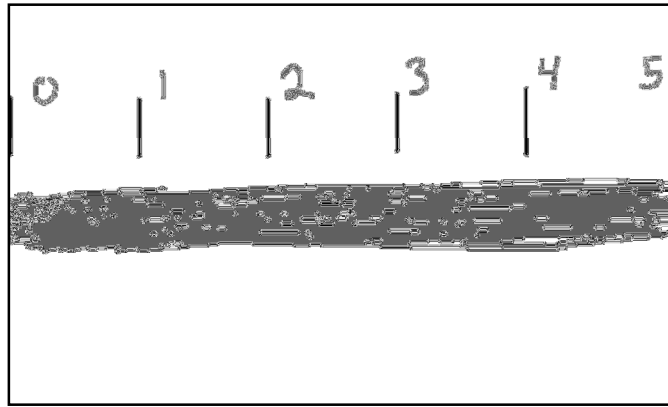


Figure 4: Figure shows diagram of completed flash card.

c. Ratios: Power Transformers

When power is being sent across long transmission lines, there are always power losses from the source of generation to the customer. These losses can be reduced dramatically by making the voltage on these long transmission lines very high, but customers can't use these high voltages. Power engineers use special devices called transformers to raise and lower the voltages on their network to appropriate levels. The technology of transformers makes use of *ratios* to adjust voltages. Knowing how to work with ratios is very important for engineers. In this activity students use ratios to predict output voltages from small wall transformers.

A transformer takes an input voltage and raises it or lowers it according to its specified ratio. Transformers have an input and output side. Wires on both sides are wound around a magnetic core many times. It turns out the ratio of windings from the input compared to the output directly relate to how the voltage will be converted. For instance, if the input side has 1 turn around the core for every 2 turns that the output wires makes around the core, then the output will have twice the voltage of the input. See Figure 5 for a diagram of an ideal transformer. This ratio is called the *turns ratio* and it is what power engineers use to predict what voltages will be produced on either side of the transformer.¹

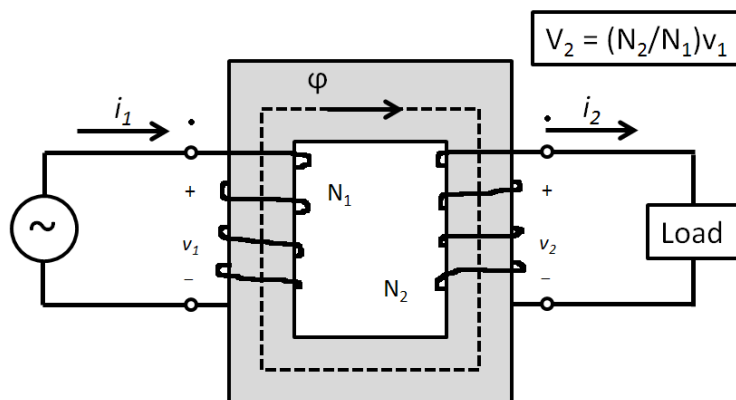


Figure 5: Diagram of an ideal transformer, where N refers to the number of turns of the wire.

Wall transformers of different output and input ratios are prepared with labels that give the ratio on either side of the transformer. The class is divided into groups and each group given a wall transformer. Knowing that North American wall sockets provide 120 Volts, the students are next asked to predict the output voltage if they hook the transformer into the wall with the high voltage (HV) side going into the wall and the low voltage (LV) facing out. For example: If given a 20:1 transformer and attaching the 20 side to the wall the output will be $120 \text{ Volts} / 20 = 6 \text{ Volts}$.

Students next verify their prediction by using multimeters to measure the output voltage of the transformer. They are then given different wall transformers with different ratios. When they complete their predictions and measurements for all of the different transformers they are given multiple transformers and asked to connect them in series and predict/measure the output. This is how real power systems work: raising and lowering voltages at different points in the network to obtain desired voltage levels. Figure 6 shows a table corresponding to a multiple transformer arrangement and the voltages at different points.

