AC 2010-780: INCREASING GIRLS' INTEREST IN ENGINEERING BY MAKING IT FUN

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Increasing Girls' Interest in Engineering by Making it Fun

Abstract

This paper describes a workshop, led by female Engineering Technology students with support from female faculty members, that introduces engineering concepts to 4th -7th grade girls through a series of interactive laboratory experiments. The day-long workshops are offered to area Girl Scouts and are intended to increase the girls' interest in engineering. In support of this goal, hands-on experiments are carefully designed to: 1) show the girls that science can be both fun and creative 2) connect science and engineering to things in everyday life that they already know and care about 3) demonstrate that women can make a positive impact on the world with a career in engineering.

The workshops take place on the college campus and make use of four different Engineering Technology laboratories. The girls spend one hour in each lab where they are presented with an overview of that particular engineering technology and a brief description of the theory behind the experiment that they will be performing. Using tools and measuring equipment found in the laboratories, the experiments are performed entirely by the girls with guidance from the student volunteers. To culminate the day all of the Girl Scouts meet with the student volunteers for a question-and-answer period. During this panel discussion, the girls are encouraged to ask questions relating to the students' decisions to study engineering and their career aspirations along with their college experiences.

Having the educational material presented by college students seems to have a much bigger impact on this age group than when the same material is presented by someone older. The participation of the female college students helps to dispel many of the negative stereotypes about engineers that some of the girls arrive with. By combining girl-centric activities with the opportunity to work side-by-side with female college students the girls leave the day with a more positive view of science than they had when they arrived. Surveys given at the start and end of the day quantitatively confirm the change in attitudes of the girls.

A corollary benefit to these workshops is for the college students who volunteer their time for the program. The students work together within their own department to develop the activities and facilitate the experiments. They also work with the female students from the other departments in the panel discussion and overall organization of the day. The students gain the satisfaction of influencing the attitudes of the Girl Scouts as well as developing a sense of community with their classmates. The students improve their communication skills and increase their knowledge of their own majors, both of which contribute to confidence when speaking to interviewers. Feedback from student volunteers indicates that this program is as important for them as it is to the Girl Scouts who attend.

Introduction

To allow the United States to continue to compete in the global marketplace we need a workforce that possesses strong skills in the areas of science and technology. With our ever increasing technology-based society and predicted high rates of retirements for engineers over

the next decade, U.S. business leaders are predicting a critical shortage of high-tech workers. One way to avoid this shortage is to increase the number of women entering engineering fields. Currently, only 8.5% of all professional engineers are women, even though women constitute close to half of the total workforce.[1] While the percentage of women studying engineering has doubled since 1980, from 10% of engineering bachelor's degrees awarded to 20%, this percent has plateaued over the past decade. Research has shown that cultivating girls' interest in science must begin early. The gender gap in math and science courses grows as students go from middle school to high school. In fourth grade, girls report the same level of interest in math and science as boys. However, by the time they reach the eighth grade; boys are twice as likely to be interested in science, math, engineering or technology.[2]

Middle school is a critical time to engage students, especially girls, in science and engineering outreach programs. If girls lose interest in math and science in middle school, when social pressures and gender differences become more pronounced, they typically won't find their way back to the subjects.[3] The middle school years are a crucial transition period. During these years, decisions, such as which classes to take in high school, are made that will open or close career options. Math and science are the keys to careers in engineering and technology. If students decide not to pursue these subjects in high school, they are essentially closing the doors to certain professions. Thus our main challenge is attracting middle school students to science and engineering.[4]

A decrease in interest in science and engineering at this critical age indicates there is a problem in the way young girls are exposed to these fields. Best practices for outreach programs for young girls include hands-on interactive activities. The National Center for Women in Information Technology-Promising Practices states that the essential ingredients for a successful outreach program for girls are: ensure that the girls are with their friends or can otherwise feel a sense of belonging in the group to which they are assigned, keep talk to a minimum and action to a maximum, connect the things they are doing to things they already know or care about, and employ experienced volunteers that can relate well to the girls and create a fun atmosphere. [5] Similarly, girls excel in learning situations that involve hands-on cooperative strategies with same-sex peer groups which alleviate the feeling of isolation.[6] Activities should be gender friendly and involve "learning by doing." [7]

