

## **Analysis of a Short-Term STEM Intervention Targeting Middle School Girls and Their Parents (Research to Practice)**

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### ***Background***

Science, Technology, Engineering, and Mathematics (STEM) are at the forefront of our nation's agenda. Both national and global advancement and sustainability are contingent upon fostering discovery and development in the STEM disciplines. Porter and Stern<sup>[1]</sup> point to the importance of scientific and technical talent to the national economic performance. However, “there is a quiet crisis building in the United States” reports Jackson<sup>[2]</sup>, who asserts that the increasing gap between the nation’s need for scientists, engineers, and other technically-skilled workers, and its production of them, could jeopardize the nation’s technical pre-eminence and well-being. This view was powerfully reiterated in the February 7, 2012 President’s Council of Advisors on Science and Technology (PCAST) Report to President Obama<sup>[3]</sup> which projected a shortfall of one million scientists in the U.S. over the next decade due to the demands of an ever-increasing technological society and also, in part, as a result of insufficient STEM graduation rates.

Closing the supply-demand gap will require a national commitment to develop more of the talent of all our citizens—especially those who currently comprise a disproportionately small part of the nation’s STEM workforce<sup>[2,4]</sup>. Women presently comprise about 51% of the population, but only 19% of the engineering workforce. Together, Hispanics and African Americans comprise about 28% of the population, but their presence in nonacademic science and engineering positions is only about 9%<sup>[5]</sup>. Clearly, these groups represent large reservoirs of untapped potential for new STEM professionals. We can no longer afford to waste the talent of two-thirds of our increasingly diverse population. As stated in President Obama’s Executive Order No. 13583<sup>[6]</sup>:

*“We are at our best when we draw on the talents of all parts of our society, and our greatest accomplishments are achieved when diverse perspectives are brought to bear to overcome our greatest challenges.”*

This important idea is extended in Peter Godfrey-Smith’s “Theory and Reality”, who writes that some female philosophers believe that “the experiences of the marginalized are more likely to be valuable *as a special kind of input* into scientific discussion”<sup>[7]</sup>. Godfrey-Smith cites the field of primatology as an important example: as women scientists began to enter the male-dominated field in the 1970s, there was an associated increase in the sophistication of research around the sexual behavior of female primates. Simply said, women appeared to bring an investigatory lens that allowed them to see past over-simplified historical accounts of female primate behavior. Godfrey-Smith suggests via this example that some advances by women appear to be critically tied to these scientists’ femaleness, and more generally, that progress in science benefits from multiple, diverse perspectives.

So how do we guarantee a continued supply of highly qualified STEM professionals who reflect the diversity of our communities and bring these “special kinds of input”? At least part of the

answer is responding to President Barack Obama's 2009 request to the National Academy of Science<sup>[8]</sup>:

*“So I want to persuade you [scientists and engineers] to spend time in the classroom, talking – and showing - young people what it is that your work can mean, and what it means to you. Encourage your university to participate in programs to allow students to get a degree in scientific fields and a teaching certificate at the same time. Think about new and creative ways to engage young people in science and engineering, like science festivals, robotics competitions, and fairs that encourage young people to create, build, and invent - to be makers of things.”*

Working with middle school science teachers, education advocates, community partners interested in STEM, and university STEM student organizations, an intervention, Girl's Day Out, was developed by Space and Naval Warfare Systems Center Pacific (SSC Pacific or SPAWAR Systems Center Pacific) in San Diego, California – one of the research, development, and science/engineering support arms of the U.S. Navy. The intervention was created to inspire and encourage middle school girls to pursue STEM subjects in high school as a possible pathway to a STEM career, and to inform parents of the opportunities this path could provide their daughters. The inclusion of parental involvement in college and STEM pathways is essential as found by Miller<sup>[9]</sup>. The main objectives of this intervention were to enact change among parents and daughters within three major categories (with the sub-goals delineated below):

- **Engineering Awareness:** development of content knowledge; appreciation for the beauty and applicability of engineering; increased global perspective capturing the diversity of the field and work environments; exposure to career opportunities; quality of life that engineering careers often provide
- **Pathway:** familiarity with a college campus through tours and interactions with college and high school students; exposure to engineering lab environments; education on coursework planning choices and explicit and implicit high school course requirements for getting into college; familiarity with post-secondary financial challenges and rewards
- **Philosophy:** awareness of gender disparity; exposure to high school, college, and professional women role-models; interaction with student diversity organizations; participation in discussion forums exploring gender inequality and stereotypes; hearing keynote speeches by prominent women STEM professionals

Targeting the objectives at the middle school level was especially important, for the decline in STEM interest among girls is found to begin in adolescence (by eighth grade, only half as many girls as boys are interested in STEM careers<sup>[5]</sup>) and increasingly manifests itself in a lack of STEM participation in the last years of high school. The question many are asking is why girls, who perform strongly in science and math in middle school, are not choosing to pursue degrees and careers in the physical sciences, engineering, or computer science. Several potential reasons for the gender disparity include previous coursework, ability, interests, and beliefs<sup>[10]</sup>. Girls need to engage in projects that relate to their lives and have a larger social impact, and they need to see clear pathways and support for persisting in STEM learning. Exposure to women in science and engineering fields can provide a major impact on middle and high school girls' perceptions

of STEM fields<sup>[11]</sup>. This paper explores these critical issues by evaluating the attitudinal changes around engineering that occur in young girls and their parents as a result of the intervention described below.