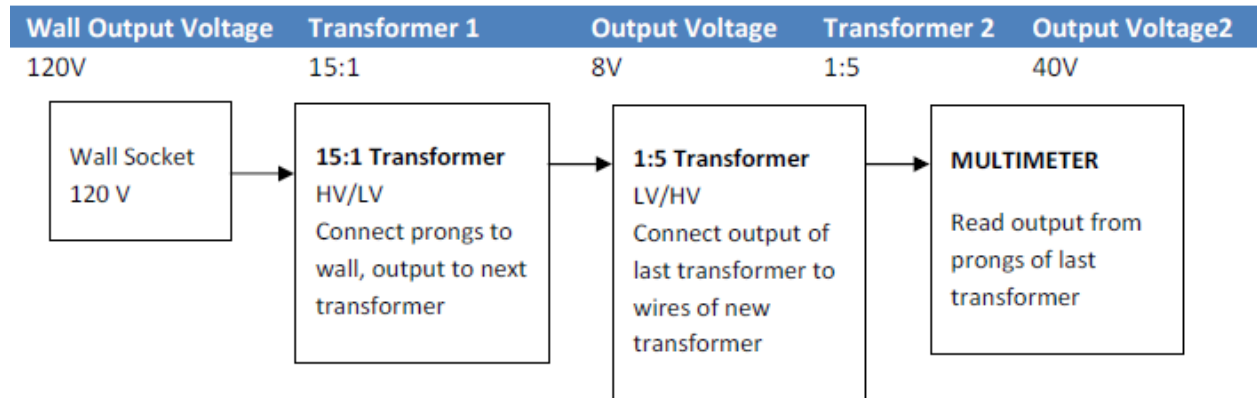


Figure 6: Example of multiple transformer arrangement where the voltage is lowered and then raised.

d. Finding the Energy of a Spark

In power transmission systems engineers must take special care to separate the conductors and equipment by enough space in order to prevent power arcing: large sparks or streaks of energy that go from one conductor to another. These arcs can cause equipment to be destroyed, service to be interrupted to customers, and even injuries or death to those who are in the immediate vicinity. These arcs are caused because the conductors are carrying electricity at very high voltages and if there is not enough spacing between the conductors, the energy can “jump” from one line to the other. This often happens when a switch is being opened or closes while the wires are still energized. The Van de Graaff Generator used in this activity creates a very high voltage charge on a sphere and when a conducting material is placed close to it, a spark is created. This short-duration “arc” is similar to the ones experienced when power systems fail.

This generator Van de Graaff uses a hand crank to create friction, which in turn generates static electricity. This process is similar to the process of rubbing wool against a balloon to create a static charge. The source of the charge comes from belts inside the generator which rub against one another creating a charge which is transferred to the sphere on top. See Figure 7 for a diagram of the generator.

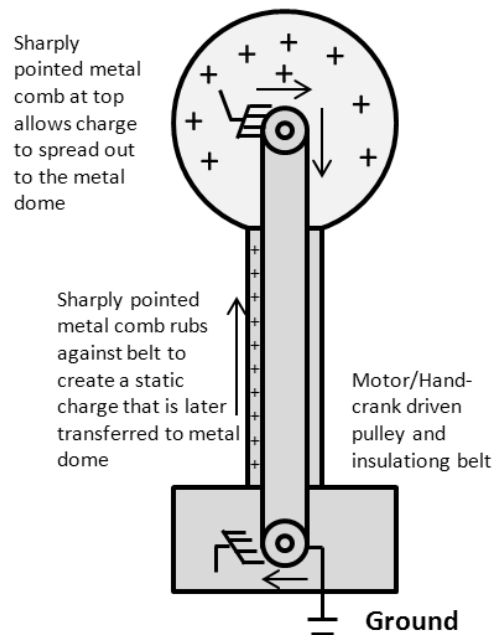


Figure 7: Diagram of a Van de Graaff generator which uses belts to create a charge which is stored on the large sphere above.

The generator used can generate voltages of up to 200,000 volts. To give an idea of just how much voltage this is, a wall socket in the United States delivers a voltage of 120 volts. Even though the generator creates extra high voltages, the voltage can only be sustained for a fraction of a second and is extremely low current. Current is the measure of flow of electricity. The energy delivered by the generator is quite low, usually on the order of less than 1 joule.

