AC 2007-1533: HIGH SCHOOL OUTREACH: A LOOK AT RENEWABLE ENERGY

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High School Outreach: A Look at Renewable Energy

Abstract

YESS (Young Engineers and Scientists Seminars http://www.yesshem.com) is an enrichment program for gifted and talented high school students from the Baltimore/Washington areas who have a strong aptitude in mathematics and science fields. Letters are sent to Science, Mathematics, Technology and Engineering High School teachers requesting the nomination of students for participation in the program. This program was founded in 2002 and is funded by the Historical Electronics Museum with a grant from Northrop Grumman. YESS has presented speakers on topics as diverse as plasma physics, stealth radar, biomedical imagery, super computers/micro technology, aeronautical engineering, astrophysics and satellite reconnaissance.

In recent years, the program has been revised from a strictly seminar series, to a hands-on program designed to help students understand the engineering design process. Two-hour sessions are held biweekly and students learn how to go from brainstorming to designing, building, and testing. The objective of the 2006 program is for students to learn about renewable energy sources. The overarching project, performed in teams, is to design an energy system which harnesses (from a renewable source), stores, transports, and converts the energy to function a small light bulb. The effectiveness of each energy system will be judged based on the power generated from the renewable source, the overall system efficiency versus a cost analysis of the system.

Each week, a technical expert will speak about a topic relative to the use of science and engineering in the advancement of renewable energy. These presentations include: So You Want to Be An Engineer, The Engineering Method, Power and Energy Conversion, Ethics and Critical Reasoning in Engineering, Power Transmission & Delivery and Solar Technology & Power Systems and Power. Following each seminar, students participated in a fun-filled game of *Who Wants To Be An Engineer* modeled after the popular television game show *Who Wants to Be a Millionaire.* This activity posed a number of questions to make students consider the lessons presented in prior lectures, as well as the application of renewable energy in the world today. After the conclusion of the game, students participate in mini hands-on design challenges, which require the utilization of newly-learned concepts as well as general engineering methods. Following the five sessions of seminars and mini challenges, the students must combine concepts they have learned to determine the optimal source and methodology to design, construct and test the most efficient renewable energy system.

The overall effectiveness of the YESS program will be determined based on observation of an improvement in implementation of engineering concepts and methods as the program progresses. To assist with this analysis, each team is required to keep a design notebook to document the evolution of the final design. In addition, participants complete pre- and post-surveys measuring interest, attitude and content knowledge of the engineering design process and the underlying principles associated with a successful

design solution. The results of these findings will be documented, compiled, and presented. Since this is the third year of this revised program, comparisons will be made to examine the evolution and the success of this high school outreach program.

Background

The mission of the Historical Electronics Museum is to educate industry, government, students, and the general public on the evolution and the importance of defense and commercial electronics of the past through the exhibition and interpretation of historically significant artifacts and documents related to electronics technology[1]. The education goal of the museum is to provide visitors with an understanding of the basic concept of electronics and an appreciation of evolutionary milestones of sophisticated electronics systems. In support of these objectives, the museum's priority is to provide a motivational environment for students of all ages to gain an understanding of basic engineering and the career opportunities available through higher education. With this priority in mind, the Historical Electronics Museum began the Young Engineers and Scientist Seminars (YESS) program in the fall of 2002, intended for highly gifted high school students in the Baltimore/Washington area with a strong aptitude in mathematics and/or science. The first two years of the program consisted of a series of solely seminars and covered topics as diverse and dynamic as plasma physics, stealth astrophysics, and satellite reconnaissance. During the second year of the program, in 2003, two University of Maryland, Baltimore County (UMBC) professors presented a seminar entitled "Careers in Engineering and Introduction to Engineering Design." For this seminar, the typical talk and presentation was accompanied by a variety of hands-on activities relative to engineering, which was rated favorably by students upon completion of the program. This prompted the Board of Directors at the museum to strategize about ways to generate more hands-on involvement throughout the duration of the program in an effort to stabilize attendance which was quite erratic.

