

## **AC 2009-1490: AN ASSESSMENT OF A HIGH-SCHOOL OUTREACH PROGRAM**

### **Taryn Bayles, University of Maryland, Baltimore County**

Taryn Bayles is a Professor of the Practice of Chemical Engineering in the Chemical and Biochemical Engineering Department at UMBC, where she incorporates her industrial experience by bringing practical examples and interactive learning to help students understand fundamental engineering principles. Her current research focuses on engineering education, outreach and curriculum development.

### **Tania Monterastelli, University of Maryland, Baltimore County**

Tania Monterastelli graduated Summa Cum Laude in 2008 with a BS degree in Chemical Engineering from the University of Maryland, Baltimore County. She is a member of Phi Kappa Phi and Tau Beta Pi. She has been working on the YESS program for the last two years. She is currently an Lubes Engineering Specialist with Exxon-Mobile Corporation.

## **An Assessment of a High School Outreach Program**

In 2002, the Historical Electronics Museum with a grant from Northrop Grumman founded the YESS (Young Engineers and Scientists Seminars) high school outreach program. This enrichment program is provided for gifted and talented high school students from the Baltimore/Washington area who have a strong aptitude in mathematics and science fields. The program began as a strictly seminar series which addressed diverse topics such as plasma physics, stealth astrophysics and satellite reconnaissance. After two years the program evolved to a hands-on project based learning program which emphasized the engineering design process. Each year the program focuses on a central theme and design project, around which a variety of mini challenges are used to teach students about fundamental engineering concepts which relate to their design project. To date the YESS program has incorporated such projects as hot air balloons, mouse trap cars, renewable energy systems and hemodialysis devices. In addition to trying to increase student's understanding of engineering concepts, the program is designed to increase student awareness of the opportunities available to engineers as well as the various career fields a student can pursue. Every year the program invites a variety of guest speakers, from both industry and academia to provide insight and advice to the prospective engineering students.

This paper presents how the outreach program has evolved over the last four years and presents new data and analysis which were not previously presented. Since the program's inception in 2002, student participation has more than tripled and female participation has been steadily on the rise. Since 2004 female participation increased by 27%, with the number of female students ranging from a quarter to a third of the total number of participants. The overall effectiveness of the YESS program is determined based on observation of an improvement in implementation of engineering concepts and methods as the program has progressed. To assist with this analysis, 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 project solution. The results of these findings are documented, compiled and presented. Comparisons will be made to examine the evolution and success of this high school outreach program during 2004-2008. In addition, it will be determined if different design topics are successful in attracting more young ladies to this high school enrichment program.

### **Background**

A study by Jeffers<sup>(1)</sup>, et al., of various outreach programs categorized that most programs fall into the following categories: develop classroom material; conduct outreach activities on the college campus; conduct outreach activities at the K-12 school; conduct/sponsor engineering contests; sponsor teaching fellows/offer service learning courses; offer professional development. The goals of the programs are to: increase engineering enrollment; diversify engineers; educate the students; teach the teachers; develop undergraduate students. The goal of the Young Engineers and Scientists Seminars (YESS) program is similar and provides an interactive and education program to stimulate high school student interest in science,

mathematics and engineering. The YESS program was originally developed by the Historical Electronics Museum and debuted in the fall of 2002. In 2004 with the assistance of one of the authors the program transitioned from a lecture based seminar style to an interactive and hands-on program. This new teaching style was modeled from the “Introduction to Engineering Design” course the co-author teaches at the University of Maryland Baltimore County. This style requires the design teams to not only research, design, construct, evaluate, test and present their product, but also to develop a mathematical model of their product’s performance. The structure of the program is intended to provide a fun yet inexpensive project for students to design and test, while still allowing students to develop a mathematical understanding of the fundamental engineering principles that make their designs work.

From 2004 to 2008, the YESS program has seen a steady rise in student attendance. Comments attained from both students and parents have reflected that the weekly hands-on activities<sup>(2)</sup> which supplement guest speakers have been important in gaining student interest in the program. In order to assess the effectiveness of the YESS program surveys are used 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.