The Van de Graaff generator will be used in this activity to create sparks, or *arcs* as they are referred to in power engineering. When power engineers construct power lines, special care must be taken to separate the conductors enough to prevent arcing. Usually there must be a conductor between two points of different voltages for current to flow, but power lines have such high voltages that under some circumstances, current will jump from one conductor to the next. This usually occurs during switching, which is when one circuit is switched on or off, usually by means of a large mechanical switch that connects one power circuit to another. When this switch opens or closes, there is a gap between conductors of very different voltages and when the gap becomes small enough, an arc occurs. See Figure 8 for a photo of a 500,000 Volt arc during switching.



Figure 8: Photograph of a 500,000 Volt switching at Eldorado Substation in Boulder City, Nevada. Substation owned by Southern California Edison.⁶

As mentioned before, the Van de Graaff generator creates a large static charge on a sphere. An estimate of the energy stored by the sphere can be made by calculating the sphere capacitance, $C = 4\pi\epsilon_0 r$ (where C is the capacitance in farads, r is the sphere radius in meters and ϵ_0 is the permittivity of free space: $8.85418782 \times 10^{-12} \text{ m}^3 \text{ kg}^{-1} \text{ s}^4 \text{ A}^2$). Capacitance is the ability of a system to store electric charge. Usually special electrical devices called capacitors are used to carry charge, but many objects have their own capacitance. After the capacitance, C , is determined, the voltage, V , can be estimated by using the length of spark gap, where $V = 2500 \text{ V/mm}$. Next, the energy E , in joules, can be calculated from $E = 0.5CV^2$.^{7,8}

During the activity, students were asked to come up two at a time, where one student would turn the hand crank and the other would slowly move a wand with a sphere on the end of it towards the large sphere of the generator. As soon as the spark occurs, the student stops moving the wand forward. The other student then takes a ruler to measure the distance in millimeters from the wand to the generator sphere. Figure 9 shows a student moving the wand towards the generator while the fellow turns the hand crank.

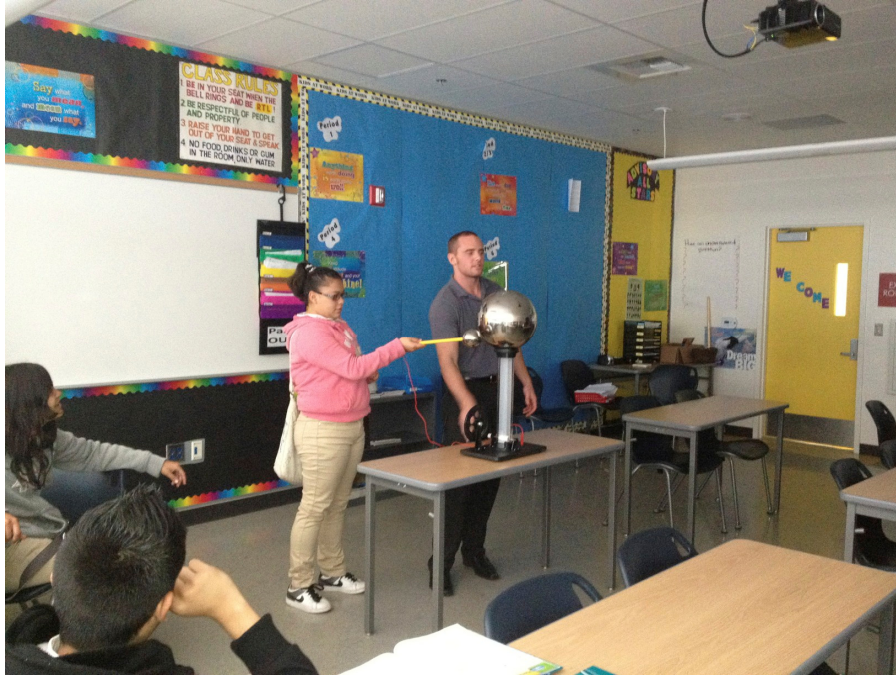


Figure 9: Photograph of Van de Graaff generator being used by a student to create a spark.