The following year, the directors approached one of the co-authors about the possibility of revising the program to model it as a miniature version of the Introduction to Engineering Design course which she teaches at UMBC. The directors were aware that in recent years, the course was revised from a traditional lecture and design-on-paper course, to an active learning lecture and project-based learning engineering design course.[2] The newly developed methodology was created to promote an enjoyable experience in the field of engineering while also introducing key principles as students begin their collegiate path. Therefore, the Board of Directors requested an attempt to accomplish the same goals on a scaled-down level for their YESS program participants.

In August, letters were sent to Science, Technology, Engineering and Mathematics (STEM) high school coordinators from Anne Arundel, Howard, Harford, Queen Anne's, Baltimore, and Carroll counties, as well as the City of Baltimore, inviting them to nominate students (teachers and parents also welcome) for the program. A website[3] was also maintained for the program to provide updated information for all participants, including specifications for the overall design project, archived presentations from prior seminar dates, and photos and videos of the weekly hands-on activities. IRB approval

was secured for the project and students were asked to submit released forms with his/her signature along with that of a parent or guardian prior to any participation.

In order to assess the effectiveness of the YESS program, surveys were distributed to capture self-reported data from the students regarding demographic information, parent/guardian occupations, interest levels in relevant fields, level of understanding in key content area, measures of confidence in math and science, and expectations for the program.

Following the alteration of the program in 2004, student attendance began to grow. The average number of students in attendance for each seminar more than doubled from 2003 to 2004 and the number of interested teacher and parents in attendance was also on the rise. Comments attained from a number of the attendees reflected that the introduction of the hands-on activities to supplement the weekly presentations provided an enjoyable addition to each seminar.[4] The improved attendance in 2004 delighted the museum directors prompting them to continue with the restructured program in 2005 and 2006.

The 2006 program was structured similarly to the previous two years and was designed to facilitate the high school students learning in going from brainstorming to designing, building, and eventually, testing. The overarching project, to be performed in teams, revolved around renewable energy sources, a very important worldwide issue in the years to come. Great effort was made to ensure that each seminar would provide information relevant to the engineering behind energy systems and to make students aware of issues regarding the development of any engineering process. The hands-on activities were also geared towards introducing students to several factors that would ultimately play a role in the final design project.

The program met every other Thursday, at 6:45 PM, from September 29 through December 14, with final project testing scheduled for January 18. There was no charge for students to attend and complementary pizza was provided prior to the start of each lecture. Gift cards for various establishments in the area were provided as prizes for the hands-on activities, the *Who Wants to Be an Engineer* activity, as well as the overall design project, as well as certain attendance awards. Cash prizes will be awarded to the top performing design projects at the final evening of the YESS program. In addition to the seminar series, the program also featured complementary guided tours of the Historical Electronics Museum (October 12) and a Northrop Grumman site (October 26) prior to the start of the seminar.

The Design Project

The 2006 YESS program design project was to design, construct, test, and evaluate a device that simulates a system for collecting, storing, transporting, converting, and utilizing renewable energy. The overall goal of the project was simply to be able to light a 1 cell AAA Maglite® light bulb after being allowed to collect energy for one hour.

Students were given the option to utilize water at an approximate flow rate of 0.5 liters per second, solar energy provided by a 90-watt flood light, or wind energy provided by a box fan with settings of 166 watts, 117 watts, or 87 watts. In addition to providing the above means of energy, program coordinators also provided a variety of solar cells, DC motors, gears, and rechargeable batteries with holders that teams could borrow for use in their system. All supplies were provided by the Chemical and Biochemical Engineering Department at the University of Maryland, Baltimore County under the NSF funded **S**cience, Technology, Engineering and Mathematics **T**alent **E**xpansion **P**rogram (STEP-DUE-0230148). This grant also funded all materials purchased for the weekly hands-on activities.

The primary criterion for the design project was **SAFETY**; the system must operate without any hazards. There was a cost restriction of $100.00 placed on the overall design, which must include **ALL** parts utilized in the design. While students were encouraged to scavenge and use materials from sources outside the program, they were required to price those as if they were newly purchased. Lastly, students were required to maintain a design notebook (also provided by program coordinators) which summarizes the evolution of the design.

System performance was judged based on the power generated, system efficiency and device cost index as used in the formula below:

Power Generated* x *Overall System Efficiency* x *Device Cost Index

Power generated refers solely to the ability of the system to light the light bulb. It is determined by the maximum current and voltage that the device produces as measured using multi-meters.