Enrollment in the program is free and students are provided complementary food during the sessions. Additionally, the program has been sponsored by Northrup Grumman who donates the food and prizes awarded to the winning design teams each year. During the 2007-8 program the Baltimore BWI Airport Hilton also donated food for each session and hosted the final competition and awards banquet.

### **Program Format**

The YESS program is designed to span three and a half months with biweekly meetings, during which students learn how to apply theoretical engineering principles to modeling, designing, building, and finally testing. At each session guest speaker’s present material on topics related to the final design project and engineering in general. Additionally, students participate in mini-design challenges intended to prepare students for the final design project, as well as playing the popular *Who Wants to Be an Engineer* game. This game was developed by Professor David Silverstein<sup>(3)</sup> from the University of Kentucky, Paducah and requires students to match answers to engineering questions. The game was adapted for delivery to a larger audience and students were given brightly colored index cards; the students would raise the coordinated colored card when the selection of answers were displayed by the projector, as shown in Figure 1. Students are awarded a “YESS buck” for every correct answer, which is redeemable for gift cards upon conclusion of the program.



Figure 1: *Who Wants to be an Engineer?*

Each year the final design project (as well as the mini-design challenges) is changed to offer students different engineering experiences from mechanical engineering related problems to chemical and bioengineering problems to systems engineering problems and in the future, environmental engineering related problems. Changing the curriculum content each year helps maintain interest in the program, as well as affording students the opportunity to participate on a yearly basis as the program activities will not be repetitive.

In addition to exposing students to thinking like an engineer, another goal of the program is to inform students about the numerous fields of engineering, its importance, and the many opportunities and career paths available. These goals are accomplished through presentations delivered by the weekly guest speakers. Every year a new group of speakers is invited to share their experiences of why they chose a career in engineering, the challenges they may have been faced with, the career choices they've made, and their advice to prospective engineering students. Speakers have been both male and female ranging from undergraduate engineering students to doctoral students and medical students to professors and industry professionals.

The YESS program series of the past four years are briefly outlined below.

### ***Hot Air Balloon (2004-5)***

In the 2004-5 program series<sup>(4)</sup>, the overarching design project was to construct a hot air balloon of a maximum volume capable of achieving the longest time aloft while carrying the heaviest payload. This design challenge encouraged students to use knowledge of geometry, heat transfer, and buoyancy in order to create the best design. These concepts were emphasized each week by guest speakers and through mini-design challenges. The mini-design challenges (shown in Figure 2) used to prepare students for constructing their hot air balloon included the following activities:



***Introduction to Engineering Challenge***

introduces students to the design process by having them design and construct a structure of maximum height capable of supporting a volume of water



***Tinker Toy Team Building***

provides students an opportunity to develop an appreciation for working in teams within a time constraint

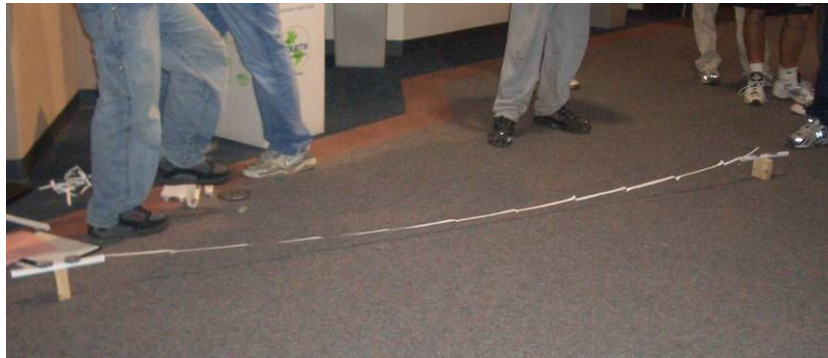


***What Floats Your Boat?*** challenges students to use their knowledge of buoyancy to construct a boat that floats the maximum number of marbles from a specified size of aluminum foil



***Keep It Kool***

requires students to keep a ½ cup of ice-cold water as cool as possible using only the materials provided to them



***A Bridge to the Future***

challenges students to construct a free-standing structure that supports a load across an open distance

Figure 2: Mini-design challenges for the Hot Air Balloon Design Project

For the final design project of constructing a hot air balloon, students were required to construct a balloon of a maximum volume of eight cubic meters that would carry a minimum of 10 grams, while staying aloft a minimum of 12 seconds.

