# AC 2011-2109: GIRLS EXPERIENCING ENGINEERING: EVOLUTION AND IMPACT OF A SINGLE-GENDER OUTREACH PROGRAM

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# Girls Experiencing Engineering: Evolution and Impact of a Single-Gender Outreach Program

Abstract

The Girls Experiencing Engineering (GEE) program is a fast-paced, interactive program that seeks to instill young women with confidence, interest, and awareness of the wide array of career opportunities within science, technology, and engineering fields. The GEE program began in 2004 as a one-week session targeting 24 middle school girls and four math and science teachers. The program has expanded tremendously, with the 2010 program structured in a series of one week, 20-hour intensive sessions, accommodating 143 middle and high school student participants, 20 peer mentors, and 21 middle and high school math and science teachers. Over the course of the past 7 years, GEE has involved 641 middle school and high school participants, along with 100 teachers and 128 high school and college mentors. Importantly, 85% of these girls represent minority groups traditionally underrepresented in math, science, technology, and engineering fields.

The primary goal of the GEE Program is to increase the number of girls pursuing careers in STEM fields by offering female middle school and high school students an opportunity to increase their awareness and interest levels regarding existing and potential opportunities in the fields of mathematics, science, and engineering. Secondarily, the program seeks to create a broader impact by providing high school and middle school science and math teachers with new pedagogical methods and tools for use in their classrooms and by providing high school girls with leadership training and practice opportunities through peer mentoring. Finally, the program includes a goal of broadening knowledge of participants' parents about career opportunities in engineering.

This paper outlines the program evolution and the lessons learned over the past seven years. Findings from the formal assessment of the program are described, in particular with respect to unexpected outcomes. Although data has been collected and analyzed for both teacher and mentor participants in addition to student participants, this paper will focus strictly on the findings from assessment of middle and high school student participants. Finally, recommendations of the program developers applicable to other outreach activities will be addressed, with specific examples from the GEE program used as illustration.

## Program Background

Since 1996, the Herff College of Engineering has presented summer enrichment programs aimed at middle-school students to generate interest in engineering as a possible career. Initially in concert with the Memphis City School System and the Carrier Corporation and then in partnership with the CN Railroad, programs were available continuously for seven years. These programs were co-educational one-week programs for middle school students and were presented on the University of Memphis campus. The middle school age group was specifically targeted due to the significant amount of research indicating students must be reached in the middle school years in order for them to become aware of opportunities and shift to appropriate course tracks that will prepare them for pursuing engineering majors[1,2,3]. Each program included

middle-school teachers as mentors and classes of approximately 36 students. Topics in the programs ranged from simple structures to robotic programming with a shift in emphasis to transportation with CN funding.

Based on lessons learned from these programs, and particularly recognizing that female participants tended to take only 'supportive' roles in co-ed groups while male participants tended to dominate the idea generation and design roles, the Women's Foundation for a Greater Memphis (WFGM) was approached with a proposal to present a similar program for young women only. The program's goals were to sharpen the focus for the young women on the career possibilities in engineering while providing them with strong female role models by contact with successful female engineering students and working professionals. As the Memphis community is 61% African-American, the potential for attracting minority women to the program, and hopefully to engineering careers, was another significant factor in the decision to pursue this program model as women and minorities continue to be underrepresented in engineering fields[3, 4, 5, 6, 7, 8, 9, 10]. The WFGM agreed to support a pilot model for the summer of 2004 with two one-week sessions for middle school students. The same model of middle-school teachers as mentors for groups of four to five middle-school students was utilized.

GEE is designed to be an interactive, fast-paced program that features daily, team-based design competitions using context-rich manipulatives and prizes for the best team technical presentation and experimental component[11]. The fast-paced format is intentional; our experience in delivering outreach programs has shown that keeping students engaged and interested is directly related to the program 'pace'. Design challenges provide young women with opportunities to apply content covered each day under authentic engineering simulations, providing them with insight into the work responsibilities of an engineer. Simple manipulatives are utilized as the framework for showing the engineering design process. Each group of young ladies is asked to design, develop, test, and perform competitive tasks of increasing complexity during their program. The manipulatives used for all the general session programs are K'NEX building sets designed to support varied topics that include simple machinery, structures, solar power, roller coasters, and vehicle design.

