When is a Motor More Than an Electromechanical Device: Teaching K-12 STEM Subjects through Hands-on Experiments

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I ABSTRACT:

It is well known that electric motors convert electric into mechanical energy. This paper will discuss how Oakland University's Science, Technology, Engineering and Math (STEM) camps during the summer of 2012 used an electric motor experiment to stimulate young minds. Also included will be the teaching methodology used to develop the camps and experiences gained during leading them as part of a multidisciplinary group of graduate engineering students. This group was assembled to bring our areas of expertise together and develop an earth sciences program for several K-8 and K-12 student-centered, active-learning STEM camps revolving around inexpensive yet substantive hands-on experiments that fit into one hour teaching modules. The modules all had similar formats; a short lecture, an experiment, and some fun time to reinforce the positive learning experience and increase retention of the material.

One such created module centered on electricity generation, electricity flow, electromagnets and electric motors. The students used these module templates to have fun while creating an electric motor out of a table top, permanent magnet, some tape and a copper winding they constructed from a spool of wire. The background of why this type of lesson plan was chosen and how experiential learning creates positive, lasting memories in the young students' minds associated with STEM subjects will be discussed. These positive experiences will hopefully inspire students to choose STEM majors in secondary education and in turn pursue professional careers upon graduation.

II INTRODUCTION:

There is much to be understood about how to fill the emerging STEM field jobs; key components to attracting students in these fields, and producing qualified professionals to fill these jobs. The U.S. Department of Commerce's Economics and Statistics Administration (ESA) [1] reports that the growth of new STEM field jobs will outpace non-STEM employment opportunities by 70% over the next 5 years. This paper will discuss the how Oakland University STEM camps in part attract and train K-12 students by using fun hands-on experiments to reinforce the theoretical concepts taught during the lectures.

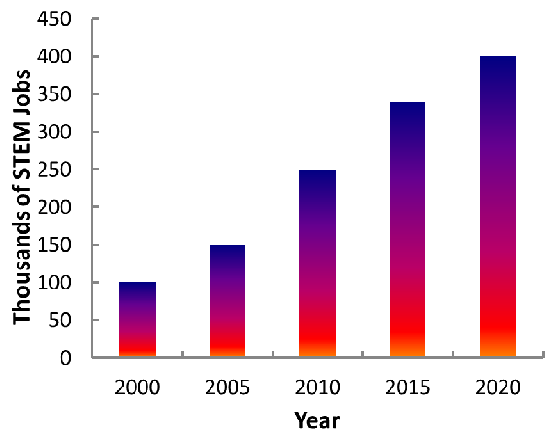

Figure 1 - Students with STEM Interest by Grade

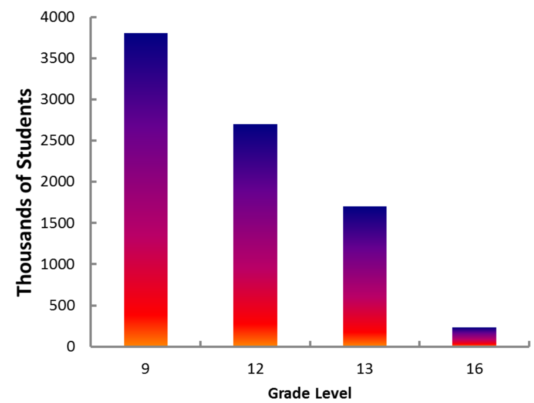

Figure 2 - Number of Students by Grade Interested in STEP Subjects

Of the 1.7 million Bachelor's Degrees granted in
2011, only approximately 250,000 received degrees in the STEM fields. [4] Contrast this with the new jobs of figure 1. This shortage of STEM graduates undermines the United States ability to remain on the technology forefront of innovation. Studies have shown that of the 3.8 million 9th graders with interest in STEM fields, only 6% of them graduate with a STEM degree. [2]
Figure 2
The reasons cited are, it is boring, not relevant to everyday life, or they were not prepared for secondary STEM majors in during their K-12 education. [3]

III MAKE IT FUN:

The goal of teaching K-12 students STEM subjects through hands-on experiments is to create STEM professionals in the future. Of the 6th – 12th grade students that are interested in STEM careers, more than over half of them believe they are either not qualified or it is too much work to go into as a professional career. [3] To combat these obstacles, this paper discusses the benefits of active learning exposing them to fun hands-on experiments. These positive, fun, memories stay with the student creating positive STEM learning experiences making them more likely to remain in technical curriculums and be attracted to STEM careers.