Background

Women In Technology (WIT) is a group that was formed on our campus by female faculty in four engineering technology departments; Mechanical and Manufacturing Engineering Technology, Electrical, Computer and Telecommunications Engineering Technology, Civil Engineering Technology and Packaging Science. The objective of the group is to provide social and academic support to female students in these engineering technology majors thus increasing retention and graduation rates. While the social and academic activities sponsored by WIT have been successful in increasing retention rates of female engineering technology students, the students indicated that they would like to see the program expanded to include opportunities for community outreach. This request by the female students is consistent with current literature on what attracts women to a career. A study by WGBH Educational Foundation for Extraordinary Women Engineers showed that females seek careers that are enjoyable, have a good working environment and where they feel they can make a difference. The female students felt that what

was lacking in WIT's programming was an opportunity to make a difference. When polled, 72% of the students active in WIT (approximately 42% of the female engineering technology students) said that they would like to be involved in an outreach program that involved Girl Scouts.

Planning for the Girl Scout event, named "Girl Scouts in Technology" was left up to the student members of WIT. The intent, from the beginning, was for this to be a student-run activity with faculty members' only role being that of taking care of administrative details. By having the students in charge of planning, they have a sense of ownership for the program. Additionally, many of the students involved were former and life-long Girl Scouts who have better ideas than the faculty members on how to reach girls in the middle school age group. It was decided that each of the four engineering technology departments represented would develop a hands-on experiment to be conducted in one of their laboratories. The program was first offered in February of 2008 to a troop of 9 girls and has been offered five times since then. The students involved continually update and change the experiments to keep it interesting for themselves and to reflect the interest levels demonstrated by the Girl Scouts to the various activities. Each of the four engineering technology departments has a core group of students who plan and organize their experiment with other volunteers from the department helping with facilitation of the event.

Funding for the Girl Scouts in Technology Program was made available through a grant from the Rochester Area Community Foundation. The grant money covered the cost of supplies, website development, faculty stipend and pay for student volunteers.

Program Details

The Girl Scouts in Technology program was designed such that it encompasses the essential ingredients for a successful outreach program for girls.

1. Ensure that the girls are with their friends or can otherwise feel a sense of belonging in the group to which they are assigned: This program is primarily promoted as a troop activity so that the girls can participate with their friends. The girls in a troop are used to working together to achieve other goals so there is an immediate sense of camaraderie when performing the experiments. By having troops attend together, the girls already feel comfortable with the group and thus they are free to focus their attention on the activities instead of spending time worrying about how they fit in.

2. Keep talk to a minimum and action to a maximum: With this in mind, the experiments were designed to be hands-on with the girls performing as much of the experiment as possible. This involves letting them use the tools in the engineering technology labs to complete their own experiment from start to finish. The result is two-fold in allowing them to do so. First, they learn proper use of some of the tools and safety precautions such as the use of rubber gloves when handling chemicals and safety glasses when working with concrete. Secondly they feel a greater sense of accomplishment that they did it all themselves and nothing was "pre-done" for them. While we feel that providing theory is an important part of each experiment, the theory discussion is only a small portion of the activity. Theory is presented with colorful slides and drawings and in an interactive manner.

3. Connect the things they are doing to things they already know or care about: This proved to be a challenge as the girls come from different school districts with very diverse backgrounds in science. The experiments were chosen to best represent the connection between engineering and objects in everyday life and efforts were made to have the experiments be especially interesting to girls. Wherever possible, the supplies for the experiments were materials purchased in regular department and/or hardware stores to further show that science and engineering can be easily accessible.