The GEE program hosts female engineering professionals as guest speakers. These women volunteer time to engage in question and answer sessions with the young women. The speakers represent a wide array of the professional opportunities in engineering, and represent local industry leaders. Speakers discuss their jobs and careers providing practical insight into what it means to be a female engineer on a day-to-day basis. Emphasis is placed on the importance of preparing for these careers with appropriate math, science, and technology courses in middle and high school.

Program Evolution

The GEE program began in 2004 targeting middle school girls and has grown and evolved since this time to accommodate more participants. In addition, we had such positive feedback from participants from the outset, that we recognized a need to accommodate repeat participants with new programming each year. Providing opportunities for repeat participation was important, as

this improves the likelihood that students will seriously consider engineering majors in college[1, 2, 9, 10]. Specific milestones for program expansion and evolution are as follows:

- The program was expanded in 2005 to include high-school students as participants and peer mentoring for middle school participants (using high-school participants as mentors).
- In 2007, a second high school program week (focus session) was developed to provide participation options for high school students who had already completed the general GEE session and allow for more in-depth focus on two engineering disciplines. In addition, peer mentoring was extended to high school groups, and leadership training was added to the high school focus program to better prepare these participants to become middle school mentors.
- In 2008, a brief orientation session for parents was introduced to broaden their knowledge of career opportunities in STEM fields, and middle and high school teachers selected to serve as educational consultants developed formal lesson plans for GEE activities that will be implemented in classrooms throughout the regular school year.
- In 2009, an additional focus session was added for high school students. In addition, an educational consultant was used for the entire 2009 program to provide consistency throughout the lesson plans developed from program activities.

Structured in series of one week, 20-hour intensive sessions, GEE was able to accommodate 143 student participants, 14 peer mentors, and 21 middle and high school math and science teachers in its 2010 program. This was the largest program offered to date, yet we still had extensive waiting lists for each program week totaling over 100 interested girls that had to be turned away. Over the course of the past 7 years, GEE has involved 358 middle school and 283 high school students, along with 100 teachers and 121 high school and college mentors. Importantly, 85% of these girls are African-American and are traditionally underrepresented in math, science, technology, and engineering fields, and more than one-third of the students are repeat participants.

Project goals

The primary goal of the GEE Program is to increase the number of girls pursuing careers in STEM fields by offering female middle school and high school students an opportunity to increase their awareness and interest levels regarding existing and potential opportunities in the fields of mathematics, science, and engineering. Secondarily, the program seeks to create a broader impact by providing high school and middle school science and math teachers with new pedagogical methods and tools for use in their classrooms and by providing high school girls with leadership training and practice opportunities through peer mentoring. Finally, the program includes a goal of broadening knowledge of participants' parents about career opportunities in engineering. Specific program objectives include the following:

- To demonstrate links between mathematics, science, and engineering study;
- To highlight career opportunities in engineering fields and the preparation involved for professional admission into these fields;

- To design real-life applications of engineering content through hands-on, interactive design challenges based on a series of increasingly complex variables in team settings;
- To develop leadership skills among future female scientists and engineers;
- To provide middle and high school math and science teachers with pedagogy methods, training and classroom tools; and
- To provide participants' parents with information about the excellent career opportunities available through engineering fields.

Assessment Methods

A mixed-methods approach has been used to assess the GEE program since its inception. A combination of Likert-scale and free response questions are distributed to students in the form of an introductory and exit survey to assess changes in perceptions and attitudes of program participants toward engineering over the course of the program. Daily journal entries (free response questions) are also used to solicit feedback to specific activities each day. Focus groups are also used to obtain more detail about various program components, such as mentoring. In addition, effort is made each year to identify students that have graduated from high school and are pursuing math, science, or engineering degrees. This takes place through email requests for information, brief online surveys (soliciting information regarding current courses students are taking, likelihood of pursuing an engineering major, and likelihood of participating in GEE again), and more recently through social networking via a GEE Facebook group. In December 2010, a formal longitudinal assessment took place through distribution of a more detailed online survey.

Over the course of the program, we have collected intro/exit survey and journal entry/focus group information from 641 middle and high school participants. For the longitudinal study, a survey link was distributed via email to 410 valid email addresses for previous program participants. This number is significantly lower than the overall participant data, due to the fact that many students participate in GEE multiple times, and the fact that many email addresses collected for participants (particularly from early program years) are now out of use. For the longitudinal survey, 43 responses were obtained, which is roughly a 10% response rate.

