Electricks: Pre-College Activities in Electro-Mechanics

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***Abstract*— This research to practice full paper is a survey based paper that examines the impact of a set of experiments in electro-mechanics, designed to introduce pre-college students to electrical engineering in a fun, hands-on manner that demonstrates the basic principles of power generation and electromagnetism. It involves a set of 3 experiments which build on each other to teach the participants about how electrical currents and magnets create an electromotive force that can be used to generate power. These activities were presented alongside information about regional college level engineering programs that are accessible to the students. The program is an easily scalable addition to camp-based programs that can be taken to schools to introduce students who are unable to participate in Science, Technology, Engineering and Math (STEM) related extracurricular programs to engineering. Participating students were given surveys to gauge their level of interest and their tendency to choose engineering after performing the experiments. Participating schools were in the Springfield Public School district in Missouri.**

Keywords—electromechanics, pre-college, outreach, electrical engineering

I. INTRODUCTION

The supply of STEM graduates ready to enter the work force is not keeping up with the demand [1]. Enrollment in electrical engineering programs is declining as the need for these graduates is rising [2][[3]. Alongside the general shortage is a lack of diversity [2][4][5]. In particular, women and minority students are not choosing to go into engineering. These groups represent a significant potential source of new engineers to fill the gap. Engineering and STEM oriented jobs are typically higher earning, and contribute significantly to the economy, making them an important contribution.

This project was designed as an outreach to local pre-college students to introduce them to electrical engineering in a fun and hands-on way that enables the participants to connect theoretical information they are given with real-time experiences, enabling them to see the forces they learned about in action. Having a physical demonstration in their hands that requires them to use the information they have been given to help connect theory with reality in a more meaningful way than a simple presentation could [6]. Students are more engaged and excited by this type of experience [7] and that engagement can translate into a change in attitude for the participants.

With all this in mind, the goal was to improve the participant's attitudes towards engineering in general and electrical engineering in particular. Even short introductions to the field can have a positive impact on how the participants perceive electrical engineering [8].

Locally, varieties of outreach programs are already available to students who are interested. Project Lead the Way (PLTW) [9] is active in several local schools. Several STEM based summer camp-based activities are also available to area students. A list of the local outreach programs available are listed in Table I. These programs, with the exception of PLTW, are dependent on the student or their guardian's ability to enroll, pay for and transport them to and from the experience.

TABLE I. LOCAL STEM OUTREACH PROGRAMS

LOCAL STEM OUTREACH		
Organization	**Description**	**Program Type**
O-STEAM	Local organization that sponsors a variety of programs to promote science local, including day camps and day events	Various
Discover Engineering Day	Single day events aimed at K-8 students with a focus on electrical and civil engineering demonstrations and experiments.	Annual Day-Long event
Discovery Center Summer of Science	Day camps focusing on K-8 students with a focus on biology, weather, physics, design, and 3-D printing.	Day Camps
Professor Powers Science Symposium	Classes and camps for K-12 students focusing on STEM subjects like chemistry, physics, engineering, and problem solving.	Day Camps, Classes

The project discussed in this paper is designed to reach a broad range of students more effectively by going to their schools and conducting the experiments in a classroom setting [10]. Instead of targeting students who are already interested in STEM, this project hope to reaches out to students who may not have considered it or may not have had the opportunity for

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exposure to engineering in a meaningful way. This approach guarantees that the participant groups will be a representative sample of the region as the project seeks to pique their interest.

II. THE ACTIVITIES

The experiments were packaged in portable kits. The kits were assembled from components found in local hardware and electronics shops. A few items (the magnets) were ordered online. This enabled the program to be taken to different locations easily, making it more accessible than programs that require the students to travel. Each student works on the experiments by themselves to achieve the 'wow' factor when it is fully assembled and working. This project is also easily scalable and requires less time and financial investment than a traditional summer camp or field trip type program, making it more viable for students to participate in it. [11].

Electricks is divided up into a brief presentation given to the students on what electrical engineers do, and information about the electrical engineering degree programs available regionally. During the presentation the students were presented with information about the role electrical engineers play in power generation and transmission, electronics design, and communications. The engineering programs available to them in the area at Missouri University of Science and Technology in Rolla, University of Missouri in Colombia, Missouri State University, University of Kansas, and Kansas State University.