4. Employ experienced volunteers that can relate well to the girls and create a fun atmosphere: As discussed earlier, an important aspect of this program is that it is run by female engineering technology students. This is an area that sets our program apart from others. The student volunteers are passionate about what they do and their enthusiasm is contagious with the girls. Because many of the girls arrive with the preconceived notion that an engineer is a socially awkward individual in a white lab coat as stereotyped by the media, spending the day with female college students whom they perceive as "cool" often changes their perception of who can be an engineer. When one Girl Scout was asked why she felt it was better to have students rather than teachers lead the experiments, she replied, "The students are so enthusiastic about the experiments it's hard not to have fun doing them. Adults always make experiments seem hard, but the students make them easy."

The day includes four laboratory experiments conducted in the Civil, Mechanical, Electrical and Packaging Engineering Technology Labs. Registration is limited to four troops and each troop does a different activity during each one-hour time slot. It is important to us that the ratio of volunteers to girls is 1 to 2 or 1 to 3 so that the girls receive a great deal of individual attention and none are forced to spend much time waiting for somebody to help them. If the girls have to wait for help and become frustrated, they will form negative feelings about the experiment.

The Civil Engineering Technology experiment involves the study of concrete and bridge construction. Concrete is a material the girls are well familiar with, but probably have never really thought of the science behind it. After learning about how concrete is made, the girls are given a recipe to make their own small batch of concrete. They use a precision scale to weigh their dry ingredients and a graduated cylinder for measuring liquid ingredients. They are then given a choice of molds to pour their concrete into and a small straw is used to form a hole. The end result is a concrete pendant that can be put on a cord and worn as a necklace.

The second part of the concrete experiment is strength testing. Several different concrete cylinders are prepared ahead of time with different cure times and core materials. The girls take turns hitting the concrete with a sledgehammer to see which cylinders break more easily. They see the relationship between the cure time or core material and the strength of the concrete. This activity always results in loud cheering and clapping. Wearing a hardhat and swinging a hammer gives the girls a true feeling of being part of the experiment and being a real engineer.

Using uncooked spaghetti and various sized marshmallows, the girls learn about bridge construction. Teams of two are challenged to construct a bridge that will support as many toy cars as possible. The student volunteers offer tips along the way, but ultimately allow the girls to complete the bridge on their own. After the bridges are tested under load, the volunteers discuss

the pros and cons of the girls' designs and use the materials provided to demonstrate various construction techniques.

The session in the Electrical and Computer Engineering Technology lab starts with an overview of what electrical and computer engineers do. When asked at the first session what electrical engineers do, the girls responded "wire houses." This led to the realization that the girls needed more background. The experiment performed in this lab involves building a motor from a battery, a magnet and a coil of wire. Since the state science curriculum introduces electricity and magnetism in 4th grade, the girls are familiar with some of the theory introduced in this lab. This allows for deeper explanation and experimentation. When told that they will make a motor out of the materials in front of them, they never believe it is possible. This leads to a greater sense of accomplishment when they do get the motor to work on their own. Like many of the experiments, the girls can take the motor home with them to further experiment with. An important aspect of this activity is that it demonstrates that an engineering experiment does not have to involve expensive parts and equipment and that science is all around us.

One of the most important things that the girls (and their leaders) learn in the packaging engineering experiment is that Packaging Science is a possible career field. The majority of Girl Scouts that participate in the program have never heard or thought about the field of packaging engineering. This activity begins with a display of antique and modern packages including packages from products the girls are familiar with. Considerations for package designs including costs and environmental concerns are discussed. To appeal to girls' growing concern about the environment, a discussion about sustainability in packaging has been added to this presentation. Computer Aided Design software is then demonstrated and the girls are shown how a flat two-dimensional design is rendered in three dimensions by the software. In conjunction with the software, an automated cutting table is used to cut out the 2-D design on tag board. Each girl is given a cut design and instructions on how to fold it into a 3-dimensional "package."' The packages are picked to be of interest to girls and seasonally relevant. For example, a haunted house for Halloween, a heart-shaped box for Valentine's Day and a basket for spring. To make this activity of further interest to girls, stickers, decorations and markers are provided for them to creatively embellish their package. Not only do the girls learn about packaging, they also discover that science and creativity are not mutually exclusive.

