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Energy Sustainability in Transportation Systems: Translating Electric Vehicle Research Results to 7th and 8th Graders

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Abstract

Electric vehicles can play a major role in addressing some of the energy problems faced by the U.S., including climate change, dependence on fossil fuels, and air pollution. One major obstacle to this technology is the shortage of engineering talent in the U.S. needed for the advancement of electric drives vehicles. Therefore there is need for more engineers in this field if the technology is to be sustainable. In this paper we discuss a workshop designed to promote knowledge building in the area of sustainability and alternative energy use in transportation, and to stimulate greater interest in science, technology, engineering, and mathematics (STEM) subjects particularly in the field of alternative automotive engineering. This workshop took place in November 2012, during "Expanding Your Horizons" (EYH) at Missouri University of Science and Technology. The EYH is a series of hands-on workshops that attracts 7th and 8th grade girls with the aim of fostering interests in STEM subjects and STEM careers. The workshop consisted of two 50 minute sessions of approximately 15 students each and focused on basic concepts of electric vehicles and electric vehicles batteries including lithium which is a key component of lithium-ion batteries in electric vehicles. These sessions were based on research conducted at Missouri University of Science and Technology and were designed to make the potentially complicated topic easily understood and accessible to these students. Tests were conducted before and after each session to evaluate the students' knowledge and perceptions of electric vehicles s and to determine the impact of the workshop. Early exposure to meaningful engineering experiences for these middle school students may boost interest and the eventual pursuit of engineering and technology education paths.

Introduction

The U.S. transportation sector obtains most of its energy from the combustion of petroleum-based fuels and is heavily dependent on oil, most of which is imported. Electric vehicles have several benefits over conventional gasoline-powered vehicles and can play a significant role in addressing some of the energy problems faced by the U.S. Some of these problems include climate change, dependence on fossil fuels, energy security and air pollution. This is because electric vehicles typically have better fuel economy and emit less greenhouse gasses compared to similar conventional vehicles. One major obstacle to this technology is the shortage of engineering talent in the U.S. needed for the advancement of electric drives vehicles. Therefore there is need for more engineers in this field if the technology is to be sustainable.

In this paper we discuss Charge It! Electric Vehicle Batteries, a workshop designed to promote knowledge building in the area of sustainability and alternative energy use in transportation, and to stimulate greater interest in science, technology, engineering, and mathematics (STEM) subjects particularly in the field of alternative automotive engineering. This workshop took place on November 2, 2012, during “Expanding Your Horizons” (EYH) at Missouri University of Science and Technology. The EYH is a series of hands-on workshops that attracts 7th and 8th grade girls with the aim of fostering interests in STEM subjects and STEM careers by exposing them to new and interesting learning opportunities. EYH attracts approximately 600 students to the campus for the day. Each workshop is a small class or discussion led by women and other professionals in STEM fields. Each student attends two workshops, a keynote speech, and other activities. This workshop is particularly important in encouraging girls to expand their career visions since this is the age that they generally become disinterest in these subjects. According to Leslie[1], the major period influencing women's later choices in science and engineering is during adolescence.

The workshop discussed in this paper consists of two 50 minute sessions of approximately 15 students each from four middle schools in Missouri. The focus of the workshop is on basic concepts of electric vehicles and electric vehicles batteries including the supply chain of lithium which is a key component of lithium-ion batteries in electric vehicles. These sessions are based on research conducted at Missouri University of Science and Technology and are designed to make the potentially complicated topic easily understood and accessible to these students. Tests are administered before and after each session to evaluate the students’ knowledge and perceptions of electric vehicles and to determine the impact of the workshop. Early exposure to meaningful engineering experiences for these middle school students may boost interest and the eventual pursuit of engineering and technology education paths. According to the National Action Council for Minorities in Engineering[2], women are currently underrepresented in engineering fields and careers. Therefore, this exposure may spark these young girls’ interests in engineering and could potentially increase the number of women, who are currently a minority, in the engineering education pipeline.

In addition to fostering the students’ interests in STEM fields, this paper uses Bloom’s Taxonomy to assess the knowledge and comprehension levels of the participants of the workshop. More specifically, the main objectives of this study are

1. To evaluate the students’ knowledge and perceptions related to electric vehicles.
2. To translate graduate research in clear and simple terms to the participants and assess their learning during the workshop.