Assessment Findings – General Program Assessment

Program results are gratifying and annually prove the model's success in meeting program objectives. Pre and post program surveys, qualitative data collected through daily writing exercises (journal entries), group discussions, and narrative feedback from the program's participating teacher-mentors indicate that the greatest gains are in the areas of attitude and confidence. Students begin the program with skepticism. Girls (and sometimes their teachers) typically view engineering as a field/career for men, and engineering jobs as boring, 'uncool', or too difficult. They don't believe engineering requires creativity, imagination, or inventiveness and are unaware that engineers have a direct impact on people and their daily lives. By the end of the program, we get quotes like these:

- *The best thing about this program was getting engineering and problem solving experience.*

- *Coming into this program, I did not know much about engineering, but after completing GEE I have a better understanding of what engineers do. I enjoyed building with K-nex.*
- *The best part was the different challenges. This week there was something new and different everyday and it kept everyone on their toes.*
- *Meeting new people, having fun, and learning things that I could never learn in any other setting were the best things about this program.*

The most influential aspect of the program is the hands-on application of engineering problem solving through daily "design challenges." This portion of the program allows girls to gain confidence in their ability to solve problems and to be successful as an engineer. One student remarked, "I really enjoyed the group activities and projects during the program." Another remarked, "We got a chance to build our own car design and test it just like a real engineer!" Statistical data from the pre/post program surveys compiled and analyzed by program faculty reinforce this message. More than ninety percent (90%) of program participants reported they enjoyed their overall experience with the GEE program; and over 85% of participants would recommend the GEE program to a friend. In addition to enjoying themselves, over 65% of participants state they feel more confident in their math, science, and engineering abilities because of the GEE program. Exit surveys further indicate that 85% of participants report an increase in problem-solving knowledge and strategies after participating in GEE. GEE clearly impacts the thinking and confidence of participants vis-à-vis math and science.

Further testimony to the program's impact comes from the large number of students who return for a second or more years. Over the life of the program, more than 30% of our participants have been repeaters—some for multiple years. Repeat participation is extremely desirable, as it increases the possibility that students will remain interested in engineering throughout middle and high school, which increases the chance that they will select an engineering major in college. Along these lines, we are also beginning to see more long-term results of our program, as some of our high school participants have now graduated and are pursuing engineering majors in college. We are proud to report that we have been able to identify at least 20 of our previous participants who are now enrolled in engineering programs in college, seven of whom are currently undergraduates in engineering programs at The University of Memphis.

One surprising finding was identified in the 2007 when students were asked to report how likely they thought their families would be to support their decision to pursue a career in engineering. This was the first time this question was included in the program introductory/exit surveys, and it was added because of data from engineering students at our University indicating that parents/family influence are stronger factors in determining the majors that students choose to pursue in college, as compared to high school teachers, guidance counselors, or other mentors[12, 13]. Other published studies also indicate that parents play an important role in this decision, particularly if the parent is in a STEM field[14, 15, 16, 17]. Given the fact that parents are frequently the reason that students attend the program, we expected a strongly positive response to this question. However, in response to the statement, "My family would like for me to be an engineer or scientist," only about 35% of participants agreed at the conclusion of the 2007 GEE program. A parent orientation was added to the program beginning in 2008 in an effort to address this issue. Positive response rates have improved (46 % in 2010), however, there is still need to make more substantial impact in this area.

Assessment Findings – Longitudinal Study

Although only 10% of participants responded to the survey (n=43), results of the longitudinal study indicate that GEE has been successful in influencing students to consider/pursue majors in science, technology, engineering, and math (STEM) fields. It also indicates that some program components are more influential than others. In terms of respondents, most had participated in recent program years, although a few were involved since the program inception. The distribution of participants is shown in Figure 1. It is important to note that the number of responses exceeds 43 since many of those responding participated in more than one year of the program. The current grade of respondents is shown in Figure 2. Most of the respondents are currently in high school or college.