Oakland University's School of Engineering and Computer Science's (SECS) K-12 outreach program focuses on 5th -12th grade students with an interest in STEM. The outreach program attends career days, hosts college fairs [5], supports collegiate Engineering competitions and holds STEM camps. The camps come in many different varieties ranging from 2 hour introductions to the engineering field to hosting 2 week residential camps on Oakland's Campus. Most of the camps are held during the summer and include collaborative efforts with other local organizations. These collaborations provide for access to a diverse community of students. The Detroit Area Pre College Engineering Programs (DAPCEP) has a nearly 40 year history of attracting underrepresented minorities into the STEM fields (http://www.dapcep.org). SECS and

DAPCEP have a 2 week residential camp for 9th and 10th grade young men primarily from inner-city Detroit schools. The Utica School District collaboration had several one week day camps for 6th - 10th grade students at a Sterling Heights elementary school. To expand SECS's exposure in Oakland University's new Macomb County extension campus, a one day engineering camp was held there last summer. The most development evolution of this experience is a biweekly after school program at Pontiac High School for 6th-12th grade students. In addition to these STEM camps other demonstrations and informal meetings, SECS outreach attends events at various high schools, college fairs and Oakland University open houses throughout the year.

IV HANDS-ON LABORATORY:

SECS's outreach camps follow a basic formula: short on lecture, long on experimentation and fun. The lectures are typically 15 to 20 minutes long and cover a single STEM topic. These topics range from history of energy, lighting, fossil fuels, electricity, truss design, computer science, robotics and transportation. Depending upon the length of the camp and age of the students, these subjects can be broken down into deeper modules consisting of a lecture followed up with a hands-on experiment. In addition to the experiments being educational, they need to be fun and affordable.

To make the experiments fun, they were chosen such that the students had a basic understanding of them before hand and could relate to them in some way. For the Electrical Engineering module, the four 4 basic concepts from table 1 were taught.

Electrical Engineering Labs

Conductors, Insulators and Semiconductors
After a lecture on what is electricity and how is it transported, the students were give some brief training on how to use an Volt Ohm meter (VOM) and set lose in small groups with common household items (a penny, brass fitting, hot dog, tap water, salt water, salt, wood, a nail, copper wire, etc) to measure their resistance. The students then tabulated their results into three columns; conductor, insulator and both.

Lemon Battery
A multi-discipline lecture on chemistry and electrical energy coved the chemical reduction process and how it frees electrons to produce electricity. Each camper built his/her own lemon battery and calculated the power output of their single cell with a VOM and some basic math. A fun competition was created where the students formed teams and compared their team's total power output in watts.

Magnetism
Following a science lecture on magnetism, the students were given unstructured laboratory time to experiment with various types of magnets and materials. Using both inexpensive permanent magnets and rare earth magnets, the students documented their effects on wood, copper, brass, iron filings, paper, steel, a compass and other household items.

Electromagnetism
This lecture was followed by a short video showing electromagnets used for train levitation and in scrap metal transfer station. The campers then would lacquer coated magnet wire around a