The overall system efficiency is calculated by dividing the useful work output by the energy input. The useful work output reflects the amount of work that the system outputs in lighting the light bulb while the energy input reflects the amount of energy put into the system during the collection time.

The device cost index simply refers to the minimum design cost of a functional energy system created by on of the YESS program teams divided by the cost of the team being tested. All of the "bragging rights" calculations were executed by YESS program coordinators shortly after conclusion of testing.

This design project was developed based on the Energy Solutions Module for the NSF funded (ESIE – 0352504) **INSPIRES** (**IN**creasing **S**tudent **P**articipation, **I**nterest, and **R**ecruitment in **E**ngineering and **S**cience) curriculum, also generated in the Chemical and Biochemical Engineering Department at UMBC.

Seminars

Introduction to Engineering

For the opening presentation of the 2006 YESS program, one of the co-authors presented an overview of the engineering field. This included a description of what is engineering, outlining the various types of engineers, including specific opportunities, possible jobs, salary outlook, and requirements for becoming an engineer. Furthermore, the list of the greatest engineering achievements of the 20th century was presented, emphasizing the extreme importance of this field to societal and technological development. The presentation was concluded with an overview of the Introduction to Engineering Design course at UMBC. The overview featured several videos of previously used design projects to allow students to realize what will be expected upon entering the field of engineering.

Following this presentation, students were invited to play the *Who Wants to Be an Engineer* game. Developed by Professor David Silverstein[5] from the University of Kentucky – Paducah, the game required students to match answers to engineering questions by raising color coordinated index cards as the questions were displayed by the projector. As a reward for correct answers, students were given a "YESS buck" as shown in Figure 1, redeemable for prizes upon conclusion of the program. The overwhelming success of this activity promoted its inclusion at each additional seminar, allowing students to collect a number of "YESS bucks" over the course of the entire series. After completion of the game, the hands-on activity for the evening was set to begin.

Figure 1: *Who Wants To Be An Engineer* Activity

Introduction to Engineering Design Challenge:

The goal of this activity was mainly to introduce students to working in groups while executing a task relative to engineering. The students were assigned to design and construct a free-standing structure to the maximum height possible that was capable of supporting a volume of water. After the structures were created, each team had to carry the structure filled with water while walking through an obstacle course as quickly as possible. The height of the apparatus was measured from the base to the bottom of the cup holding the volume of water.

Materials provided:

- Twenty straws
- Twenty pipe cleaners
- Ten rubber bands
- Ten toothpicks
- Eleven paper clips
- Two cups
- One paper bag

The contest winner (bragging rights) was determined using the following formula:

$$(\text{Height of tower})^3 \ (\text{Final Volume of Water})^2 \ / \ (\text{Time on course})$$

Capture and Conversion of Energy

On October 12, Dr. Gary Bayles, President and Founder of Energy Systems Design, Inc., presented a seminar regarding overwhelming necessity for the development of energy solutions in the United States and across the world. This presentation featured staggering numbers about the amount of fossil fuels utilized each year, leading to the key point of the importance of an increase in development for effective renewable energy systems. This presentation provided a foundation for the overarching project of the series by introducing the concepts of renewable energy and allowing students to recognize the importance of advancing the technology in this area.

At the end of the presentation, the students were introduced to the overall design project. After introducing the project and completing another episode of the *Who Wants to Be an Engineer* game, students began the hands-on activity for the evening.

Light It Up and Make It Spin!!!

The goal of this activity was to introduce students to the use of electricity by asking them to create a system that ran a simple motor and could light a small light bulb. At the beginning of the activity, students were given a clear plastic bag of materials with twenty minutes allowed for designing and planning, during which none of the materials could be removed from the bag. The first objective

for the design teams was simply to utilize the battery and alligator clips to light the bulb. While this might seem like an oversimplified task, a BBC program showed that four mechanical engineering graduates from MIT were unable to complete it![6] The overall objective was to then use all of the materials to be able to run a motor while also lighting the bulb.

Materials provided:

- One Dixie cup
- One D battery (with holder)
- Three insulated mini jumper leads
- Two feet of coated 26-gauge wire
- Two six-inch pieces of 24-gauge bus wire (uncoated)
- One Maglite® AAA 1-Cell light bulb
- Two magnets
- A pencil
- One glue stick
- One roll of masking tape

Each group of students that were able to simply light the bulb was given one "YESS buck" per student. The overall contest winner was determined by the first team to present a viable system with running motor and lit bulb at the judging station. One of the teams with their winning design is shown below in Figure 2.