The design of this study centers on the cognitive domain of bloom’s taxonomy, specifically, focusing on the knowledge and comprehension levels. The educational material was delivered through lecture, and a demonstration of the working of the battery of electric vehicle. This study evaluates the learning outcome by using a post-lecture test. The test consists of questions that assess two levels of the cognitive domain, knowledge and comprehension. Questions that assess knowledge learning goals compare the students’ knowledge prior to and after the lecture and demonstration. Questions that assess comprehension as a learning goal assess if the students can interpret the information they received.

Overview of Bloom's Taxonomy

Bloom's Taxonomy, introduced in 1956, is a classification of educational objectives. Learning is classified into three domains in Bloom's Taxonomy: cognitive, psychomotor and affective. Cognitive domain classifies the various levels of intellectual or mental development, the acquiring of knowledge. Psychomotor domain classifies the development of manual or physical skills, the acquiring of various skills. Affective domain classifies the emotional development, the development in attitude. Within each domain, the learning goals are further classified into different level, with order or difficulties. Bloom's Taxonomy was originally developed to provide a framework for knowledge sharing among educators. A revised version of the Bloom's Taxonomy was introduced in 2000[3].

This study focused on the knowledge building in the area of electric vehicles. The acquiring of knowledge falls under the domain of cognitive in Bloom's Taxonomy. Cognitive domain, the acquiring of knowledge, in Bloom's Taxonomy is further classified into six dimensions, ranging from the simplest to the most complex knowledge acquiring. The original Bloom's Taxonomy Cognitive domain consists of the following six categories:

Knowledge dimension: Knowledge dimension's educational goal is the ability to recall data and to remember information. The Knowledge dimension is further divided into three categories:

i) Knowledge of specifics, which include knowledge of terminology and knowledge of specific facts;
ii) ii) Knowledge of ways and means of dealing with specifics: conventions, trends and sequences, classifications and categories, criteria, and methodology;
iii) iii) Knowledge of universals and abstractions in a field, which include knowledge of principles and generalizations, and knowledge of theories and structures.

Comprehension: Comprehension dimension evaluates the ability to interpret, understand the information acquired. Comprehension dimension includes translation, interpretation, and extrapolation.

Application: Application dimension educational goals is the ability to use learnt concept in a new situation, to calculate, to solve

Analysis: Analysis dimension evaluates the ability to break down complex information, to derive and explain. Analysis dimension is further breakdown into three categories: analysis of elements, analysis of relationships, and analysis of organizational principles

Synthesis: Synthesis dimension evaluates the ability to create, formulate, design. The three subcategories within synthesis are production of a unique communication, production of a plan, or proposed set of operations, and derivations of a set of abstract relations.

Evaluation: Evaluation dimension evaluates the ability to make judgment, including the evaluation in terms of internal evidence, and judgments in terms of external criteria.[3, 4] In the revised Taxonomy, the number of dimensions in the Cognitive domains remains the same, with modifications to the name of the dimensions and the subcategories. Figure 1 shows the six dimensions of the cognitive domains in the revised taxonomy.

1.0 Remember – Retrieving relevant knowledge from long-term memory.
- ***1.1 Recognizing***
- ***1.2 Recalling***

2.0 Understand – Determining the meaning of instructional messages, including oral, written, and graphic communication.
- ***2.1 Interpreting***
- ***2.2 Exemplifying***
- ***2.3 Classifying***
- ***2.4 Summarizing***
- ***2.5 Inferring***
- ***2.6 Comparing***
- ***2.7 Explaining***

3.0 Apply – Carrying out or using a procedure in a given situation.
- ***3.1 Executing***
- ***3.2 Implementing***

4.0 Analyze – Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose.
- ***4.1 Differentiating***
- ***4.2 Organizing***
- ***4.3 Attributing***

5.0 Evaluate – Making judgments based on criteria and standards.
- ***5.1 Checking***
- ***5.2 Critiquing***

6.0 Create – Putting elements together to form a novel, coherent whole or make an original product.
- ***6.1 Generating***
- ***6.2 Planning***
- ***6.3 Producing***

Figure 1- Dimensions of Cognitive Domain of Bloom's Revised Taxonomy[3]

Workshop

The workshop consisted of two sections. The first section, which was 30 minutes long took place in a classroom and included the pre-test, a presentation and discussion. The second section took place in a laboratory and involved a demonstration of electric vehicle operation. The presenters of the workshops included four graduate students and a post-doctoral fellow in three engineering disciplines including engineering management, electrical engineering and mechanical engineering.