So, for example, from the manufacturer's specifications, the diameter of the sphere on the generator is 10 inches which gives a radius of 5 inches. Knowing that 1 inch is equal to 2.54 cm and that there is 100 cm per meter, this gives a radius of $r = 5 \text{ inches} \times \frac{2.54 \text{ cm}}{1 \text{ inch}} \times \frac{1 \text{ m}}{100 \text{ cm}} = 0.127 \text{ m}$. Substituting into the equation for capacitance, $C = 4\pi(8.85418782 \times 10^{-12})(0.127) = 1.4131 \times 10^{-11} \text{ F}$. Also from the manufacturer, the maximum voltage from the generator is 200,000 Volts. So the maximum energy stored on this sphere is given by: $V = 0.5 \times 1.4131 \times 10^{-11} \times 200,000^2 = 0.283 \text{ Joules}$. The maximum energy stored on this energy is actually quite low even though the voltage is very high. Note, if the voltage from the spark corresponds to about 2500 V/mm, the largest spark observed should only be about $200,000 / 2,500 = 80 \text{ mm}$ or 0.8 cm. When the activity was conducted, students did not reach this maximum.

e. Building and Powering a DC Power Grid from Renewables

There are many different energy sources for electric power generation. In the United States, power is primarily generated from coal, natural gas, nuclear, and hydro sources. There is a growing trend to obtain more power from renewable resources: wind, solar, and hydroelectric. When planning a power grid, power engineers need to take into account how much power can be generated from their sources and how much power will be required by the loads on the system. Power engineers are busy creating generating plants from renewable resources. For example, there is a growing trend towards creating large scale wind farms.²

This activity deals with both power generation and consumption. Students constructed a miniature power grid which was supplied with DC power. On the grid were many small loads which made use of this power. All power systems possess at least three parts: a source (or generator), a load (a device that uses the power), and transmission lines (wire). In the United States and most of the world, much of the power grid uses alternating current (AC) power. AC

power describes the oscillating nature of generated power. Its amplitude over time resembles that of a sinusoidal. By contrast, direct current (DC) power has constant amplitude over time and appears as a straight line. AC power generation and transmission is still usually preferred because it can be generated at low cost, the generators require less maintenance, the transmission usually costs less, and most of the industrial motors make use of AC power. See Figure 10 for a comparison between AC and DC currents.

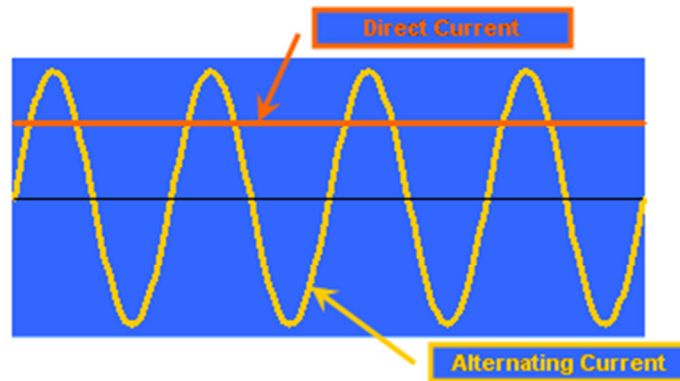


Figure 10: Graph of AC current (sine wave) vs. DC current (flat line).

This activity however, used DC power for several reasons. First, AC power systems must be synchronized and achieving this on a small grid would be very difficult. Second, the loads on the system will be LEDs (light-emitting diodes), which require DC electric current. This activity was an end-of-the-year project which was conducted over many days. Students were first asked to design/build their own wind turbines out of cardboard. When this process was complete, they built a power grid using wires and LEDs, which was setup to utilize DC power sources at many different points in the grid.

The students did not just use their wind turbines, but also made use of mini solar panels and batteries. When the grid was completed they attached all of their sources to the grid. The wind turbines were turned from blow-dryers or fans, the solar panels were placed outside to gather light energy, and the batteries were hooked directly to the grid. Power, P , is the product of voltage, V , and current, I : $P = VI$. The students used multimeters to measure the voltage and current at different points on the power grid and next calculated the power at these points. Figure 11 shows a photograph of the powered LEDs. The LEDs were placed on top of miniature buildings which were also constructed by the students.

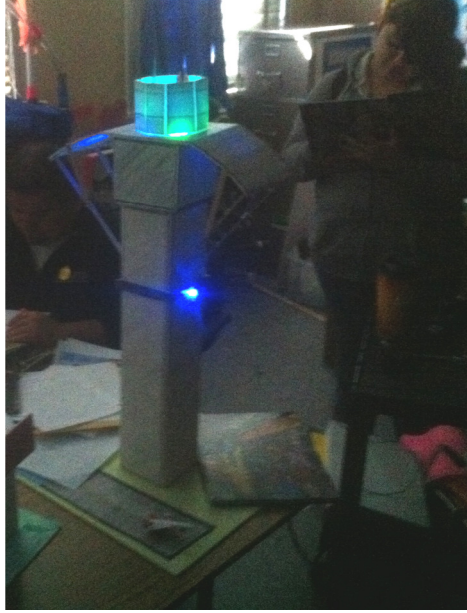


Figure 11: Photograph of a miniature DC power grid with LEDs lit up. The power grid has been placed over a model city.