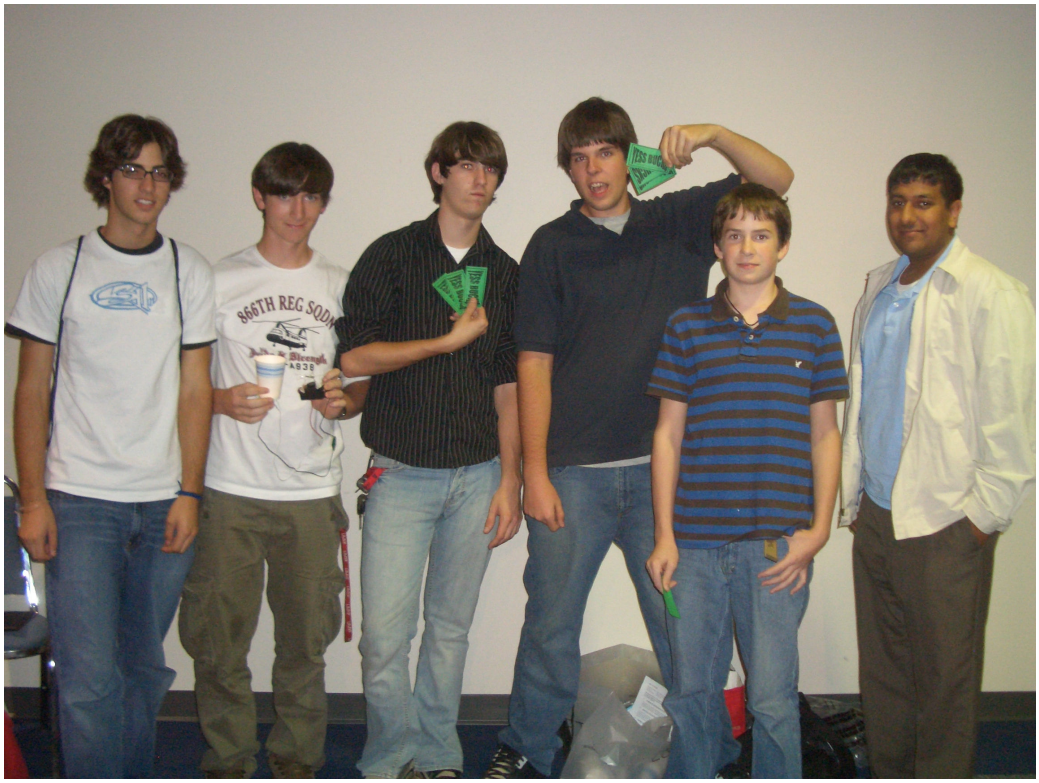

Figure 2: One of the Light It Up and Make It Spin challenge winning teams.

The Engineering Method

On October 26, Mr. Roland Anders, Chief Scientist of Space Systems at Northrop Grumman, delivered a presentation on the engineering method. Mr. Anders emphasized the importance of planning throughout the entire engineering process and included several examples of engineering accomplishments, explaining how the engineering method applied to the development of each. Even more interesting was the presentation of several disasters of engineering such as the Leaning Tower of Pisa and the identification of possible errors in the engineering method that may have led to the various failures. The seminar concluded with an episode of *Who Wants to Be an Engineer*, followed by the hands-on activity.

Hydro-Power It Up!!!

In this task, students were given twenty minutes to create a cost-effective mechanism that could use flowing water to raise a weight. In addition to manufacturing some sort of waterwheel, students were also required to utilize gears in their mechanism to stress the importance of gear ratio to a system's overall efficiency. The overall goal for the project was to familiarize students with energy transfer, specifically from a renewable source, while stressing the importance of cost minimization.

Materials provided:

- K'Nex building parts (assorted, including gears)
- Eight small Dixie cups
- 48 inches of fishing line
- One roll of masking tape
- A reference guide for costing K'Nex pieces

The effectiveness of each system was judged based on the power generated by the mechanism divided by the its cost. Power could be determined by multiplying weight lifted by distance lifted and dividing by the time of operation. Each team was given two quarts of water to pour over their device and they were also allowed to select the amount of weight utilized during testing. Some of the winning designs are shown in Figure 3.