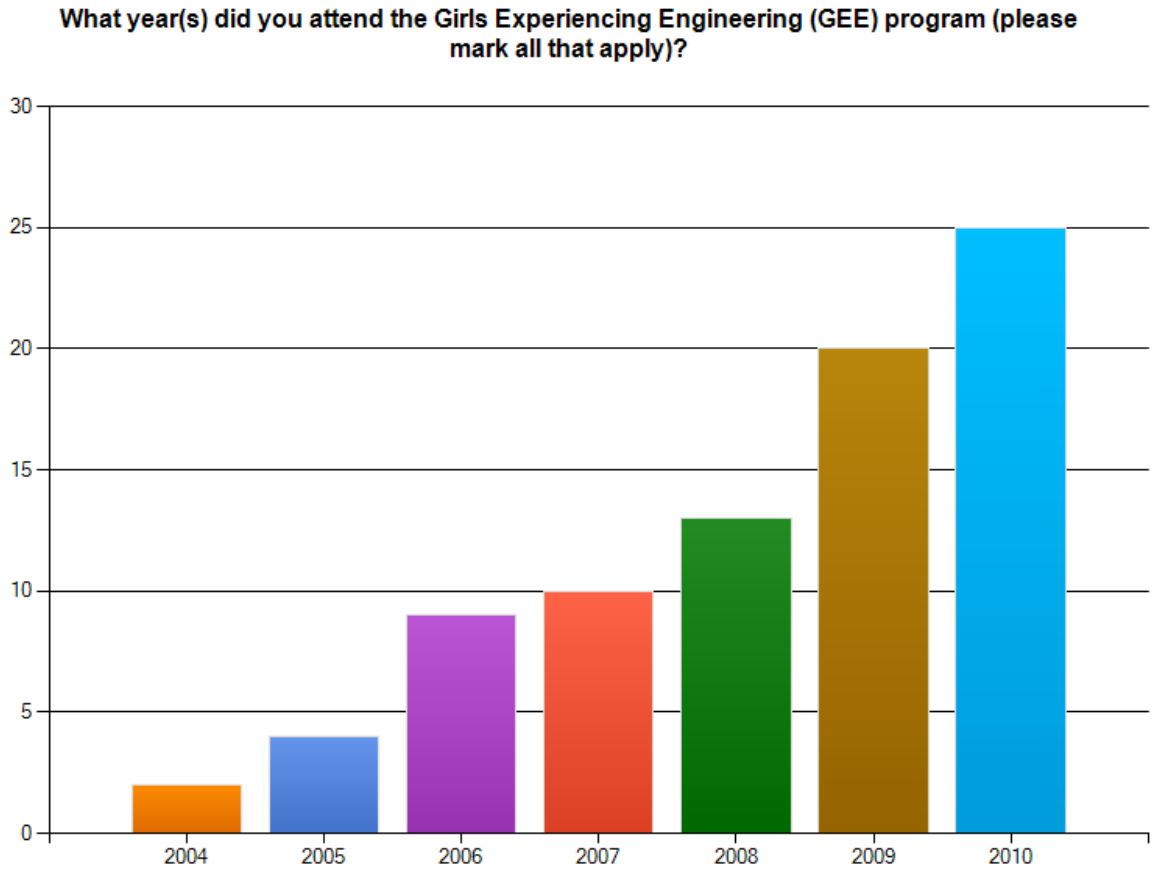


Figure 1. Participation Year for GEE Survey Respondents.