Electric Motors

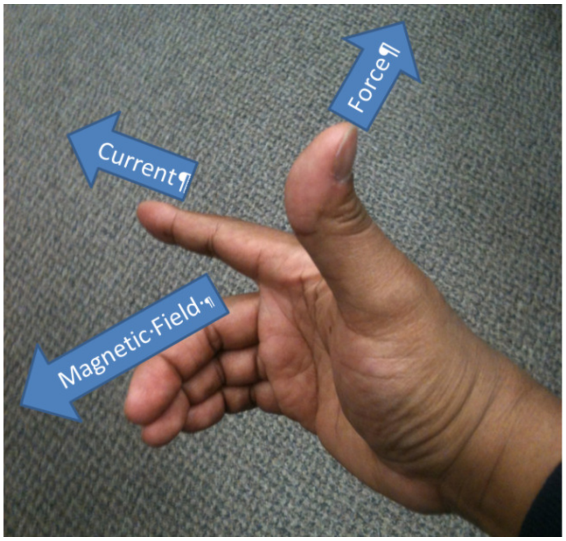

Figure 3: Right Hand Rule

The electric motor laboratory was the capstone project for the electrical engineering modules. It was largely based on the magnetism and electromagnets experiments. The lecture reinforced the magnetic principles of magnets, either electro or permanent; they have magnetic fields that emanate from their two opposite poles. When magnets are placed in close proximity of other magnets, their magnetic fields interact and create a force on each other. When the poles have the same polar orientation they repel one another. And when they are opposite each other, they attract. Electromagnets have the added property of whenever current flows through a conductor a magnetic field is produced in around that conductor. Conversely, whenever a conductor is moved through a magnetic field, current is produced. The interaction of the current and magnetic fields is categorized by the right hand rule. [6] & Figure 3. When this electromagnetic field is in the presence of another magnetic field a force is created perpendicular direction to the current flow. A simple example of this force is in the action of an audio speaker. When current is introduced to the speaker coil, an electromagnet made by rapping wire around a hollow tube, a magnetic field is created. This magnetic field interacts with the speaker's permanent magnet's field and force is generated, depending on the current flow direction, in or out of the speaker causing the diaphragm to move. See figure 3 for details. To change the direction of movement, the current direction is reversed. This rapied change in current flow is called alternating current (AC) and if fast enough, 20 to 20k time per second, will cause the speaker cone to vibrate and thus generate sound.

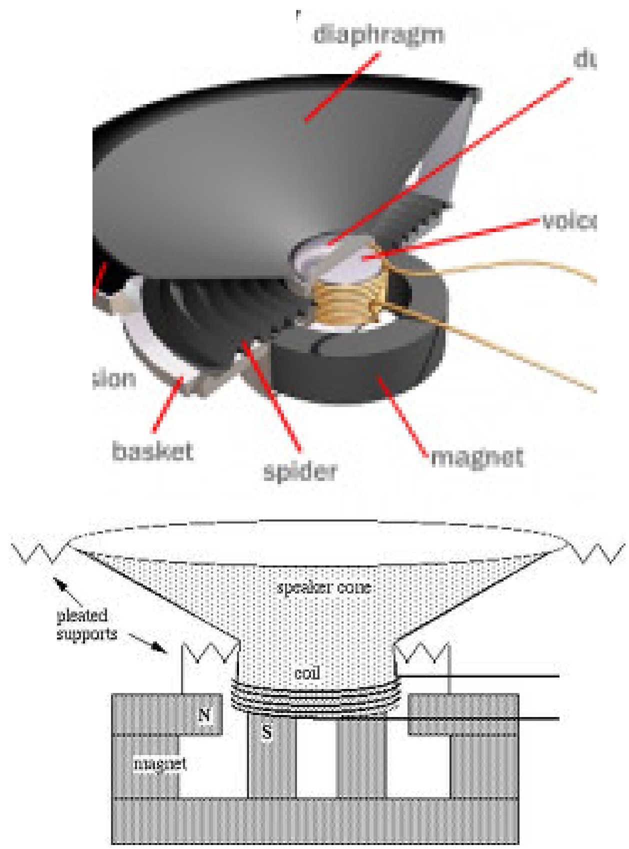

Figure 4: Speaker Basics

Electric motors use the same engineering principles as speakers but apply them in a rotary versus linear manner. Here the rotor held at both ends by bearings to allow rotational motion while preventing linear movement. The force generated by the current flow through the coil is tangential to this axis forcing the rotary assembly to turn. As the rotor continues to turn, the electromagnet leaves the permanent magnet's field and no force is exerted. The motor must be designed such that the inertia force is great enough to overcome the frictional forces and allow the rotor to spin until the rotor is once again in the permanent magnet's field starting the process over.