The Mechanical and Manufacturing Engineering Technology session centers on plastics. The girls first learn the theory of polymer chains and characteristics of plastic. As with the other experiments, it is important to make the connection between science and the objects in their everyday lives. Recycled take-out food containers are used to make plastic charm bracelets (resembling a polymer chain). The girls draw on the recycled plastic and then put it in the oven where it will shrink. High precision calipers and a scale are used by the girls to measure and weigh the charms prior to and after shrinking as they record and compare data. The use of the measuring instruments gives the girls a chance to experiment with tools actually used by engineers and meets one of the requirements for a Girl Scout technology badge. The charm bracelet activity is of special interest to girls as it involves the creativity of making the charms and also having a piece of jewelry to wear as the finished project. The second part to the plastics experiment is the creation of a polymer. The polymer the girls make is "slime" from white glue, water and Borax. This is another experiment that connects objects from everyday life to

engineering and can be performed with common household ingredients. The girls enjoy the slime so much it is tough to keep them from playing with it for the rest of the day.

The final activity in the Girl Scouts in Technology Day is a panel discussion with the student volunteers and the Girl Scouts. The student volunteers share their stories of how and when they decided to be engineers, what they like about studying engineering and college in general, what they don't like about college and some of the challenges they have faced being a female in engineering. The girls are encouraged to ask the students any questions that they may have regarding engineering or college life. Even after the long day of experiments, most of the girls are attentive and engaged during the panel discussion. An example of the impact that this discussion has on the girls was observed in the following: as one of the Girl Scouts was walking out with her mother she excitedly told her, "Mom, two of the girls said that they decided to go into engineering because when they were my age they liked to take things apart – just like me."

Results for Girl Scouts

Girl Scouts and leaders alike have provided us with feedback that this program has had a positive influence over their views of science and engineering. This feedback provides anecdotal evidence that the program is successful in its mission of increasing girls' interest in technological fields. Comments from girls to WIT include:

"I want to do that when I grow up"
"I want to be just like you guys"
"You chose awesome things to do at college"
"It left me knowing what I want to major in at college … ENGINEERING"
"I think engineering is a great job"

Leaders also reported:

> *"I couldn't help but smile when they were talking about a troop member who opted not to go because she assumed that it was going to be boring - and the rest of the troop was now laughing at her for having thought that - because they had so much fun!"*
>
> *"…and because it was led by females, it showed the girls that they themselves can be engineers. This day (and all your female engineering students) made a huge impression on the girls in our troop. "*
>
> *"Women in Technology did a wonderful job sharing their knowledge and personal stories about engineering. I think they inspired us all. Please extend a thank you to all of them for giving up time on a Saturday to spend with us. Their influence is powerful over our troop's age group."*

While this type of feedback confirmed to us that the program was worthwhile and making a difference, we wanted to quantitatively measure the success of the program. An assessment tool was developed to measure whether participation in the Girl Scouts in Technology Program had a positive influence on the girls' attitudes towards science and technology. The assessment used was an opinion survey given before and after the Technology Program. The survey consists of five simple questions that assess their (1) perception of the difficulty of science, (2) their interest

in science (boring or fun), (3) their knowledge of what an engineer does, (4) their idea of which gender an engineer is and (5) whether their interest is in pursuing science or engineering as a career. The hypothesis being explored is if the participants are inspired by the activities during the program, they may be more likely to pursue a degree and a career in engineering or science.[8] The program participants were also asked if they knew an engineer or scientist in the pre-program survey to assess if this external influence had an effect on the girls' attitudes towards science or engineering.

Statistical Analysis

The data was gathered over 130 program participants. Each of the first five questions had four responses as shown in Table 1. The qualitative answers were transformed to a 1-4 quantitative scale to allow analysis of the data. The summary statistics for each question are shown in Tables 1 and 2.