Students learned first-hand about the concepts of buoyancy, heat transfer, and the properties of materials through their design and construction of hot air balloons. Additionally, students were challenged to use Excel to develop mathematical models for their balloons which would predict the amount of time their balloons would stay aloft.

In order to determine the winning designs, the following bragging rights formula was used:

$$\text{Time aloft (sec)} \times \text{Payload (g)} \times \text{Model Accuracy} \times \text{Cost index}$$

And several of the winning balloon designs are shown in Figure 3.



Figure 3. Winning Hot Air Balloon Designs

An average attendance of 63 students was seen in the 2004-5 YESS program with 50-72 students attending throughout the course of the program and 11 students attending each session. Seventy-five percent of the students were male and 25% female.

The 2004-5 program marked an evolution for the YESS program from a lecture based to hands-on style program. Increasing student interest and enthusiasm was of particular importance to coordinators of the series. At the beginning of the seminar, 63% of students expressed a strong to very strong interest in the program which increased to 84% by the end of the program.

### ***Mouse Trap Cars (2005-6)***

In the 2005-6 program series<sup>(5)</sup>, the overarching design project was to build a mouse trap car capable of accomplishing four tasks: traveling a maximum distance, pulling a maximum load, achieving a maximum speed, and accurately stopping at a specified distance. This design challenge encouraged students to use knowledge of potential and kinetic energy, friction, torque, and gearing in order to create the best designs. To help students develop a better understanding of these concepts the following mini-design challenges (shown in Figure 4) were used:





***Let It Launch***

challenges students to design and construct a mechanism to launch a ping pong ball a maximum distance



***Zoom Across the Finish Line***

provides students an opportunity to develop an appreciation for working in teams



***Let's Sail Away***

requires students to construct a vehicle made from K'NEX parts capable of traveling a maximum distance



***Power It Up***

challenges students to design and construct a waterwheel for raising a maximum weight in the shortest possible time



***Mousetrap Pull***

provides students the opportunity to design a device using a mousetrap. The goal is to construct a device capable of pulling a load across an open space

Figure 4. Mini-design challenges for the Mouse Trap Cars Design Project

The multifunctional mouse trap cars were required to be built from materials found around students' homes, no new materials could be purchased. The requirements included:

1. traveling the maximum distance in feet
2. pulling a maximum load over a distance of three feet
3. attaining a maximum speed over a distance of 20 feet
4. accurately stopping at eight feet.

The bragging rights for vehicle performance were assessed according to the formula:

$$\text{Distance traveled (ft)} \times \text{Load index} \times \text{Speed index} \times \text{Stopping index}$$

Examples of some of the winning mouse trap car designs can be seen in Figure 5.



Figure 5. Winning Mouse Trap Car Designs

The 2005-6 program saw an average attendance of 75 students at each session and a total attendance of 57-90 students for the program. 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. Eighty-three percent of the students were male and 17% female.

For the second year in a row, data regarding parental occupations was analyzed to determine if there was a correlation between students with parents holding technical occupations and students' perceptions of their technical knowledge as well as their expectations for the program. Data indicated 27% of students' mothers and 35% of students' fathers held technical occupations. Comparison between students with and without parents in technical occupations showed *no* statistical differences in their interest in an engineering career, their knowledge of science and engineering fields, their plans to major in science or engineering in college, or whether their interest in science is related to becoming a doctor or other health professional. Similar trends were also seen in the 2004-5 program.

### *Energy Systems (2006-7)*

In the 2006-7 program series<sup>(6)</sup>, the overarching design project was to construct an energy system that would harness renewable energy, store, transport, convert, and utilize the energy to illuminate a small light bulb. Students could choose between using the following renewable energy sources: solar, wind, or water. This design challenge encouraged students to use knowledge of potential and kinetic energy, power, gearing and energy conversion in order to create the most efficient designs. In order to assist students with their final design project, students were able to participate in the following mini-design challenges (shown in Figure 6).