After this, an explanation of electromagnetic concepts was given. The students were given a hand-out that explained how currents traveling through conductors generated magnetic fields and that these magnetic fields can interact with permanent magnets to generate electro-motive force that can move objects. It was explained that an electrical current could also be generated by moving a permanent magnet through a series of thoughtfully designed conductors. The information on the hand out was then discussed in the context of the experiments they would be completing. A currently enrolled electrical engineering college student gave the presentation. The experiment portion was handled by both the presenter and the classroom teacher who assisted groups in completing their experiments when necessary.

The students then divided up into groups of two or three students and started the three experiments.

A. Experiement 1

The first experiment was accelerating a projectile though a copper solenoid as shown in Fig 1. The student participants were given the following:

Supplies:

- 10 ft length of uninsulated copper wire
- 2 N48 neodymium magnets
- 1 ft section of dowel rod
- 1 AAA battery

Instructions:

1. 1.Wind the wire into a coil around the dowel rod
    a. Keep approximately 9 windings per inch for ideal performance
    b. Keep the windings as uniform as possible.
2. Attach one magnet to each end of the battery
3. Place the assembly in the coil

The battery and magnets would then create a circuit that created an electromotive force that accelerated the assembly through the coil. As the groups worked, they each got a visit from the researcher or classroom teacher, who went over how the device worked.

Fig. 1. Experiment 1 kit assembled

B. Experiment 2

The second experiment was creating a simple DC motor, seen in Fig 2.

The student participants were given the following:

Supplies:

- 1 D-cell battery
- 1 board that had a battery terminal with leads attached 2 posts drilled into the board on either end
- 5 ft length of insulated copper wire
- 2 3-inch lengths of uninsulated copper wire
- 1-inch diameter, 3-inch-long dowel rod section
- 1 ¼ inch diameter, 6-inch-long dowel rod section
- 2 N52 neodymium magnets
- 1 small piece of sandpaper

Instructions:

1. Wind the length of magnet wire around the 1 inch dowel rod
2. Leave 2 inches on opposite sides to function as arms
3. Sand the insulation off one side of one of the arms and completely off the other
4. Take the 2 short lengths of wire and wind them twice around the ¼ inch dowel.
5. Wind the other end around each one of the screws to form holder for coil.
6. Insert the coil in the holder
7. Place the magnet on top of the battery
8. Connect the battery leads to the screws
9. Give the coil a gentle spin

This experiment illustrated how electricity flowing through a conductor generated a magnetic field. That magnetic field interacted with the permanent magnets to create electromotive force.

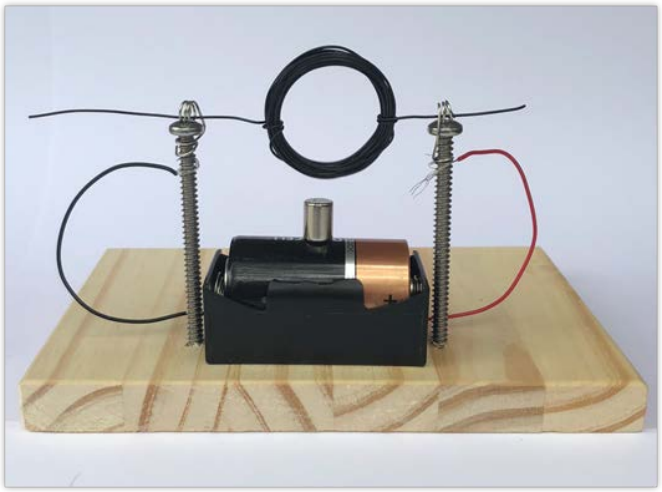

Fig. 2. Experiment 2 kit assembled

C. Experiment 3:

The third experiment was a wind turbine generator demonstration as shown in Fig 3. They were shown a diagram of the generator, and the similarities between it and the DC motor they just made. The students were given the following:

Supplies:

- 1 red LED
- 1 yellow LED
- 1 green LED
- 1 blue LED
- 1 white LED
- a square of poster board
- tape
- 2 alligator clamps
- Bread Board

Instructions

1. Fold the paper square according to the pattern of your choice
2. Tape the blades to the generator
3. Connect the alligator clamps to the leads on the generator and the jumpers on the breadboard
4. Insert the LED's in the breadboard
5. Use the hair dryer to turn the blades
6. As each LED lights up remove it and observe the next color to light.