Figure 3: Hydropower Design Challenge

Ethics and Critical Reasoning in Engineering

On November 9, Mr. Richard Wilson, an ethics professor at the University of Maryland, Baltimore County, presented an overview his Ethics of Engineering class required for most engineering majors at UMBC. Students were able to see that the decisions relative to a project are not entirely governed by cost effectiveness or even system performance. Instead, Mr. Wilson explained that every engineer is responsible to maintaining an ethical standard, generally more important that any other factor for a given project. This presentation awakened students to the big picture of being an engineer, forcing them to think beyond the typical things that engineers are commonly thought of doing.

Following Mr. Wilson's talk, students participated in *Who Wants to Be an Engineer* and then proceeded with the daily hands-on activity.

Let It Blow!!!

During this activity, students were able to gain experience with harnessing another type of renewable energy: wind. This project featured similar goals to the hydropower work, in expressing the point of cost effectiveness while introducing an additional possibility for a renewable energy source. Each team was responsible for designing, creating, and manufacturing up to four blades for a windmill to be attached to a Lego windmill base during a twenty minute period. During testing, the team would attach their blades to the pre-constructed base and run a box fan to lift a weight. The groups were given three materials to choose from (sail cloth, plastic transparencies, and poster board) as well as the option to vary the number of blades in determining the most effective design.

Materials provided:

- Lego rods/connectors (assorted, enough for up to four blades)
- Two plastic transparencies
- One piece of poster board
- One piece of sail cloth
- Hole Punch
- One roll of masking tape
- A reference guide for costing Lego pieces

In this activity, the overall winner (bragging rights) was determined by dividing the power generated by the windmill by the cost of the blades. Power was determined based on the amount of weight chosen, the height over which the weight was lifted, and the time of operation. Some of the winning designs are featured in Figure 4.