As previously mentioned, the objectives of this study are to test the students' prior knowledge of electric vehicles and evaluate their comprehension of the concepts covered in the workshop. Therefore, a two page paper based test was designed to collect this data. This test was carefully designed around specific concepts of electric vehicles including electric vehicle batteries, battery materials (specifically lithium) and the advantages and disadvantages of the vehicle technology to ensure that the students were evaluated on concepts on which the workshop focused on. This short test took approximately 5 minutes for completion realizing that a test requiring more than 5 minutes may not be completed by the students. Each student participated in both a pre-test and post-test to measure changes in the students' knowledge of electric vehicle concepts. The pre-test were administered immediately before any classroom presentation of the topics and activities related to the workshop. The same test was administered immediately after the electric vehicle demonstration was concluded to assess student learning. The full version of the test is included in Appendix A.

Both sections of the workshop were made as interactive as possible to keep the students engaged. Participants had the opportunity to ask the presenters questions about being an engineer in general and about concepts specific to the workshop. Some topics covered during the classroom section of the workshop include definition and types of conventional vehicles, advantages and disadvantages of conventional vehicles, the need for alternative vehicles, definition and types of electric vehicles, the battery requirements of different electric vehicle types and implications for cost, lithium-ion batteries, lithium resource and reserves and countries where this important battery material can be found. For example an electric was defined as a vehicle in which at least one of the sources or storage units can deliver electric energy. The types of electric vehicles were defined as follows.

The hybrid electric vehicle combines the engine used in conventional vehicles along with an electric motor to achieve a higher fuel economy than similar-sized vehicles.

The plug-in hybrid electric vehicle has a smaller engine than the hybrid electric vehicle, has a larger battery, which is rechargeable and can be restored to full charge by connecting a plug to an external electric source. The electricity used for charging is supplied from either domestic power generation or power plants generating electricity from renewable and/or non-renewable energy sources.

The battery electric vehicle is powered solely by a rechargeable electric battery and has batteries that are usually larger than the plug-in hybrid electric vehicle and can travel longer distances on a fully charged battery.

The last part of the classroom presentation was a discussion of the countries with significant lithium reserves. Each participant was provided a global map and asked to circle countries that had significant lithium reserves or resources. When the correct answers were revealed by the presenter, students who had answered the question incorrectly were asked go back and make the corrections on their maps.

The second part of each session was approximately 20 minutes long and involved the demonstration and the post-test. The students were shown a 500 pound lithium-ion battery taken from an actual electric vehicle and the process of how the battery works was described to them. Participants were also shown the cells that make up the lithium-ion battery pack. In addition, the students were shown a demonstration of how electric vehicles operated using a miniature electric vehicle. A computer simulation was used to demonstrate drive cycle of a typical electric drive vehicle, which is basically bringing the road to the test lab.

Results

The two workshop sessions had a total of 37 participants, 31 students and 6 teachers and guides. In this section we will discuss the results from thirty complete responses by the students. The responses of the teachers and guides were not included for the purpose of this study. We first present the result of the pre-tests, assessing the knowledge of the students prior to the workshop. Next we report the results of the post-test to evaluate the participants' learning.

<u>Pre-test</u>

The students provided definitions of electric vehicles in response to the question "What is an electric vehicle or electric car?" Though responses varied, four emergent themes were identified that represented the students' perceptions and are shown in Table 1 below. By far the most frequently used word in describing electric vehicles was electricity and was used by 20 students or 67% of the sample. Some representative definitions include "A car that runs on electricity instead of gas", "A car that runs half on electricity and half on fuel like a hybrid" and "A machine that is run by electricity that takes you places". The second most used words in describing electric vehicles were charge and batteries. Some representative comments include "Car you charge up", "A car that doesn't use gas, it has to be charged", and "…charged on electricity, runs on a battery and even sometimes has gas tank too". Other descriptions of electric vehicles include "A vehicle you have to plug-in to run", and "Ford Taurus".

Table 1 – Themes reflecting students' perception of electric vehicles

Keywords	No of responses	%
Electricity	20	67%
Charge	6	20%
Batteries	6	20%

Plug-in	2	7%

In response to the question “Have you seen an electric vehicle or been driven in an electric vehicle. Circle all that apply”, 57% and 7% reported that they had seen an electric vehicle and had driven in one respectively. In addition, 23% and 57% indicated that they had never seen an electric vehicle or ever driven in one respectively. Figure 2 shows that 13% and 7% of the sample were unsure if they had seen or been driven in an electric vehicle. As shown in Figure 3 roughly 57% (n=17) of the students thought electric vehicles are good; 3% (n=1) thought electric vehicles are bad and 40% (n=12) were unsure about the benefits or disadvantages of electric vehicles. The large number of unsure responses may be due to lack of familiarity and direct experience reported by the students. Students that have never seen or driven in an electric vehicle are likely to be unsure about the advantages or disadvantages of electric vehicles.