As each group came up they were told about the wiring configuration of the breadboard and how to connect the circuit to allow the electricity to flow through the LED's. Because the turbines typically didn't generate enough power to light all the LED's at once, they removed each LED as it lit up, illustrating the path the electrical current will take if faced with varying resistances.

Fig. 3. Experiment 3 kit assembled

III. Results

At the end of the experiments, the students were given the opportunity to ask any additional questions. They were then given the survey, which collected data about their gender, race, favorite subjects studied, intention to go to college and participation in, or prior exposure to STEM oriented extracurricular activities. 214 student responses were collected and analyzed. The age range was 9-17 with an average age of 12.9, and a median of 13. To address the question of their prior exposure to STEM extracurricular activities, they were given a list of local programs, with school club options, as well as the option to write in experiences that were not covered by the previously listed options. The survey asked the students to rank the following questions on a Likert-like scale of 1 to 5:

- Are you interested in performing more experiments that deal with power generation and electro-mechanics?
- Would you like to study engineering in the future?
- Would you like to learn more about electrical engineering?
- Do you feel like you learned something from the experience today?

They were also asked for any subjective feedback they had about the experience. In total, 214 participant responses were collected. The demographic breakdown can be seen in Table II.

The student's prior participation and interest in STEM fields was also looked at in the context of the outreach experience. The percentages who reported either a STEM

favorite class, or participation in STEM-related extracurricular activity can be seen in Table III. Most of the students indicated they had no STEM related activities outside of the classroom. A majority also reported that STEM subjects were not among their favorites. Only 22.5% of students reported having both STEM related extracurricular activity and a STEM related favorite class.

Overall the response to the project was varied, with some groups responding much more favorably than others. The percentages who responded positively can be seen in Fig. 4. While only 25.7% of participants indicated an interest in studying engineering in the future, 42.5% of students expressed an interest in learning more about electrical engineering. Likewise, 45.3% indicated that they were interested in doing more experiments dealing with electromagnetism and power generation. A sizeable majority reported that they felt they learned something about power generation and electrical engineering from the experience (78.5%). A closer look at the data shows the results varied significantly between the groups of students encountered.

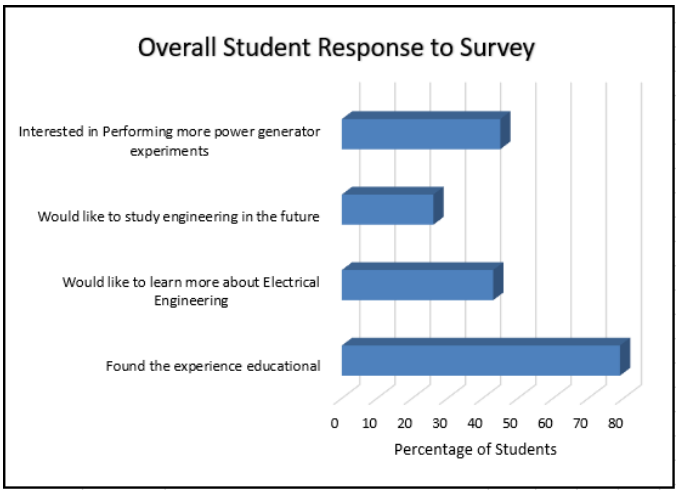

Fig. 4. Overall Student Responses

Female students have consistently expressed less interest in studying engineering and in learning more about electrical engineering. In [12] the author looks at the underrepresentation of women in the engineering disciplines and their show of lesser interest in pursuing engineering as a career. Students who reported prior experiences with STEM extracurricular activities or having a STEM favorite class were significantly more likely to indicate an interest in studying Engineering. These experiences correlate to a higher rate of enrollment in STEM majors in college [13][14].

Overall among female participants 12.4% expressed an intention to study engineering in the future. Despite this apparent lack of interest, 25% indicated they were interested in learning more about electrical engineering. There was a significant increase in the number of female participants who expressed an interest in learning more about electrical engineering in general without prior exposure to STEM.

Among the female students it was found that a few things were correlated with an increased interest in engineering. Students that reported a STEM subject among their favorite classes were twice (24.3%, vs 12.4%) as likely to express an intention to study engineering in the future as shown in Fig. 5. Within that group, they were 1.8 times as likely to express an interest in learning more about electrical engineering specifically (45.9% vs 25%).