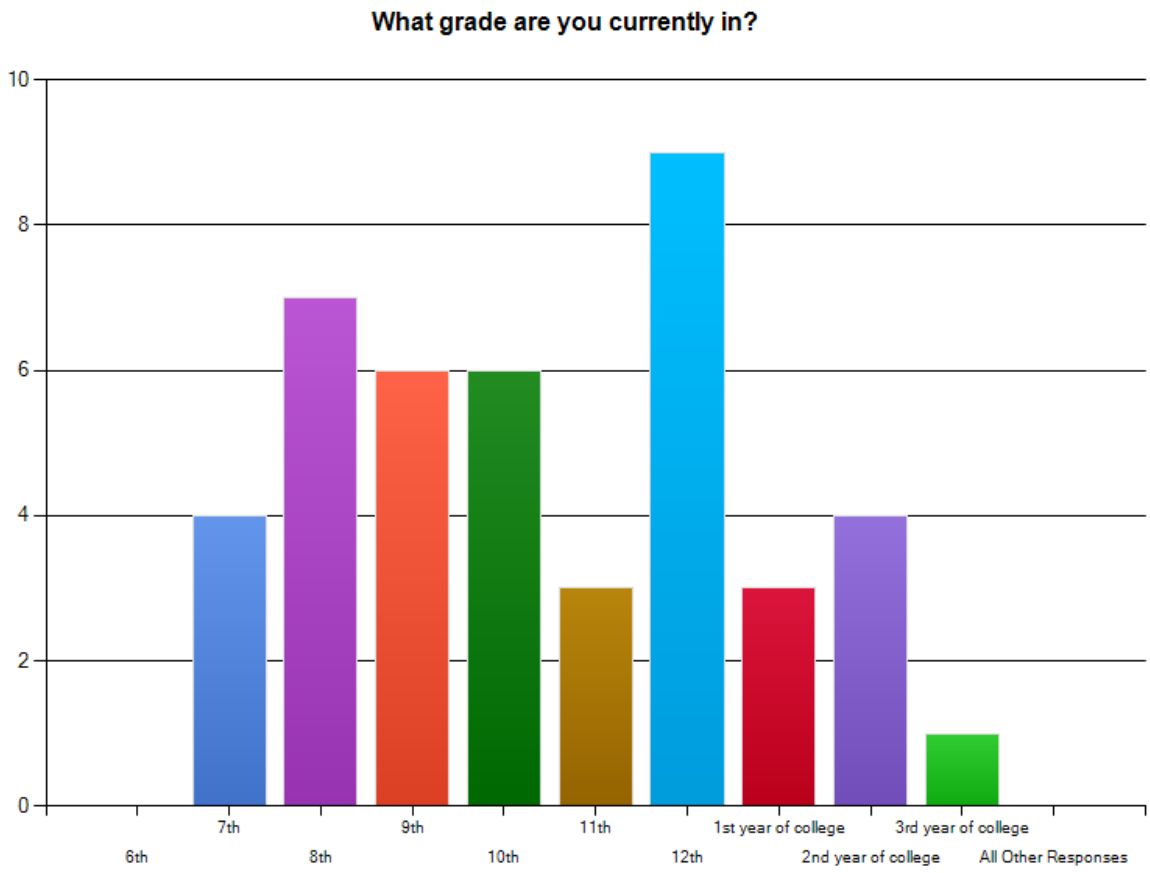


Figure 2. Current Grade of Survey Respondents.

In terms of impact on math/science attitudes and career decisions, 95% of respondents indicated the GEE program helped them understand how math and science are used to solve problems, and 73% reported greater confidence in math/science abilities. 23% of respondents indicated they changed their middle/high school course load to include more math and science classes following the GEE program, while 63% indicated they were already in a strong math/science track.

Regarding career preparation, 85% reported that the GEE program helped them understand the courses they needed to take in middle/high school to prepare for a STEM major, 98% reported the program helped them understand career opportunities available through engineering fields, 80% reported greater interest in engineering careers, and 78% reported being more likely to major in engineering in college because of their experience in GEE. Finally, of those students responding that are currently in middle or high school (n=31), 50% report they plan to pursue a STEM major in college, 28% medical degrees, and the remainder business or liberal arts degrees. For those that have graduated (n=12), more than 80% are pursuing STEM majors in college.

More than 90% of respondents indicated that the daily design challenges were both increasing their understanding of engineering problems and their interest in engineering fields. 85% of

survey respondents reported that the emphasis in the program on creativity and innovation increased their interest in engineering careers. The GEE mentors and program speakers were also critical to the positive impact of the program on participants. More than 95% of respondents indicated the GEE mentors and speakers were positive role models that were important to the program, and 85% reported that they influenced them to consider an engineering career. Table 1 displays the frequency and response percentages for factors influencing college major/career decisions. As expected, parents are reported to have the greatest influence, with 93% of respondents indicating that they are 'Very Important' or 'Important'. Programs designed to introduce career options, such as GEE, were 'Very Important' or 'Important' to 88% of respondents. Interestingly, friends were only reported to be 'Very Important' or 'Important' to 28% of respondents.