Table 1: Participant before program responses

KEY:	I think science is:	I think science is:	I know what an Engineer does	Most Engineers and Scientists are:	I'd like to become a Scientist or Engineer	Someone I know is an Engineer or Scientist
1	very hard	Boring	I don't know	men	definitely not	no
2	sometimes hard	neither boring nor fun	I'm not sure	women	I don't know	not sure
3	neither hard nor easy	sometimes fun	I think I know	I'm not sure	Maybe	yes
4	easy	always fun	I definitely know	anybody can be an engineer or scientist	definitely yes	
1	1.59%	1.59%	11.11%	13.49%	11.90%	21.09%
2	46.03%	2.38%	13.49%	0.79%	26.98%	39.06%
3	42.06%	53.97%	58.73%	9.52%	50.79%	38.28%
4	10.32%	42.06%	16.67%	76.19%	10.32%	----

Table 2: Participant before program responses

I think science is:		*I think science is:*		*I know what an Engineer does*		*Most Engineers and Scientists are:*		*I'd like to become a Scientist or*		*Someone I know is an Engineer or*	
Mean	2.611	Mean	3.365	Mean	2.841	Mean	3.548	Mean	2.595	Mean	2.175
Standard Error	0.062	Standard Error	0.055	Standard Error	0.076	Standard Error	0.090	Standard Error	0.074	Standard Error	0.068
Standard Deviation	0.692	Standard Deviation	0.615	Standard Deviation	0.852	Standard Deviation	1.009	Standard Deviation	0.831	Standard Deviation	0.760
Sample Variance	0.480	Sample Variance	0.378	Sample Variance	0.727	Sample Variance	1.018	Sample Variance	0.691	Sample Variance	0.577
Kurtosis	-0.477	Kurtosis	1.800	Kurtosis	0.385	Kurtosis	2.207	Kurtosis	-0.370	Kurtosis	-1.205
Skewness	0.400	Skewness	-0.835	Skewness	-0.633	Skewness	-1.890	Skewness	-0.393	Skewness	-0.305

As noted in table 1 most participants perceived the difficulty of science as either 'sometimes hard' and 'neither hard nor easy' this can also be seen in the table 2 mean participant rating of 2.61 with a slight positive skewness of 0.4. Most participants rated science as 'sometimes fun' or 'always fun' with a mean participant rating of 3.365. The participant knowledge before the program of what an engineer does was lower with the most common rating of 'I think I know'. Most participants were open to considering engineering or scientist careers as seen by the common 'maybe' response in this career option, and the perception that these career options are available to both men and women. A positive correlation (correlation coefficient of 0.40) was found between how the girls perceived science as being boring or fun and their interest in

becoming a scientist or engineer. A smaller positive correlation (correlation coefficient of 0.28) was found between how the girls felt about science being hard or easy and their interest in becoming a scientist or engineer. For those girls who reported knowing someone that was an engineer or scientist no correlation was found (correlation coefficient of -0.04) to an interest to becoming a scientist or engineer. A slight positive correlation (correlation coefficient of 0.18) was found between those girls who knew a scientist/engineer and knowing what an engineer does as would be expected due to increased exposure to a scientific professional. Overall from the before program data analysis the authors concluded that the girl participants did not have a very strong negative or very strong positive perception of science or their abilities to enjoy science and were open to considering careers as scientists or engineers. This represents a group of participants that with an effective program could show improvements in their perception of science and an increase in wanting to become and engineer or scientist.

Upon completion of the program the survey was again administered to assess the change in perception that had occurred due to the program. The summary results are shown in Table 3.

Table 3: Participant <u>after</u> program responses

KEY:	I think science is:	I think science is:	I know what an Engineer does	Most Engineers and Scientists are:	I'd like to become a Scientist or Engineer
1	very hard	Boring	I don't know	men	definitely not
2	sometimes hard	neither boring nor fun	I'm not sure	women	I don't know
3	neither hard nor easy	sometimes fun	I think I know	I'm not sure	Maybe
4	easy	always fun	I definitely know	anybody can be an engineer or scientist	definitely yes
1	0.00%	0.75%	0.75%	6.77%	6.77%
2	29.32%	3.76%	6.77%	0.00%	16.54%
3	47.37%	32.33%	40.60%	2.26%	63.91%
4	23.31%	63.16%	51.88%	90.98%	12.78%
Change from Pre-Post					
1	-1.59	-0.84	-10.36	-6.73	-5.14
2	-16.71	1.38	-6.73	-0.79	-10.44
3	**5.30**	-21.64	-18.13	-7.27	**13.12**
4	**12.99**	**21.09**	**35.21**	**14.79**	**2.46**