### ***Existing Literature and Positioning***

It is valuable to step back and consider some of the current research on STEM outreach efforts in order to situate this paper within existing dialogues and to discuss how the work to follow differs from what has been done. In addition, while the Background section of this paper attempts to establish the critical nature of K-12 STEM outreach, it does not suggest how to best do this or what results have already been observed in practice. Indeed, outreach efforts vary dramatically across the dimensions of time (one hour, one day, one week, etc.), level of expertise tapped (college students, educators, professionals in the field, etc.), goals (interest, enjoyment, exposure, etc.), setting (after-school, stand-alone, science fairs, etc.), and target audience (minorities, girls, age-specific, etc.). The high, multi-dimensional nature of the outreach space suggests that much terrain remains to be explored, and at a global level, this paper works to shine light on a new region of that important domain.

Some of the existing literature points to improvements in the affective dimension of the student experience. These interventions often cite increased positive attitude, interest, and/or enjoyment of science/engineering<sup>[12,13,14,15,16,17]</sup>. For example, Bottomley and colleagues reported fewer elementary students responding “no” to the questions “Is science fun?” and “Are you good at science?” after an intervention by nine undergraduate and graduate engineering students<sup>[12]</sup>. In addition to affective growth, studies have demonstrated the expansion of the views students hold on STEM fields/STEM professionals<sup>[13,14,15]</sup> and improved understanding of STEM content<sup>[14,17]</sup>. These changes include a broadened understanding of fields with which students are already familiar, an awareness of new fields, and burgeoning ideas of relevance about both new and old fields<sup>[14]</sup>.

Other studies have tried to measure the effectiveness of outreach efforts by looking to the future (both academically and professionally). A number of studies have showed that various types of interventions are capable of increasing student self-reported desire to enroll in future STEM activities, classes, and informal coursework<sup>[16,17,18,19,20]</sup>. Looking even further into students’ trajectories, Sinadinos chronicled the effect of a ‘Researchers in Residence’ program that was able to inspire eight out of nine survey participants to think more deeply about pursuing a career in science research<sup>[16]</sup>. Longitudinal efforts to measure the true effects of such work have been sporadic and difficult due to the large time gap between interventions and college major/post-college career choices, as well as the multitude of factors that eventually comprise such complex decisions<sup>[14]</sup>.

While these studies begin to paint a positive picture of the effects of STEM outreach efforts, they have some limitations that the current work helps to address. First, this research rarely considers the importance of parents in the student/parent STEM equation. While some papers do explore parents’ beliefs<sup>[12]</sup>, often these are not about the STEM topics being considered, but about their perceptions of their children in relation to STEM topics. In addition, parents are usually not the targets (or co-targets) for such work. In Girl’s Day Out, parents were key participants in the

intervention *and* its assessment. That is, student-parent dyads were formed, and the correlations between parents and their children were studied.

Second, some of the current research on STEM interventions fails to leverage modern methodological practices as fully as possible. On the quantitative front, research must move beyond simply reporting occurrences and displaying bar charts. Considerations of statistical significance, knowledge of underlying distributional assumptions, dealing with low cell-counts in tables, and careful handling of the conversion of Likert scales to quantitative data are often overlooked. This paper works to clean up such practices by establishing statistical significance using tests that rest on few distributional and minimum-cell-count assumptions. Furthermore, affective change is studied using more than one type of metric (mean changes and threshold crossings). Qualitatively, this paper moves beyond simply relating student responses to open-ended questions. Care is taken to organize participants' comments into a thematic structure using the technique of Grounded Theory<sup>[21,22]</sup>. Most critically, this work explores the power of STEM interventions using both quantitative *and* qualitative lenses; a methodological move that helps expose both *whether* and *how* changes are occurring. To give an example of the explanatory power of this pairing: the statistical analysis to follow suggests that significant changes are observed in the Pathway objective for Girl's Day Out. It is only after doing a qualitative analysis, however, that one realizes the inclusion of female role models *at all levels* (high school, college, and professional) is particularly salient for helping middle school girls envision the route toward becoming an engineer.