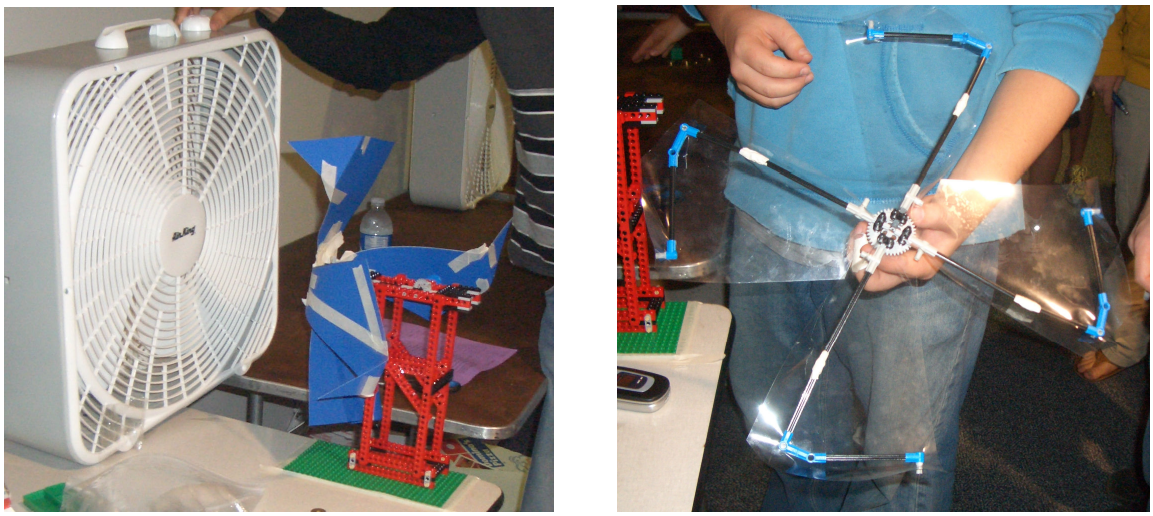

Figure 4: Various Blade Designs for the Wind Energy Design Challenge

Power Transmission and Delivery

On November 30, Mr. Ben Shives and Ms. Corrine Rodowsky presented a seminar about their place of employment: Baltimore Gas and Electric (BGE). During this presentation, students were introduced to the plethora of the activities that occur behind the scenes in order to make electricity available to the Baltimore area. It astonished a number of attendees to see the large amount of work that is involved to generate something that so many people take for granted in their households. In addition, Mr. Shives and Ms. Rodowsky provided some astronomical data relative to the amount of power provided, amount of money collected, and number of customers serviced by BGE each year. To conclude the presentation, they provided a look at the methodology behind generating the necessary energy. While there are a few hydropower (renewable energy) plants currently being utilized in this area, this talk expressed the importance of development in the field of renewable energy by revealing that a number of power plants operate using non-renewable sources.

At the conclusion of the presentation, students participated in *Who Wants to Be an Engineer* and prepared themselves for the hands-on activity.

Power It Up with Solar

> During this project, students were introduced to solar energy, the third and final form of renewable energy that is focused on in the overarching project. In addition to familiarizing the students with solar panels and their usage, this activity also revisited the importance of gears. Students were allotted twenty minutes to generate a geared device which could use solar energy in conjunction with a DC motor to most cost-effectively lift a weight. As in the previous two exercises, a major goal was to emphasize the vitality of being as efficient as possible, particularly with cost, while still attaining the desired outcome. Most

interesting about this project was allowing students to see the extremely low efficiency of a renewable system by comparing the 90 watts utilized by the light bulb to the mere milli-watts utilized in lifting the weight.

Materials provided:

- K'Nex building parts (assorted, including gears)
- DC motor
- Two solar panels (different size/cost/rating)
- 48 inches of fishing line
- Four small Dixie cups
- One roll of masking tape
- A reference guide for costing K'Nex pieces

Upon conclusion of the construction period, testing was done utilizing a 90-watt outdoor flood light as the artificial sun. Overall effectiveness was again based on power divided by cost, with power being determined by the amount of weight selected, height over which the weight was lifted, and time of operation.

Solar Technology and Power Systems

On December 14, Mr. Jack Shu from NASA Goddard Solar Technology and Power Systems was invited to present. During this presentation, Mr. Shu brought a number of props from various NASA missions which the audience really enjoyed. His discussion of solar energy sparked a wonderful set of questions and discussion, especially useful for the teams considering the harnessing of solar energy for the final project.

Upon conclusion of the presentation, students were given the remainder of the time to work on the final design project. Testing for the projects was set to occur after the winter break on January 18.

Testing Day

On January 18, 2007, the YESS program came to a conclusion by featuring the testing of students' overarching design projects for the series. A total of twenty-six teams completed design projects, each allowed to collect energy for up to one hour. While all three possible renewable energy sources were represented (as shown in Figure 5, clearly the most popular was hydro (50% of teams). The winning team utilized a solar powered mechanism which collected enough energy to light the bulb for over three minutes, which along with the efficiency and cost effectiveness of their design was enough to earn first prize.