***Introduction to Engineering Design***

introduces students to the design process by having them design and construct a structure of maximum height capable of supporting a volume of water



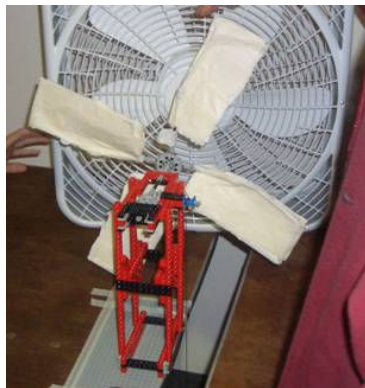
***Light It Up and Make It Spin***

requires students to use knowledge of electricity to create a circuit capable of running a simple motor and lighting a small light bulb



***Hydro-Power It Up***

challenges students to create a cost-effective mechanism that uses flowing water to lift a weight



***Let It Blow***

allows students to gain experience harnessing wind energy by constructing a windmill capable of lifting a weight



***Power It Up with Solar*** provides students an opportunity to design a device using solar panels and gears capable of lifting a weight

Figure 6. Mini-design challenges for the Energy Systems Design Project

As mentioned, students could choose which renewable energy they wanted to utilize: solar, wind, or water. However, several restrictions were placed on these energy sources which included:

1. solar energy – provided by a 90 watt flood lamp
2. wind energy – provided by a box fan of 166, 117, or 87 watts
3. water energy – provided by a flow rate of approximately 0.5 L/sec

Bragging rights for the energy system designs were calculated using the formula:

$$\text{Power generated} \times \text{Overall system efficiency} \times \text{Device cost index}$$

Through this design challenge, students learned about the concepts of power generation in terms of current and voltage, and system efficiency in terms of useful work output and amount of energy input into their systems. Pictures of the final energy system designs are shown in Figure 7.

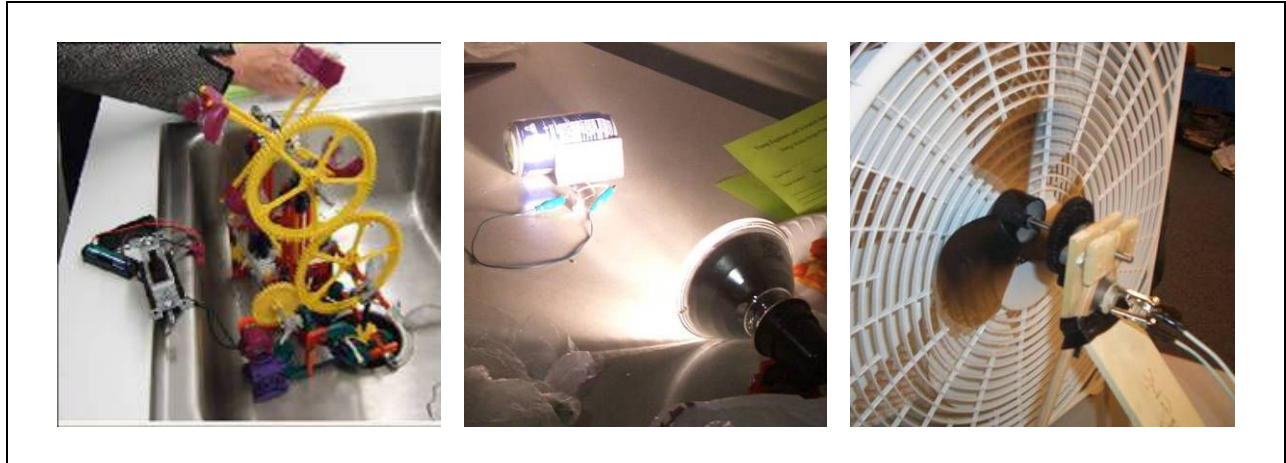


Figure 7. Examples of Energy System Designs

The 2006-7 program saw a record attendance of 76-136 students, with an average attendance at each session of 107 students. Female participation also increased from the previous year to 28%.