TABLE II. DEMOGRAPHY OF STUDENT SURVEYED

DEMOGRAPHICS OF STUDENTS SURVEYED	
Race	
White	60.4%
Multiple Races Selected	15.4%
Black	7.1%
Asian	5.3%
Hispanic	3.6%
Other	12.4%
Gender	
Male	49.1%
Female	45.3%
Other	4.7%

TABLE III. PRIOR EXPOSURE TO STEM ACTIVITIES

Interest In Stem	
Stem Subject Listed As A Favorite	
No	45.8%
Yes	54.2%
Prior Participation In Stem Related Extracurricular Activities	
Yes	34.5%
No	65.5%

On the other hand, female students who did not report a STEM class among their favorites showed the least amount of interest both in engineering in general and electrical engineering in particular. Of these students, only 5% expressed an intention to study engineering in the future, and 13.3% expressed an interest in electrical engineering.

Female students who reported having no STEM related extracurricular activities showed an increased interest in engineering. The results can be seen in Fig 5. Of the students who reported STEM related extracurricular activities, 28.6% expressed an intent to study engineering in the future and 39.3% expressed an interest in electrical engineering. Those who indicated no participation in STEM related extracurricular activity had 23.2% expressing an interest in studying engineering in the future. This is significant and goes to the core of why a program like this should be the norm rather than the exception.

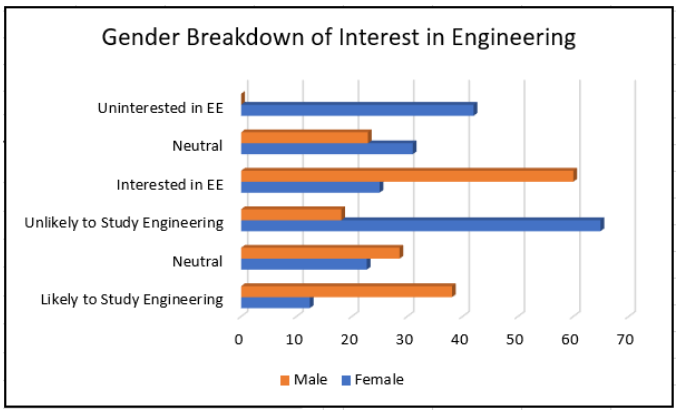

Fig. 5. Breakdown of Response by Gender

Some of the feedback received from the female students that was overwhelmingly positive are listed below. Among the responses were:

- "It was a fun way to learn about electromagnetism and I liked doing the experiments."
- "It was really fun and exciting. I really enjoyed doing these experiments. They were interesting, and I hope to do more like these in the future."
- "Science is cool!"
- "The experiments were so much fun! Thank you so much for stopping in and teaching us! Keep doin' you boo boo. Your experiments are mag-neato!"

The project seemed to be an effective reinforcement for girls who either had a pre-existing interest in STEM as evidenced by their favorite subjects in school and it also had a 'wow' factor for girls who had not participated in any extracurricular STEM related activities in particular.

The male students expressed significantly more interest in engineering than the female students did. A comparison can be seen in Fig. 5. Of the male students, 38.1% expressed an intention to study engineering in the future. A significantly larger number, 60% of the male students expressed they were interested in learning more about electrical engineering.

Like the female students, the male students who had participated in STEM related extracurricular activity or reported having a STEM subject among their favorite class were more likely to indicate an interest in engineering in general and electrical engineering in particular. Among students who reported having a STEM subject as their favorite class, 50.9% indicated that they were interested in studying engineering in the future. An increased number (68.4%) expressed an interest in electrical engineering. Students who had participated in STEM related extracurricular activity were even more likely to report an intention to study engineering in the future, with 56.1% reporting an intention to study engineering in the future and 78% were interesting in learning more about electrical engineering. The least amount of interest was shown by boys who reported they did not intend to go to college. Only 5 male students indicated this, and of those 3 reported the least amount of interest possible in studying engineering in the future. Similarly, 3 of the 5 reported they were uninterested in electrical engineering. Boys who did not report a STEM related class as being among their favorite subjects studied also reported lower levels of interest. That group had 22.9% report that they intended to study engineering in the future. This same group had 50% indicating they were interested in learning more about electrical engineering. Despite the relatively low levels of interest in engineering in general in this group, the largest share of responses showed an interest in electrical engineering.