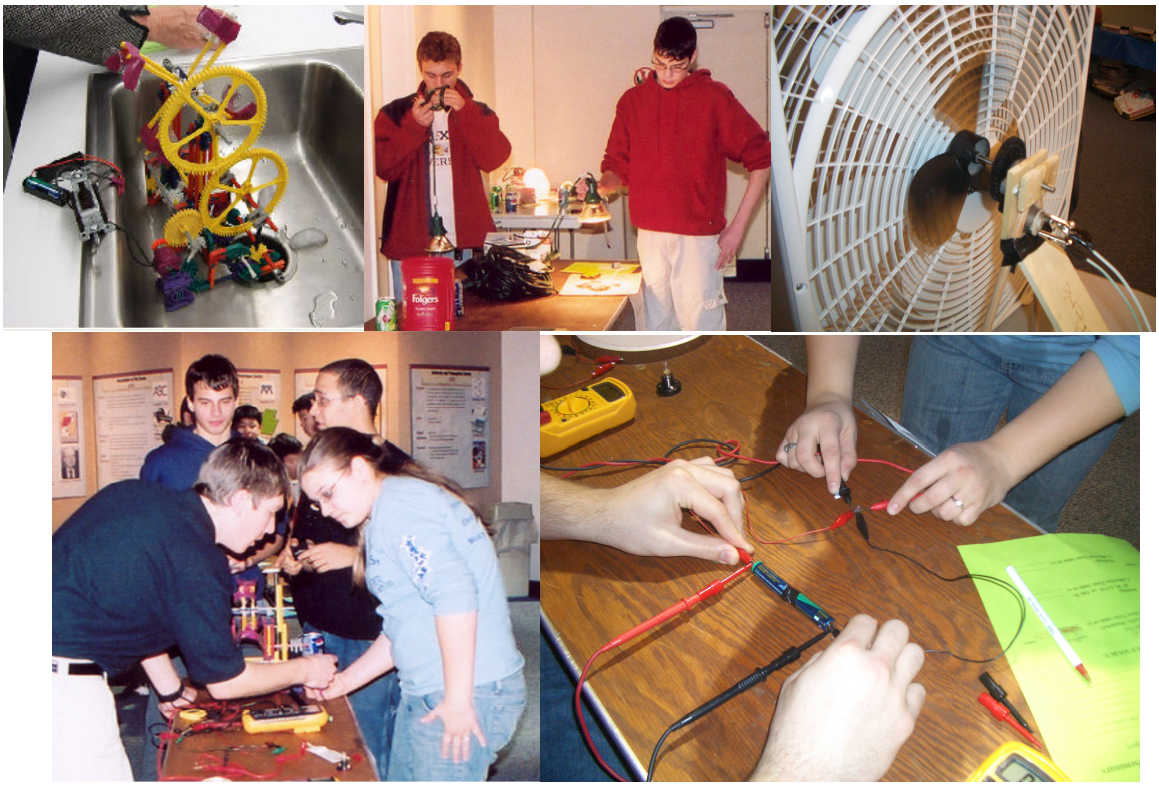

Figure 5: Examples of the Final Designs and Testing

Results and Conclusions

The Board of Directors of the Historical Electronics Museum met during summer 2004 to strategize how to improve the erratic attendance of the Young Engineers and Scientists Seminars program. The attendance in the 2003-4 program ranged from 23 to 55 students per seminar, with only one student attending all of the seminars. The program was subsequently reformatted to be a hands-on program with an over-arching design project enhanced with mini design challenges held during each seminar. The attendance in the 2004 program ranged from 50 to 72 students (with an average of 63 students at each session). Eleven students attended all of the seminars, and fifty students attended at least two-thirds of the seminars during the 2004 YESS program. In addition, there were 10-15 visitors (high school teachers and parents) at each seminar. At the design project testing, each of the eleven students with perfect attendance received a $50 gift card to Best Buy™. Monetary awards were also made to the top three design teams (based on the hot air balloon project bragging rights), in the amount of $800, $600 and $400 per team respectively. This format was continued during the 2005 YESS program, with a new design project, and new seminars and mini design challenge activities. The attendance in the 2005 program ranged from 57 to 90 students (with an average of 75 students at each session). Twenty four students attended all of the seminars, 78 students attended the majority of the seminars and 108 students attended at least two of the seminars. The twenty-four students with perfect attendance received Best Buy™ gift cards. The four

highest scoring teams in the design competition received awards of $800, $600, $350 and $250, respectively. Attendance of the 2006-7 YESS program has ranged from 76 to 136 students (with an average of 107 per session). Thirty-three students attended all of the seminars and were again rewarded with Best Buy™ gift cards. Prizes of $1000, $600, and $400 were given to the top three finishers in the overarching design project. The winning team (Team Depraved from Aberdeen High School) with their solar energy system is shown below in Figure 6.