The success of the 2006-7 program can be seen through several student comments regarding their experiences with the program: “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.”

### ***Engineering in Healthcare (2007-8)***

In the 2007-8 program series<sup>(7)</sup>, the overarching design project was to construct a hemodialysis device capable of providing the highest purification of simulated blood by using a minimum amount of water (dialysate), while also allowing for the most economical design. This design challenge encouraged students to use knowledge of diffusion, concentration, and flow in order to create the most efficient designs. The following mini-design challenges were used to help students understand key concepts important to their final design project (and are shown in Figure 8).



**Reach for the Stars** provides students an opportunity to develop an appreciation for working in teams by having them construct the tallest free-standing structure



**Eek! Don't Let It Leak** allows students to use their skills at designing and planning to construct a device to protect an egg from a 10 foot drop



**Separate This** challenges students to design and construct a device capable of separating sand from a mixture of other components



**Snap, Krackle & Pop** challenges students to design and construct a device capable of separating Rice Krispies™ from a mixture of other cereals, but adds the constraint of developing a cost effective design



**Let It Flow** requires students to build an apparatus to transfer 500-mL of water a distance of 4 feet as quickly as possible

Figure 8. Mini-design challenges for the Engineering in Healthcare design project.

The criteria for designing the hemodialysis devices included having a safe design, a design that maximized impurity removal (minimum of 2.5 mg of tartrazine from the simulated blood), a design that minimized the amount of dialysate (water) needed to remove impurities, and a design that minimized total cost (maximum allowable cost was \$75). Each of the design criteria are illustrated in the design target shown in Figure 9.

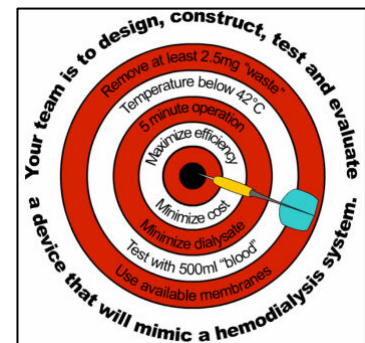


Figure 9. Design Criteria for the Hemodialysis Device



The final bragging rights for each design were calculated according to the following formula:

$$\text{Removal of impurities (mg)} \times \text{Dialysate cost index} \times \text{Device cost index}$$

As mentioned, this project encouraged students to use knowledge of diffusion, concentration, and flow in the construction of their devices. More specifically, students learned how concentration, temperature, and molecule size affects the diffusion of particle impurities through a membrane. Students also learned how different pore sizes and surface areas affect diffusion through a membrane. Additionally, students learned different techniques for analyzing and determining the proper flow rate of simulated blood and dialysate through their devices. Such techniques included flow by gravity, forced flow by pumping, and mathematical modeling using the Bernoulli equation. Pictures of successful hemodialysis devices are shown in Figure 10.



Figure 10. Examples of Hemodialysis Devices

This program saw 61-98 students throughout the series, averaging 86 students per session with 25 students having attended all of the sessions. 67% of students were male and the highest percentage of female students to date was seen at 33%.

According to Sheila Widnall, former Vice President of the National Academy of Engineering (NAE), the top reason why women don't go into engineering is a lack of understanding of the connection between engineering and the problems of our society<sup>(8)</sup>. According to Jacquelyn Sullivan engineering experiences must be created that help young people appreciate the wonders of engineering in their everyday lives and enable them to internalize engineering as a helping profession that speaks to their hearts<sup>(9)</sup>. With this in mind, the 2007-8 YESS program was an important year for the YESS program because the topic "Engineering in Healthcare" was intended to be an attraction for young women. Statistics showed that female interest in the YESS series increased by 15% from the beginning to the end of the program, compared to a decrease in female interest of 11% in the 2006-7 program and an increase of 2% in the 2005-6 program.