As noted in table 3 most participants perceived the difficulty of science as 'neither hard nor easy' with a significant increase in respondents answering easy as compared to the pre-survey. Utilizing a T-test (alpha 5%; 95% confidence) for this respondent question we can conclude that the mean participant responses changed from pre program to post program for this question. In other words, the program had a statistically significant effect on changing the girls' perception of science on the hard-to-easy scale. Figure 1 shows graphically the change in responses. Similarly, for all of the other questions T-tests showed statistically significant changes (alpha 5%; 95% confidence) for the girls' responses in the post survey as compared to the pre survey. A similar positive correlation (correlation coefficient of 0.38) were found in examining the post survey between the girls' opinion of science (boring to always fun) and their attraction to becoming a scientist or engineer. Graphs displaying the change in attitudes are displayed in Figures 1, 2 and 3.

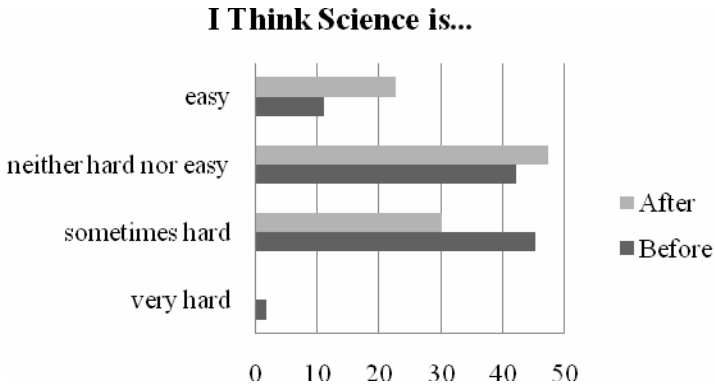

Figure 1: Before and After Responses for Perception of Difficulty of Science

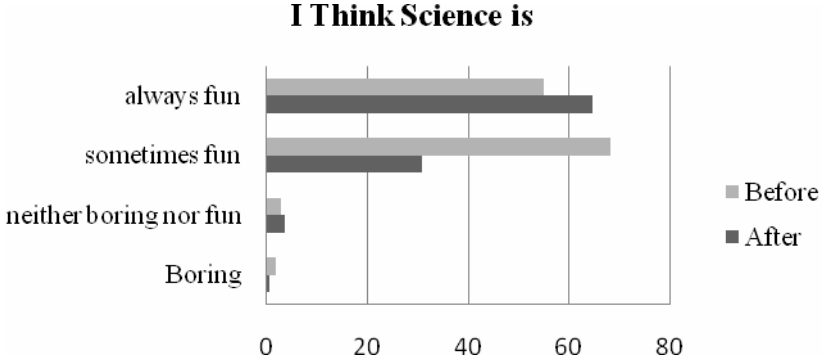

Figure 2: Before and After Responses for Perception of Science as Fun or Boring

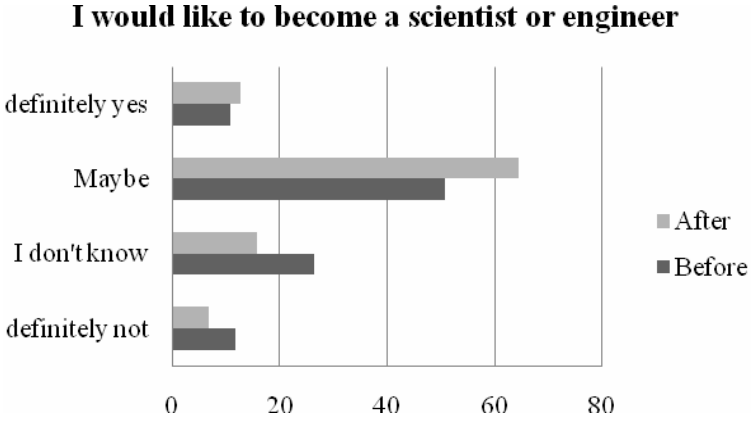

Figure 3: Before and After Responses for Interest in Becoming a Scientist or Engineer