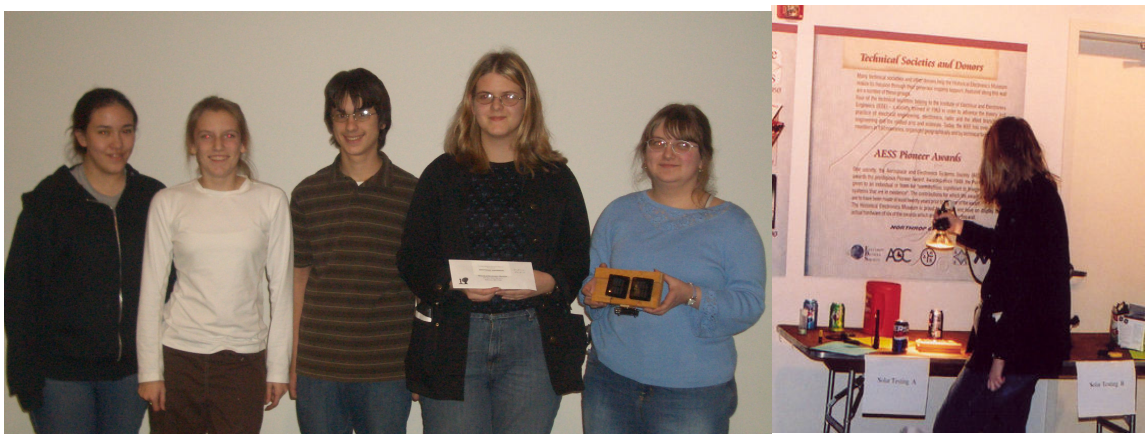

Figure 6: Team Depraved, Aberdeen High School, with their winning solar energy system

The Board of Directors of the museum has expressed their delight with the improved attendance of the YESS program over the last two years. Comments from many of the students and parents during the YESS program indicated that the hands-on activities and the design project were enjoyable additions to the seminars.

As a pilot effort to assess the effectiveness of the YESS program, student participants completed surveys at the beginning and end of the seminar series. The instruments were designed to capture changes in student interest in science and engineering as well as a host of related attitudes and confidence levels related to math, science, and engineering of interest to the seminar designers. In total, 135 students completed the pre survey and sixty students completed the post assessment. Assessments were able to be paired for the thirty-three students who submitted both of the surveys. The results were analyzed by comparing the responses as a whole, as well as considering paired responses from the individual students.

On the post assessment, students were asked to respond as to how the YESS program affected their abilities and future outlook relative to the fields of science and engineering. The data shows that very few students failed to gain something from the seminar series, with a number of students feeling improved in several areas, particularly content knowledge. The chart below represents a compilation of the students' interest and attitudes data.

Question	*Increased*	*Decreased*	*Same*
My interest in pursuing a career in science or engineering has	43.33%	6.67%	50.00%
My interest in teamwork has	51.67%	8.33%	40.00%
My ability to work on teams has	58.33%	3.33%	38.33%
My confidence in successfully studying science or engineering in college has	41.67%	11.67%	46.67%
My understanding of how math helps solve problems in science and engineering has	41.67%	1.67%	55.00%
My knowledge of science and engineering fields has	70.00%	1.67%	28.33%

Figure 7: Results from student post surveys regarding interest and attitude questions.

A more specific analysis was done by pairing the results of individuals based on their responses to identical questions on the pre and post assessments. For these responses, students were asked to rate their knowledge in several content areas on a scale from 1 to 5 (5 being the highest). The data compiled below represents the percentage of students who indicated an improvement in their knowledge of the given topic.

Content Area	% of Improved Students
Work	51.52%
Power	54.55%
Energy	60.61%
Conservation of energy	63.64%
Renewable and non-renewable energy	63.64%
Energy systems and efficiency	51.52%

Figure 8: This chart reflects the percentage of students who felt they improved their knowledge in a variety of content areas represented within the program.

In addition to the quantitative data, students were also asked to offer comments regarding the best part of the series and their overall experience in the YESS program. Out of the fifty responses for the best part of the program, 58% of students stated directly that the hands-on activities were the best portion of the series. Comments regarding the overall experience of the program included: "The YESS program has inspired me to be the greatest engineer I can be," "The YESS program over the years has sparked my interest in the engineering field and helped me to decide to pursue my career in engineering," and "This has helped me to understand and see real life engineering problems that may take place in the real world."

Clearly, the 2006-7 YESS program expanded upon the success of its previous years, reaching out to even more high school students to increase interest and aptitude in the field of science and engineering. The program was once again deemed successful in exhibiting the positive effect of hands-on activities to learning science and engineering. It is hoped that the program will continue to grow in numbers and success for its current location, as well as becoming widespread via the development of similar programs in other regions.

In addition to the data presented in this paper, a third survey will be sent to each of the YESS student participants (during the month of May) to determine if the YESS program has influenced what they plan to study when entering college.

Acknowledgement

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