## Survey Findings

Pre- and post- surveys are used to gather participant information encompassing demographics, parent/guardian occupations, interest levels in relevant fields, level of understanding in key content areas, measures of confidence in math and science, as well as expectations for the program.

Survey results as well as attendance records show that since the program's inception in 2002, student participation more than tripled. Additionally, female participation in the program is on the rise. Since 2004, female participation increased by 27%, with the number of female students ranging from a quarter to a third of the total number of participants.

The success of the YESS programs can be seen through analysis of three sets of questions. Similar analysis has been used to assess outreach programs<sup>(10)</sup>. The first set of questions designated with a “weak” to “very strong” scoring scale is used to assess student's perceptions of their understanding of key content areas related to the particular year's final design project. Students are asked to rate the same set of content areas both on the pre- and post-surveys, which provides a means of measuring the effect the program has on student understanding. Table 1 shows the results of this survey section. The 2005-6 YESS program has been omitted from this analysis since pre- and post- survey data is not available.

Table 1. Pre- and Post-Survey Student Responses to Key Content Areas

Content area	Pre-Score	Post-Score	Percent Increase
<b>2004-5<sup>1</sup></b>			
Determination of surface area/volume Relationship between mass and weight Ideal gas behavior Buoyancy Heat transfer	3.5	3.8	9%
<b>2006-7<sup>2</sup></b>			
Work Power Energy Conservation of energy Renewable and non-renewable energy Energy systems and efficiency	3.2	3.7	15%
<b>2007-8<sup>3</sup></b>			
Dialysis Diffusion Concentration gradient Relationship between diffusion, concentration, & temperature Co-current/counter-current flow Engineering design process	2.5	3.4	38%

<sup>1</sup>. Percentages based on 36 total respondents in the 2004-5 program year.

<sup>2</sup>. Percentages based on 60 total respondents in the 2006-7 program year.

<sup>3</sup>. Percentages based on 78 total respondents in the 2007-8 program year.



The data presented in Table 1 represents an overall average for all content areas. As can be seen, the data gathered each year indicates that student understanding increased throughout the program. Based on the data, there would appear to be a trend of increased overall understanding each year; however this trend can be considered a coincidence. The larger percentage increase, from 9%, to 15% to 38%, seen each year is more accurately correlated to the content areas presented each year being increasingly more challenging and less familiar to the students.

The second set of questions, designated with a “strongly disagree” to “strongly agree” scoring scale, is used on the post-survey to assess student perceptions on the difficulty of the seminar, whether their technical knowledge increased as a result of the program, and whether or not they would recommend the program to others. The results of these survey questions can be seen in the following table.

Table 2. Student Responses about Their Perceptions of the YESS Program

	2004-5 <sup>1</sup> .	2005-6 <sup>2</sup> .	2006-7 <sup>3</sup> .	2007-8 <sup>4</sup> .
<b>This seminar series has been academically challenging</b>	69%	58%	46%	50%
<b>I used knowledge from outside this seminar series</b>	75%	72%	62%	55%
<b>Overall, I learned a lot in the seminar</b>	64%	80%	60%	58%
<b>I would recommend the program</b>	78%	87%	67%	70%

<sup>1</sup>. Percentages based on 36 total respondents in the 2004-5 program year.

<sup>2</sup>. Percentages based on 49 total respondents in the 2005-6 program year.

<sup>3</sup>. Percentages based on 60 total respondents in the 2006-7 program year.

<sup>4</sup>. Percentages based on 78 total respondents in the 2007-8 program year.