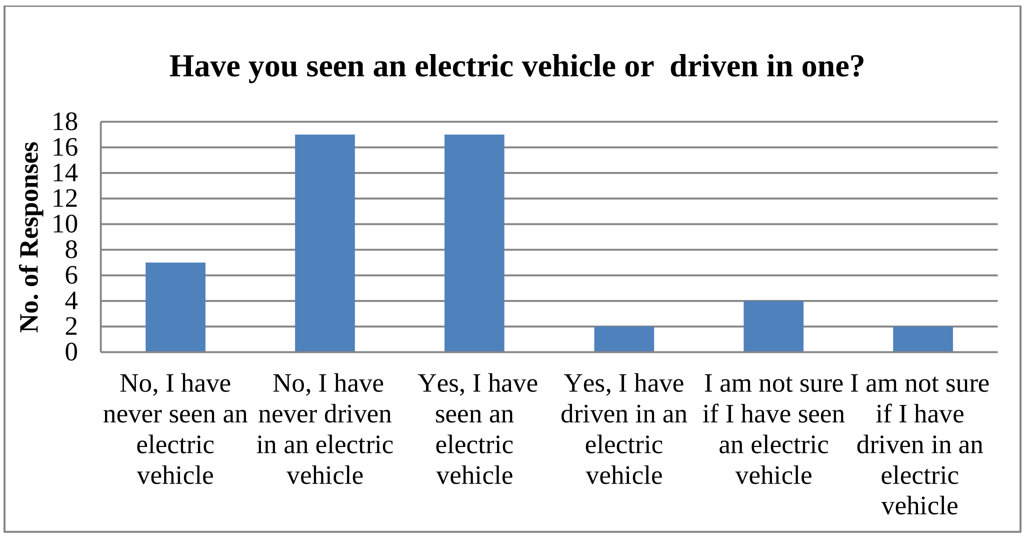

Figure 2- Experience with electric vehicles

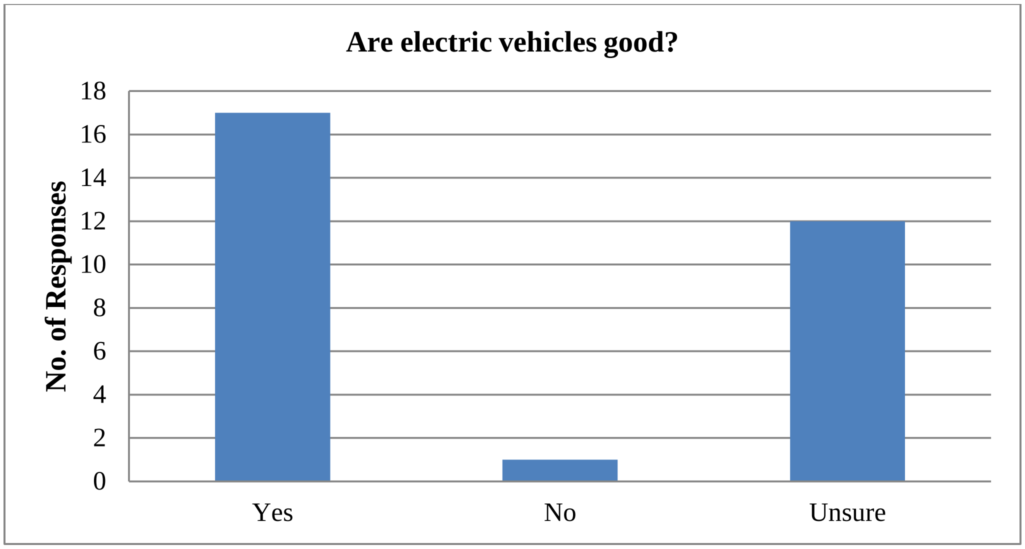

Figure 3- Students' response to "Are electric vehicles good or bad"

The students were further asked to explain why they thought electric vehicles were good or bad. The major reasons cited for electric vehicles being good include pollution prevention or reduction (40%), no gas usage (17%) and fuel economy (13%). Students that indicated electric vehicles are bad cited the cost of electricity, "bad electricity", and use of too much electricity. This represented 13% of responses. Table 2 shows that top cited reasons for the students' perceptions of electric vehicles as being good or bad.