42 boys gave unique responses. Like the girls, the most common comment (with 15 responses) was describing the experience as being "fun". Some of their responses are listed below:

- I thought it was really interesting to see the magnetic field spin the wire"
- "The things we did today were cool and it is good to know how we will use different power sources in the near future"
- "It was fun and I learned a lot"
- "I thought that it was amazing"

When looking at the different racial groups that participated, there was a wide range of responses from different groups as shown in Fig 6. The students who identified who identified as multiple ethnicities had the most positive response to engineering in general, with 32% indicating an intention to study engineering in the future. A slightly increased percentage showed an interest in electrical engineering, with 36% indicating they were interested in learning more about it. 40% of these students expressed an interest in doing more experiments of this type in the future.

The students identifying as White showed the next highest rate of interest in engineering in general. Of these, 25.4% expressed an intention to study engineering in the future. Almost twice as many indicated an interest in learning more about electrical engineering (47.1%) and 43.1% were interested in doing more power generation and electromagnetics labs.

Students identifying as African American/Black had rates comparable to Caucasian students, with 25% responding that they planned to study engineering in the future. 41.7% indicated they were interested in learning more about electrical engineering. 50% indicated they were interested in doing more experiments dealing with power generation and electromagnetism.

Asian students were less likely to report an interest in studying engineering in the future, with only 11.1% indicating an intention to do so. In terms of the percent difference between interest shown in engineering and interest shown in electrical engineering, this group had the most significant increase; they were three times as likely to indicate an interest in learning more about it. These students also showed the most negative response to the question of doing more electrical engineering related experiments, with only 33.3% indicating they would like to perform more experiments of this type.

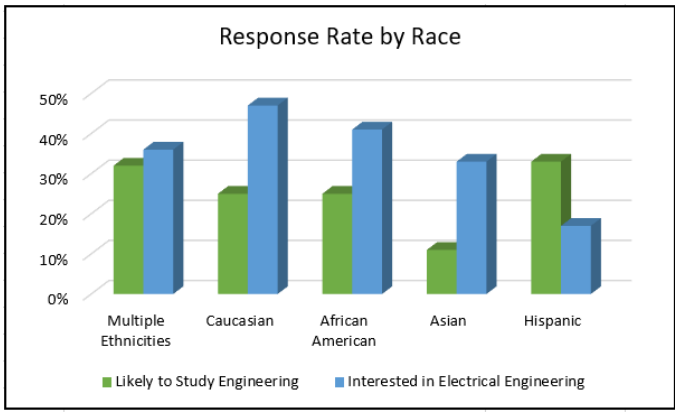

Fig. 6. Racial Breakdown of Responses

Out of the students who identified as Hispanic/Latino, 33.3% were interested in studying engineering in the future. They were less likely to show an interest in electrical engineering, with only 16.7% indicating they were interested in learning more about it. This group was unique in that respect. All other groups were more likely to express an interest in electrical engineering vs engineering in general after completing the experiments. They were also much less likely to show an interest in performing more electrical engineering related experiments, with 16.7% reporting an interest, 50% being neutral, and 33.3% expressing they were not interested in performing more.

IV. CONCLUSION

The broad correlation between prior exposure and pre-existing interest in STEM fields and a likelihood to indicate an interest in engineering seems obvious. Of particular interest is that the girls who had no prior participation in STEM extracurricular activity showed more interest in electrical engineering after being exposed to it through hands on experience. [i] Given this, the results for interest shown in electrical engineering among girls is promising.

More broadly, the number of students who reflected an increased interest level in electrical engineering relative to their interest level in engineering in general was after the outreach experience was also promising. Most groups analyzed showed more interest in electrical engineering than in engineering in general. In many of those groups the students were almost twice as likely to express an interest in electrical engineering. This indicates the students responded favorably to the experience, and some students who were not interested in engineering became interested in electrical engineering after being introduced to it in this manner. There is indication of recent efforts to introduce pre-engineering education into the Springfield Public School curriculum via the PLTW. This is a welcome development. Currently, not every school in the district is able to offer these classes in the curriculum and an outreach program like this one can continue to bridge the gap between K12 students and a degree in Engineering. Exposing K12 students to engineering in this fashion, can take advantage of a significant opportunity to influence students' decision before their decision to enroll in college.

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