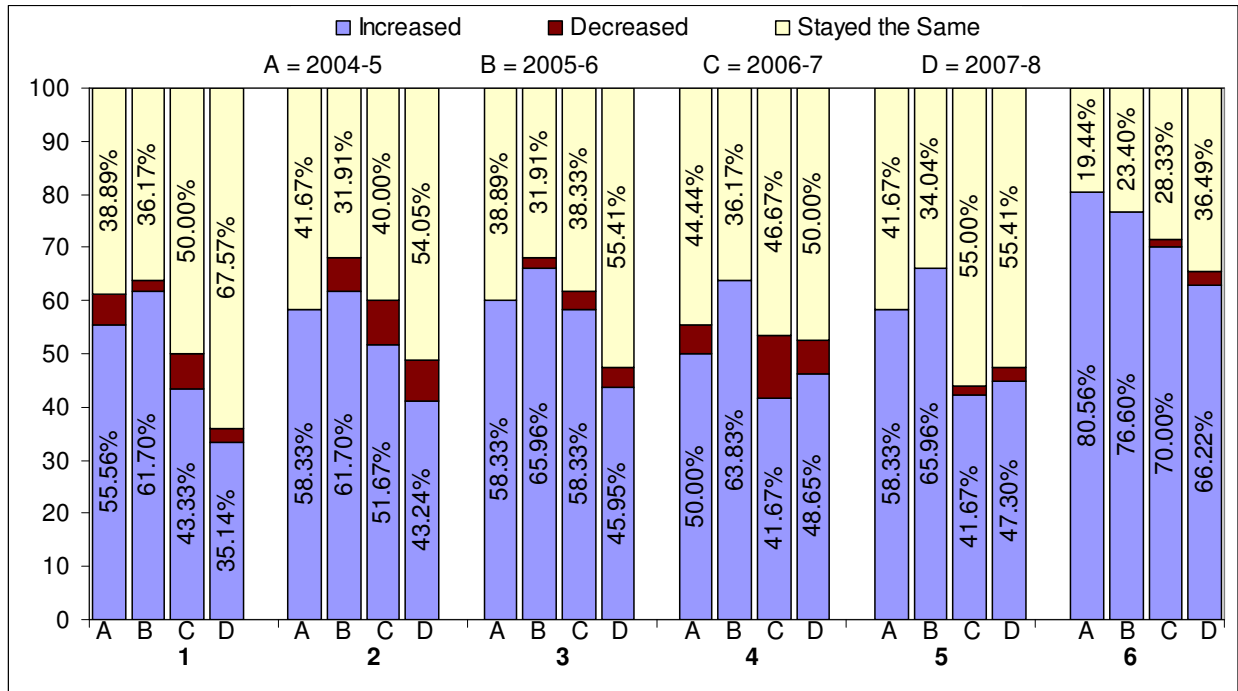
The results listed in Table 2 reflect the total percentage of students who both agreed and strongly agreed with the statements shown. The data shows that every year over 50% of all student participants either agreed or strongly agreed with every statement (except in the 2006-7 program year where 46% of respondents indicated the seminar series was academically challenging).

A third set of questions asked only on the post-survey is designed to gauge whether students’ interest levels or skills have increased, decreased, or stayed the same by participating in the program. Several of the questions focus on how students’ interest in pursuing science or engineering has changed, how their confidence in studying science or engineering in college has been affected, as well as whether or not they have seen a change in their understanding of the importance of mathematics in problem solving. The results are shown in Figure 11, where the numbers 1 through 6 correspond to the following statements:

1. My interesting in pursuing a career in science or engineering has
2. My interest in teamwork has
3. My ability to work on teams has
4. My confidence in successfully studying science or engineering in college has

- 5. My understanding of how math helps solve problems in science and engineering has
- 6. My knowledge of science and engineering fields has

Figure 11. Student Responses to Changes in their Interest, Attitude, and Confidence Levels



- A. Percentages based on 36 total respondents in the 2004-5 program year.
- B. Percentages based on 49 total respondents in the 2005-6 program year.
- C. Percentages based on 60 total respondents in the 2006-7 program year.
- D. Percentages based on 78 total respondents in the 2007-8 program year.

It should be noted that every year student’s knowledge of science and engineering fields (question 6) increased, and in particular this increase in knowledge was expressed by at least 66% of all participants. Overall, 67% of all responses through the past four years of the program show that at least 50% of student participants expressed an increase in their interest, ability, or confidence for the six questions listed above.