A residuals plot of the linear regression between these variables shows decreasing variation in residuals for those that had a more positive view of science (always fun) and wanting to become a scientist or engineer. In other words, if the girls perceived science as being fun they were more

likely to want to consider becoming a scientist or engineer. Those girls that felt science was 'less fun' had an increased variability on their willingness to consider a scientific or engineering career. Overall, the post analysis found a statistically significant change in the girls' perception and interest in science/engineering as measured by the assessment and through the program of making science approachable and 'fun'. The increased positive perception in science correlated to an increased willingness to consider a career in a scientific or engineering field as compared to the girls before the program.

Results for Student Volunteers

The program has proven to be equally beneficial to both the Girl Scouts who participate and the engineering technology students who volunteer their time to run the program. As mentioned earlier, the planning and preparation of the experiments is left to the students so that they have a sense of ownership for the activities. This also fosters teamwork among the students in each department as they work together on the experiments. The younger students are given the opportunity to interact with, and thus be informally mentored by the more senior students in their department. In the case of the packaging experiment, the first year students learn from their classmates how to use the design software since they have not taken the class yet. The Girl Scouts in Technology program also requires interdisciplinary cooperation for the overall coordination of the day along with the panel discussion portion. The students have the opportunity to meet students in other engineering technology disciplines and often help out in the other labs to get a better feel for their experiments. These interactions lead to a greater sense of community and belonging for the female students. Preparing the experiments and the accompanying presentations provides the students with an opportunity to improve their communication skills and increase their knowledge of their own majors. The students gain confidence in themselves and also gain satisfaction in knowing that they are making a difference for the Girl Scouts in attendance.

Although funds are available through a grant from the Rochester Area Community Foundation to pay students for developing and running the workshops, it has been found that students are reluctant to accept payment for their involvement. When given a timecard to complete for the day, many of the students will refuse to fill it out or request that their pay be put back into the program for supplies. Most respond that they participate because it is fun, not because they expect to get paid. Forty-five different students, over one-third of all registered females in engineering technology disciplines, have volunteered in this program. Sixty percent of the volunteers have participated in 2-3 Girl Scouts in Technology days while 30% have participated in 4 or more. When asked what it means for them to participate in the program, the students responded with the following:

"For me, it is a chance to share my love of mechanical engineering and hopefully inspire those who are thinking about engineering to follow their dreams and achieve their goals."

"This program has been very beneficial. I'm able to work closely with other female engineering students and female faculty members. As a predominantly male field, it's nice meeting and getting to know other women in engineering."

"Participating in the WIT Girl Scout events is a chance to help young girls realize the possibilities they have if they decide to pursue a future in the technological field."

"I think participating in events like this keeps college students connected to younger people they can help in the "pipeline" and community, which can be hard to do for college students."

Conclusion

The Girl Scouts in Technology Program, run by female engineering technology students, has proven to be an effective outreach program aimed at 4^{th}-7^{th} grade girls. This program combines fun hands-on activities and scientific theory presented by female college students who are highly influential to girls in this age group. The girls view the college students as fun and interesting and are highly engaged in the experiments presented.

Both objective and subjective results indicate that this program can influence a young girl's attitudes towards science and technology and to view science more positively. Participants in this program realize that science and engineering are accessible and understandable to anyone. Some even start to consider science or engineering as a possible career field.

An equally important benefit from this program is for the students who volunteer their time. Participation in this program provides both camaraderie and the opportunity to make a difference. Studies have shown that these are important characteristics of programs that are appealing to women.

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