Table 2 - Reasons electric vehicles are good or bad

Reason Cited	No of responses	%
Prevent/reduce Pollution	12	40.0%
Unsure/do not know	6	20.0%
Does not use gas	5	16.7%
Fuel economy/ saves gas	4	13.3%
Cost of electricity/ use too much electricity	4	13.3%
Saves Money	2	6.7%
Clean	2	6.7%

Only 33% of students correctly selected a type of electric vehicle battery (lithium-ion battery) from a list of options. Similarly, 33% of the students selected lithium as a raw material found in electric vehicle batteries. Furthermore, 90% of the students selected the "I don't know" when asked to name some countries where the raw materials they had previously selected as components of electric vehicles could be found, Post-Test

In the post-test, 28 students or 93% of the sample indicated that electric vehicles are good. This is a significant increase compared to 57% that reported the technology was good in the pre-test.

All the participants except one selected the correct electric vehicle battery (lithium-ion battery). In addition, all the students correctly selected lithium as a raw material found in electric vehicles. When asked again to name countries where lithium resources or reserves can be found only 2 students out of 30 indicated that they did not know. Ninety-three percent (n=28) of the students listed at least one country. Of this number all the students correctly named the countries that had significant lithium resources with the exception of two students that name one country incorrectly out of four countries listed and two students that named two countries incorrectly out of four countries named. Table 3 illustrates the countries that have lithium reserves or resources mentioned by the students, the number of times mentioned and the amount of reserves (in metric tons) available.

Table 3 – Countries with lithium reserves or resources

Country	No. of times mentioned	Lithium reserves (metric tons)[5]
Chile	21	7,500,000
China	21	3,500,000
United States	12	38,000
Australia	11	970,000
Bolivia	8	–
Argentina	7	850,000
Canada	5	–
Brazil	5	64,000

Conclusions

This paper describes two sessions of an interactive workshop developed around engineering graduate students' research and aimed at middle school girls to spark their interest in STEM fields. In addition to stimulating the interest of the participants, the knowledge and comprehension levels of the students were assessed.

A positive outcome of this workshop is that the participants learned about engineers, engineering concepts and how engineers design systems. Prior to the workshop several of the participants had little or vague knowledge about electric vehicles. Most of the students were not aware of the different types of electric vehicles, the types of batteries used by the technology and the geographic distribution of lithium reserves and resources. Based on a comparison of the pre-test and post-test it is evident that the students learned the basic concepts that were introduced during the workshop. By the end of the workshop the participants seemed more confident in their responses to questions about electric vehicles and most were able to correctly name three or more countries that had lithium reserves and resources.

Although the sample size discussed in this paper is small (30 students), it provides insight into how female middle school students learn about engineering concepts and can inform other workshops on a larger scale.

Future Work

This paper focused on knowledge and comprehension categories of Bloom's Taxonomy cognitive domain. In the future this study will be extended to include all six categories of Bloom's Taxonomy cognitive domain including knowledge, comprehension, application, analysis, synthesis and evaluation in order to assess other dimensions of learning.

Acknowledgement

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Appendix A

Electric Vehicle Survey

1. My parents drive. Circle all that apply
   a) An SUV
   b) A truck
   c) A van
   d) Small Car (e.g. Mini Cooper)
   e) Large car (e.g. Ford Taurus)

2. What is an electric vehicle or electric car?

3. Have you seen an electric vehicle or been driven in an electric vehicle. Circle all that apply
   a) No, I have never seen an electric vehicle
   b) No, I have never driven an electric vehicle
   c) Yes, I have seen an electric vehicle
   d) Yes, I have driven in an electric vehicle
   e) I am not sure if I have ever seen an electric vehicle
   f) I am not sure if I have ever driven in an electric vehicle

4. Are electric vehicles good?
   a) Yes, electric vehicles are good
   b) No, electric vehicles are bad

c) Maybe, I am not sure if electric vehicles are good or bad

5. Why are electric vehicles good or bad? Explain the reason for your answer to question 4

6. Which one of these statements is true?
   a) An electric vehicle is completely powered by gasoline
   b) A regular car is completely powered by a battery
   c) Electric vehicles are partially or completely powered by a battery
   d) Electric vehicles do not use batteries

7. Which one of these can be found in electric vehicles
   a) Fluorine battery
   b) Lithium-ion battery
   c) Helium-ion batteries
   d) All of the above
   e) None of the above

8. Which of these is a main raw material found in some electric vehicle batteries
   a) Fluorine
   b) Helium
   c) Lithium
   d) All of the above
   e) None of the above

9. What part of the world can the material/s you selected in question 8 above be found?
   a) Write down name/s of one or more countries.
   b) I don't know

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