In addition to these questions, the 2006-7 program introduced a series of 10 multiple choice questions on both the pre- and post- surveys to test students’ knowledge of fundamental engineering principles related to the program’s final design project. Data gathered in the 2006-7 and 2007-8 programs showed that the average students’ scores decreased from 60% to 57% and increased from 73% to 81%, respectively. A t-test conducted on the data sets in 2006-7 showed that the decrease in scores was not statistically significant ( $p > 0.05$ ), while the increase in scores in 2007-8 was statistically significant ( $p < 0.05$ ). The students were also asked to order the design process steps on pre- and post surveys in both 2006-7 and again in 2007-8. A paired t-test indicated that the increase from 64 % to 68 % in 2006-7 and the decrease from 72% to 68% on the survey scores were not statistically significant ( $p > 0.05$ ) in either year. Although students were tested on their ability to learn and retain technical information throughout the course of the program, student performance in this area is not the main focus of the YESS program as it is difficult to expect students to retain technical information while participating in a volunteer

program. It is for this reason that the real emphasis of the program is to attract students to science and engineering, and make them aware of the opportunities and fields of interest available to them.

## Conclusion

The Young Engineers and Scientists Seminars program was started in 2002 by the Historical Electronics Museum. Since its commencement, the program has transitioned from a lecture based to a hands-on style program which helped to triple attendance from 2004-2008. It has been previously shown that hands-on, active learning enhances the learning process for students so that they more fully engage in the excitement and satisfaction of gaining competency in science, math and technology<sup>(11)</sup>. The program's goal has been to inspire and encourage high school students to consider pursuing mathematics, science, and engineering. Additionally, the program aims to inform students about the importance of engineering as well as the numerous career opportunities available through engineering.

The success of the program was evaluated based on data gathered regarding student's perceptions of their understanding of key content areas, the difficulty of the seminar, changes in their confidence levels, and their interest in engineering as a career. Compiled survey data of the past four years of the YESS series has shown that the program has been successful at increasing young students' interest in mathematics, science, and engineering, as well as increasing their knowledge of technical content.

During the 2008-9 program year, the co-author was not available to lead the YESS program and the program returned to a strictly seminar series. Program attendance was 110 students for the first session and disappointingly, the attendance dramatically declined steadily over the remaining sessions and the final session attendance was only 37 students.

## References

1. A.T. Jeffers, A.G. Safferman and S.I. Safferman, "Understanding K-12 Engineering Outreach Programs," *Journal of Professional Issues in Engineering Education and Practice*, April, P. 95-108, (2004).
2. B. Mathias-Riegel, "A Click Away", *Prism*, Volume 14, Number 7, March (2005).
3. D. L. Silverstein, "Who Wants to be an Engineer?" ASEE Multimedia Session #2793 (2003).
4. T. M. Bayles, A. M. Spence and J. B. Leonard, "YESS – Young Engineers & Scientists Seminars" ASEE. Paper #1378 (2005).
5. T. M. Bayles, T. Foster, D. Sheridan and C. Parker, "Let it Roll with YESS." ASEE. Paper #2006-1255 (2006).
6. T. M. Bayles, J. Rice, G. Russ, and T. Monterastelli, "High School Outreach: A Look at Renewable Energy." ASEE. Paper AC 2007-1533 (2007).
7. T. Monterastelli, T. M. Bayles, and J. Ross, "High School Outreach Program: Attracting Young Ladies with 'Engineering in Healthcare.'" ASEE. Paper #2008-1006 (2008).
8. S.E. Widnall, "Digits of Pi: Barriers and Enables for Women in Engineering", *The Bridge*, 30, (2000).
9. J.F. Sullivan, "Last Word: Lessons From the Sandbox", *Prism*, Volume 16, Number 5, January (2007).
10. S.J. Poole, J.L. deGrazia and J.F. Sullivan, "Assessing K-12 Pre-Engineering Outreach Programs," *Journal of Engineering Education*, January, (2001).
11. L.E. Carlson and J.F. Sullivan, "Hands-on Engineering: Learning by doing in the Integrated Teaching and Learning Program," *International Journal of Engineering Education*, Volume 15, Number 1, (1999).