Table 1. Influential Factors in College Major/Career Decisions.

| **Please indicate how important each of the following are to your decision for selecting a college major/career:** | | | | | |
|---|---|---|---|---|---|
| **Answer Options** | **Very Important** | **Important** | **Somewhat Important** | **Not Important** | **Response Count** |
| Friends | 3 (7.1%) | 9 (21.4%) | 16 (38.1%) | 14 (33.3%) | 42 |
| Guidance Counselor | 13 (30.2%) | 10 (23.3%) | 14 (32.6%) | 6 (14.0%) | 43 |
| Teacher | 19 (44.2%) | 11 (25.6%) | 11 (25.6%) | 2 (4.7%) | 43 |
| Parent | 32 (74.4%) | 8 (18.6%) | 3 (7.0%) | 0 (0.0%) | 43 |
| Programs designed to introduce career options (career days, programs like GEE, etc.) | 31 (72.1%) | 7 (16.3%) | 3 (7.0%) | 2 (4.7%) | 43 |
| | | | | ***answered question*** | **43** |
| | | | | ***skipped question*** | **0** |

In terms of general program feedback, 98% of respondents would recommend the GEE program to a friend and 95% felt the program had at least some impact on their attitude towards math, science and engineering. When asked if there was anything else they would like to report about their experience with the GEE program, 27 responses were received, and all were positive. Typical comments included the following:

- *The GEE program was awesome and very motivational and broke stereotypes about engineering!*
- *The GEE program changed my life, and opened endless doors!*
- *I really appreciate this program since I have been involved in it for many summers and it has been a great experience for me. Thank you for programs like this for girls. I truly believe that women need to show their strong abilities in math and science in this male-dominated world. Thank you again.*

- *The program has caused me to have a more positive attitude in my math and biology classes. My teachers have noticed the change in me.*

Program Challenges

In 2004, we began with a full-day program; however, the challenges associated with providing lunch and maintaining the intensity of focus required from our participants proved to be greater than we initially thought. It was very difficult to redirect students after lunch and to get them engaged in program activities. It was apparent that the students were unable to sustain focus throughout the entire day. Beginning in year two, the program was restructured as a 20-hour program—a formatting change that has been hugely successful.

Since its inception, we have advertised the GEE program by sending email announcements to the math and science coordinators for the City of Memphis and Shelby County school districts, as well as to parochial and other private schools. In these announcements, we give a brief program and application process description, and we ask that the coordinators distribute the email to all math and science faculty in their district. Thus, we have taken the approach of having math and science teachers make students aware of the opportunity to participate in GEE. As we also have teacher participants, this makes teachers aware of the program opportunities available for them as well. We also prepared posters advertising the program, and distributed them to local schools to post in hallways, classrooms, etc. Initially, interest was moderate, and we rarely had a significant number of applicants on a waiting list. We sent the email announcements out multiple times, and made direct contact with any math/science teachers that we knew. However, by the third summer (and as we continued to expand course offerings), we began to get calls regarding the program well before the registration process opened, and we started to see significant waiting lists. We believe positive word of mouth from previous student participants (and their parents), teacher participants, and local media coverage is responsible for the tremendous interest in the program. We now send out a single email to all previous participants, local math/science district coordinators, and people who have expressed interest at college recruiting events, to announce registration details. We no longer prepare posters, and within two weeks of registration opening our middle school program is typically full, and the high school program is full within a month.

Another area where we have faced challenges is with no-shows and drop-outs. This situation is always frustrating, especially due to number of students on the waiting list that could have been accommodated. The $25 registration fee that we began requiring in 2007 dramatically reduced the number of drop-outs. Requiring the fee in advance of the program this year dramatically reduced the number of no-show participants. We only had three students during the entire program that did not show up. Scholarships were in greater demand this year, and will still be available for any student with financial need for the 2011 program, due to support from local professional societies.

In 2010, we were also faced with behavioral challenges with some of our middle school participants. These students were not interested in attending the program, and had been forced by their parents to participate. They were unwilling to join group activities, and several were discipline problems. Our primary funding agency, the Women's Foundation for a Greater

Memphis, prefers that the program spots be filled on a first-come, first-serve basis, with no academic restrictions. We typically require a brief essay or teacher recommendations from participants at the time of application. Because of the tremendous number of applications we receive (nearly 300 in 2010) it has become infeasible for us to review all of these materials. Thus, we did not require teacher recommendations or essays in 2010, but believe it is necessary that we do this, to identify students who are really eager to participate in the program. It is unfortunate that we had several young women who were unwilling to cooperate and participate in the program this year, as we had over 70 students on the waiting list for this particular session, and could certainly have filled the spots with interested students. For 2011, registration will be a multi-step process, with pre-payment of the application fee and submission of a brief personal essay required from those selected for the program to confirm their placement. Because only those students selected for the program will be asked to submit an essay, this will make the review requirements manageable. If students fail to submit the essay or application fee by the specified deadline, a student from the waiting list will be selected to fill the spot.