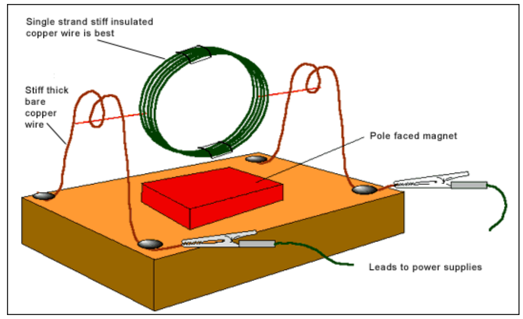

Figure 5 - replace with my own picture

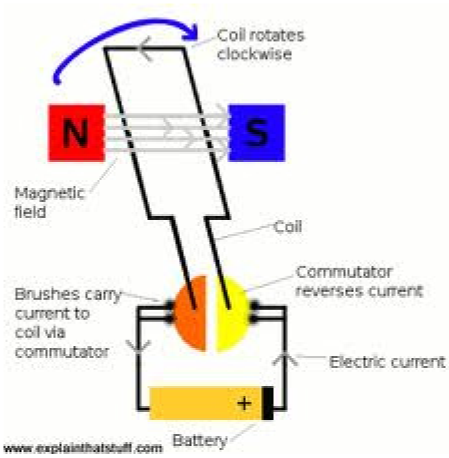

Figure 6 - replace with my own diagram of a motor


Figure 7 - Motor Armature / Rotor

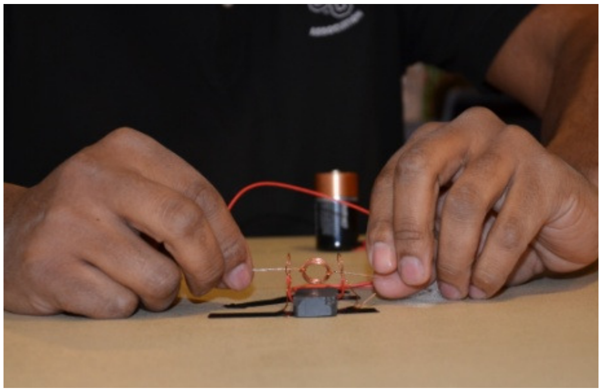

Figure 9 - Jump Starting the Motor

The electric motor lab worked best when preformed with small groups of students. Each group of 2 to 4 campers made several

Figure 2 - Motor Frame

loops in the 22 gauge wire to create the electro magnet called an armature. When it is straightened and the ends are trimmed it will function as the motors rotor. Figure 6 It is critical that the rotor/armature assembly is balanced and straight as possible or the induced electromagnetic forces will not be tangential to the rotating axis and the motor will not spin. If these forces aren't tangential, the motor wouldn't be able to overcome the frictional counter forces and the motor will not work. The students then made a motor frame by bending bare copper wire into a bearing cage to support the rotor. These bearing cages were assembled with the rotors and taped to the workbench. Figure 8 The final step in creating the motor was placing the permanent magnet in the motor. The magnet was placed, but not secured, under the armature on the workbench. This allowed for movement to tune the motor for best performance. The power for the motor was provided by one or two D cell batteries connected in series. To save cost, the students made their own battery holders out of electrical tape and connected them to the motors with short electrical jumpers. Once the batteries were connected, the motor could be jumpstarted with a twist of the rotor. Figure 9 The campers were then encouraged to find ways to make their motors better. They tweaked the rotor for straightness, added batteries, tried different and multiple magnets, improved electrical connections and reduced friction to make fast and more powerful motors.

Figure 9 - Finished Motor Assembly

V CONCLUSION

The proliferation of electric motors into our lives over the past 30 years has been tremendous. The days where they were only used in fans, washing machines and to start internal combustion engines ICE are long behind us. In 2013, it is almost impossible to spend even a minute without touching something with an electric motor. They are in computers, phones, microwave ovens, robotics and more recently, used replace the ICE to propel hybrid and electric cars. This increase in demand is partially responsible for the rapid creation of new STEP jobs. The electric motor module in the camps teaches the students concepts and skills that directly transfer to electrical engineering and physics concepts in a way that creates positive experiences in their long term memories. What makes this lab different is it is taught in a simple while substantive way. It relies heavily on hands-on laboratory experiments while keeping the cost down for proliferation and repeatability. The startup cost per motor is less than $1 and consumable cost each time it is run is just a few cents, making this teaching method adaptable to almost any curriculum as a way to create a fun and memorable STEM experience that will last a life time.

VI REFERENCES

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