6. Assessment of Activities

Assessment Data of Van de Graaff Activity

Before and after students engaged in the hands on activity regarding the Van de Graaff generator, survey responses were collected in order to measure the effectiveness of the hands on activity.

Figure 12 shows the impact of this particular hands-on activity. Before the activity 82% didn't understand the concept of static electricity whereas after the activity, almost 87% reported that they understood the concept of static electricity. A total of 94% of students reported that the activity helped them improve their math skills with order of operations, and 99% reported that the activity helped them understand how order of operations is used in real life.

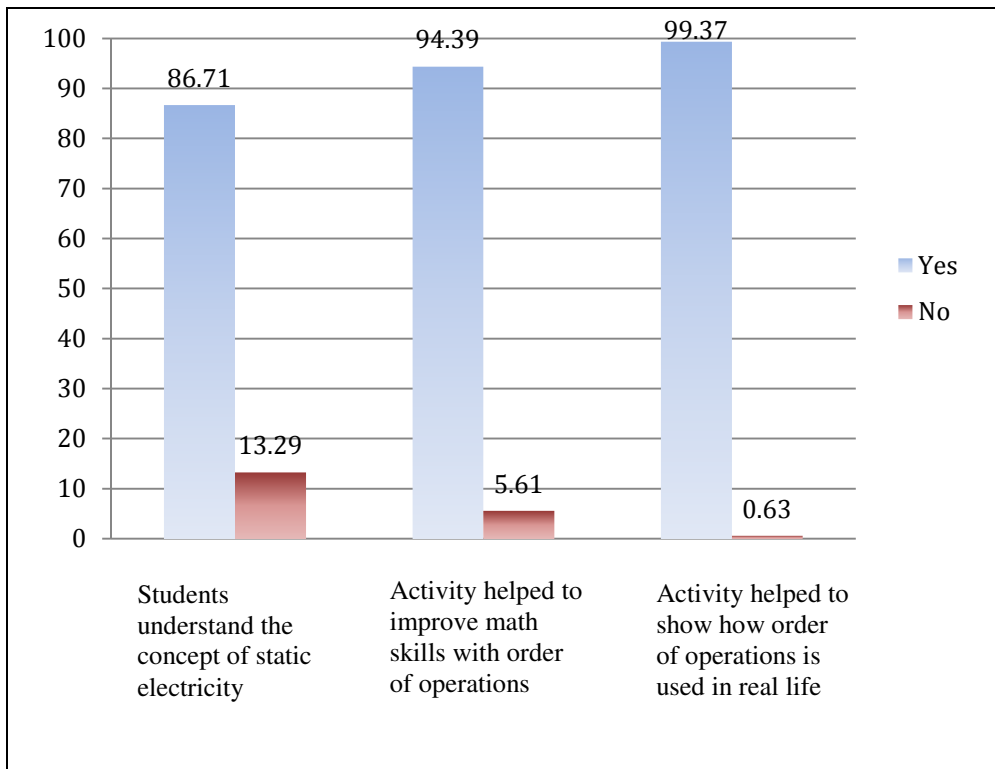


Figure 12: Students' attitudes towards Van de Graaf generator activity (n = 81).

Figure 13 shows the students' attitude towards the activity. Based on a scale from 1 to 5 (with 5 = very hard, 4 = hard, 3 = moderate, 2 = easy, and 1 = very easy), students gave a fun rating of 4.43 and a difficulty rating of 2.04. These figures show that this engaging activity was both fun and effective in teaching students about real-world engineering and helping them boost their understanding of abstract mathematical concepts.