Another key challenge has been maintaining contact with program participants for longitudinal evaluation. As evidenced by the number of 'bounced' email addresses for early year program participants, and low overall response to longitudinal surveys, this presents a significant obstacle to achieving program assessment goals. Combining email contact with social networking websites appears to be more successful, and may be instrumental for maintaining contact with future program participants. A final issue regarding assessment is the lack of comparison or control group data available to more clearly determine program impact. Because participants are middle and high school students, we do not have access to a group of students to use for control purposes. This may be an issue that can be addressed in the future through relationships with local school districts.

Lessons Learned

Over the past seven years, we have learned a lot about what works and what does not in terms of making positive impact on program participants. The lessons learned from our experience with the program and assessment results are as follows:

- A half-day program is the most effective for maintaining student engagement.
- It is essential to provide meaningful hands-on activities for students in the program so that they understand the connection between the simplified problems they are solving and those that engineers face. It is important to demonstrate links between the content they are covering and 'real-world' problems.
- The most important messages for us to get across to students are that engineering affords a wide variety of career options, engineers must be creative problem solvers, and that engineers make a difference in our society. These messages must be demonstrated repeatedly through the presentations/lectures from program faculty, design activities, and presentations from program speakers. Students have repeatedly commented to program faculty that these are the aspects that most surprised them about engineering/engineers, and that these are the factors that lead to their shift in attitudes and interest in engineering.

- High school and college mentors, along with professional women who speak to participants about their careers are critical for influencing students to consider engineering majors. Although students report that friends are not influential in their decision to pursue a major/career, mentors and professionals in engineering fields are very influential. Thus, it is very important to make sure that a wide variety of mentors/speakers in terms of engineering disciplines as well as race/ethnicity are involved in outreach programs so that students are able to identify with someone.
- Parents continue to be the most influential factor in students' decisions to pursue particular majors/careers. Although we have made headway from this standpoint with our parent orientation sessions, we still do not see they type of positive response we would expect regarding whether or not students believe their parents would support their decision to pursue an engineering career. More research is needed to determine factors affecting this perception to identify methods to address this issue.
- Outreach programs can and do result in shifts in attitudes and perceptions regarding engineering careers that lead to lasting results and make an impact in the numbers of students pursuing these careers. Providing an opportunity for repeat participation through new programming is essential to sustaining interest in engineering and encouraging students to pursue engineering majors in college.
- Formal and well-planned assessment is essential. This is critical to making informed decisions regarding program growth and direction, as well as for identifying elements of the program that work well and make positive impact and those that do not.
- Maintaining contact with program participants over many years is difficult, but critical for achieving significant impact. Although email communication is important, other avenues such as Facebook or other social media can provide additional means for keeping up with past participants. We have found that email addresses frequently change, and typically the email address we are provided is for the parent. Parents may or may not pass on communication to the student.

## Conclusions

We have made tremendous progress in changing program participants' perceptions of engineering and engineers. We have documented significant shifts in attitudes and perceptions of engineering through entrance and exit surveys, journal writings, focus groups, and longitudinal assessment. One previous participant remarked that the thing she learned from the GEE program that most surprised her was that, "…there are so few women in engineering- we need to change that!", which is exactly what program faculty hope students will take away from the experience. The program continues to be well received, as survey data indicates that over 90% of GEE participants enjoyed their overall experience in the program. We are also beginning to see more long-term results of our program, as some of our high school participants have now graduated and are pursuing engineering majors in college.

Outreach programs can be very effective means for recruiting students to engineering fields. However, program assessment is critical to achieving significant positive impact. Opportunities for repeat participation and longitudinal studies of participants are very important to achieving program goals, and identifying the program components that are most critical to success. Our

future efforts will be focused on improving the perceptions of parental support for a STEM career, through additional work with both students and their parents.

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