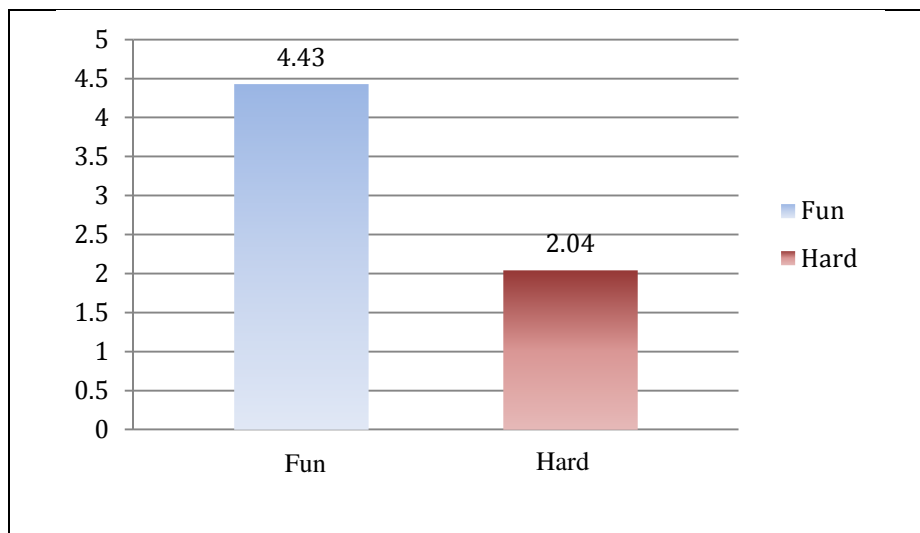


Figure 13: Students' attitudes towards Van de Graaff generator activity (n = 81).

7. Conclusion and Pre- and Post-Assessment Data

The power engineering demonstrations and activities presented in this paper reinforced the concepts being covered in 7th grade pre-algebra. The hands-on activity with the Van de Graaff generator allowed students to see how the order of operations that they are introduced to in pre-algebra have real-world applications. The students also indicated that activity was fun and not that hard.

Perceptions of Engineering

All of the activities except the Van de Graaff generator activity were performed last year (2010-2011 school year). Pre and Post-surveys are collected annually in the IMPACT LA Program to gauge students' attitudes towards math, engineering and science. The data was collected for all students participating in the program including middle and high school math and science classes. Figure 14 shows the impact of the IMPACT LA Program on the students' attitudes towards engineering and science for the 2010-11 school year. Through their interactions with the students, fellows had a relatively significant impact on students' view on engineering.

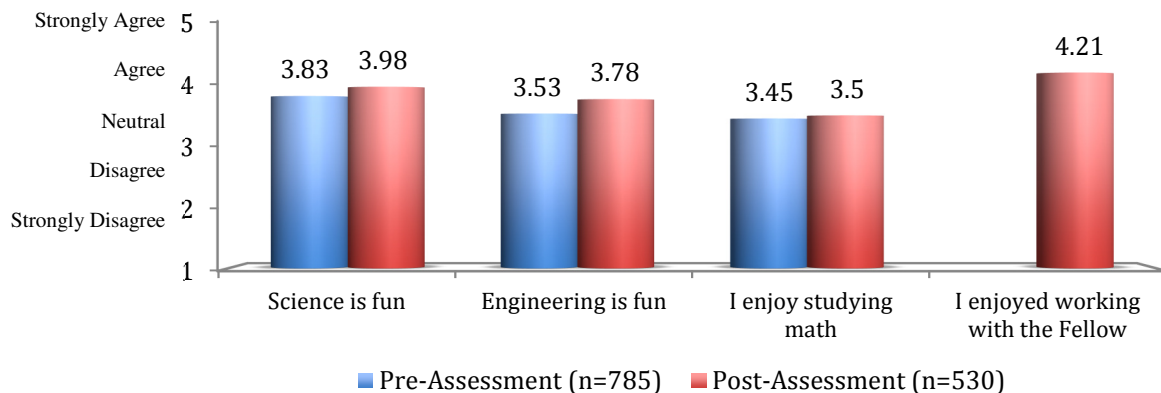


Figure 14: Differences in attitudes towards science and engineering in pre and post survey.

Characteristics of Engineers

	Pre	Post	Difference
Things that scientists and engineers do			
Experiment	16.0%	21.7%	5.7%
Make	13.5%	17.8%	4.3%
Invent	7.6%	10.9%	3.2%
Build	26.6%	29.8%	3.2%
Fix	10.2%	6.4%	-3.8%
Discover	13.2%	7.3%	-5.9%
Study	24.3%	17.2%	-7.0%
I don't know	5.8%	3.2%	-2.7%
Three words that describe a scientist or engineer			

Fun/funny	9.9%	16.9%	6.9%
Creative/innovative	7.4%	13.5%	6.1%
Cool	7.5%	13.1%	5.6%
Helpful/helpers	4.2%	7.9%	3.7%
Intelligent	7.0%	10.3%	3.3%
Hardworking	9.5%	12.7%	3.2%
Awesome	2.4%	5.2%	2.8%
Smart/wise	44.6%	47.4%	2.8%
Educated	1.1%	3.2%	2.0%
Boring	0.9%	0.2%	-0.7%
Old	0.1%	0.8%	0.6%
Nerds/nerdy	1.1%	0.8%	-0.4%
I don't know	6.6%	2.6%	-4.0%

Table 1: Pre and Post Responses: Perceptions of scientists and engineers

Table 1 shows the pre- and post-survey student perceptions of scientists and engineers. As far as what scientists and engineers do after the in-class activities more students used words like “experiment”, “make”, “invent” and build” while less used the word “study”. More students felt that scientists and engineers were “fun” and “creative”.

Figure 15 shows the impact of in-class activities on different genders. Both genders showed a rise in interest in engineering between pre- and post-surveys. As is traditionally true, males had a find engineering more fun overall. However, females had a larger rise in interest than males.

Engineering is fun: Average ratings by gender

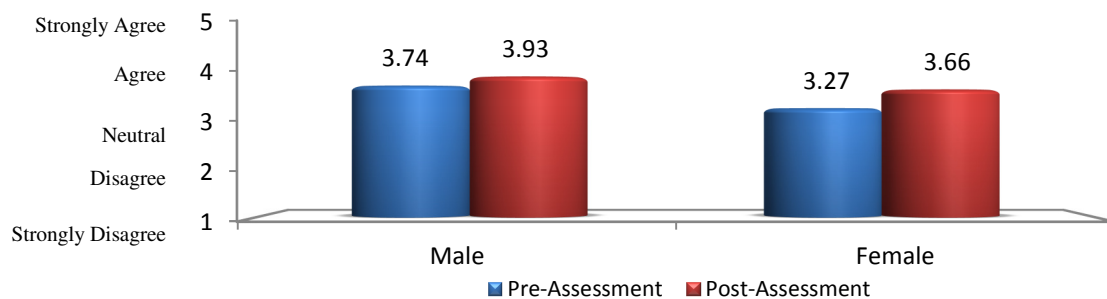


Figure 15: Impact of in-class activities on genders.

Characteristics of Engineers

In addition, students were also asked about their dream job. The top job remains in the medical field both before and after the in-class activities, but there is a rise in science and engineering. In fact, engineering surpassed science in the post-survey. There was also a drop in government and security jobs and careers in sports. On the whole, more students see a future in technical jobs. Table 2 shows the complete data for dream jobs.

Dream Jobs	Pre-Assessment	Post-Assessment	<i>Difference</i>
Medical field	25.2%	26.2%	+1%
Government and Security	17.2%	11.5%	-5.6%
Art & Music	12.7%	13.3%	+0.6%
Sport	12%	7.9%	-4.1%
Engineering	3.4%	7.5%	+4%
Law & Criminal	8.1%	7.5%	-0.6%
Science	6.4%	6.6%	+0.2%
Education	7.8%	6.3%	-1.4%
Social Science	4.6%	5%	+0.4%
Others	7.4%	3.8%	-3.7%
I don't know	6.4%	9.1%	+2.8%

Table 2: Pre and post responses. Dream jobs.

Conclusions and Future Work

During the 2010-11 and 2011-12 school years, 7th grade students were exposed to hands-on activities in power engineering that paralleled with the math concepts they were learning in pre-algebra. Using hands-on activities to integrate power engineering into K-12 curriculums helped students see math applied to real-world problems, while bringing a much needed engineering element into the classroom. The activities used topics such as power-storage, electric resistance, power transformers, capacitance, and power grid design to reinforce math concepts. Pre- and post-surveys show that the students felt that these activities helped them to understand the math they were learning. At the same time, students' perceptions of engineering and career aspirations also seemed to be affected.

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