Finally, this paper offers a well-thought-out and thorough organizational research paradigm for others doing similar studies. Specifically, care was taken to map survey questions to the categories being explored (Engineering Awareness, Pathway, and Philosophy), which were further tied to the activities/design of the intervention itself. This led to a clear relationship between the presentation, goals, and assessment of Girl's Day Out. In addition, the decision to use anonymous IDs to link students both with their parents and with themselves (pre vs. post surveys) afforded both across-group and across-time analyses (see Figure 1 and discussion below). Finally, rich quantitative and qualitative methods were employed; this synergy gave a fuller picture of what was occurring and why. In their totality, these research decisions provided strong mathematical and descriptive depth in the work to follow. For example, on the mathematical front, this study helps demonstrate the relative ease of changing participant views in the above-mentioned three categories (see Discussion section for more on this). On the descriptive front, while it is known that interventions can change participants' views of scientists<sup>[13,14,15]</sup>, the philosophical relationship between these views and the participants themselves has yet to be fully explored. This paper builds upon this theme by more carefully studying how young girls and their parents see the role of women in STEM, and how this affects their own inclusion and value within engineering (see Figure 24 below).

### ***Description of Girl's Day Out***

The first intervention was held in August 2008 and named Girl's Day Out. The event focused on middle school girls and their parents and included a female STEM keynote speaker, brief science demonstrations, and tours of the college campus and engineering labs by women pursuing

engineering degrees. Early on, it became evident that girls were not interested in long lectures. They were, however, very interested in hands-on activities and being able to communicate and bond with the female college students. It was also found that girls were most interested in speakers who talked about their profession in the context of how it makes the world a better place, how it enhances the quality of their family life and how they manage family and work. Parents were very interested in opportunities available for their child to explore STEM fields, financial considerations for college, and the parent role in their child's STEM education.

Months prior to the event, the lead from SPAWAR Systems Center Pacific would meet with the student organization(s) from the hosting university (e.g. San Diego State University, University of California at San Diego, etc.) to determine the details of the program – time allotment, choice of speakers, volunteer requirements, lab tour availability, activities, lunch, and logistics.

The attendance at the event varies, but typical participation is as follows:

Middle-School Girls (grades 5-9): 30-100  
Parents/Teachers/High School Girls/Girl Scout Leaders: 20-70  
STEM College Students (primarily female): 20-30  
STEM Professionals (primarily female): 10-15

A typical agenda for the event is shown below:

#### *Girl Program*

9:30 Participants Arrive and Complete Pre-Questionnaire  
10:00 Welcome and Introductions (parents/girls together)  
10:15 Keynote Speaker (parents/girls together)  
10:30 Ice Breakers  
10:45 Student Rotations (Campus/Lab Tours or STEM Activities)  
11:45 Group Photo  
12:00 Lunch  
12:30 Student Rotations (Campus/Lab Tours or STEM Activities)  
1:30 School/Student Organizations Presentation (parents/girls together)  
2:00 Post-Questionnaire and Dismissal

#### *Parent Program*

9:30 Participants Arrive and Complete Pre-Questionnaire  
10:00 Welcome and Introductions (parents/girls together)  
10:15 Keynote Speaker (parents/girls together)  
10:30 Admissions and College Information  
11:00 College/Professional Panel  
12:00 Lunch  
12:30 Campus/Lab Tours  
1:30 School/Student Organizations Presentation (parents/girls together)  
2:00 Post-Questionnaire and Dismissal

### *Keynote Speaker*

A short time is allotted at the beginning of the event for a female STEM professional to tell her story. Speakers are found from the local industry and academia and should be engaging and relatable. Ensuring the speaker directs the presentation to the middle school level and can convey the fascination and worth of her work is imperative. At times, a panel of a few college students and/or STEM professionals is included in addition to or in place of a keynote speaker.

### *Student Rotations*

The program begins and ends with the parents and girls together. Most of the day consists of separate student and parent tracks. Girls are split into smaller groups to encourage more verbalization and communication with female college students as well as to provide a more convenient environment for activities. One female college student may have 6-10 middle school girls in a group. If possible, a high school student, who is interested in STEM, is enlisted as an ambassador to join the group so that a middle school girl has a more near-peer experience.

### *Campus/Lab Tours*

The middle school girls (and parents in a separate group) are taken on a campus tour to get familiar with a college campus. It was determined that inclusion of science and engineering lab tours pique the interest of the girls. Labs that have sparked the most interest include: building a concrete canoe, robotics, soil erosion, materials research, solar energy, and structural engineering. This diversity provides the girls with an introduction to the many engineering fields and the hands-on nature of the work, not just bookwork, as they may have seen in middle school.

### *STEM Activities*

Science and engineering demonstrations and builds allow the girls to explore the STEM path in a real-world environment. Activities that have been effective include interactive explorations of: math puzzles, acoustic and mechanical resonance, lasers and light, liquid nitrogen, recycling, liquefaction and earthquakes, energy, and pressure. A more detailed description of these activities and a roadmap for creating such an event can be found in Appendix B (Roadmap).

### *Parent Program*

Parents are able to hear from College Advisors who provide information on college requirements and financial planning. Additionally, a panel composed of university students from diverse STEM backgrounds share their personal experiences and permit the parents to ask questions of interest. Parents also get to experience the campus and lab tours.

Advertising for the event is normally done through a local science advocate organization and by directly contacting partner schools of the university. The cost of the event is free to participants, with local industry and organizations picking up the expenses for food and supplies. The college students and professional attendees volunteer their time. Registration is required for participants to attend the event. Since there is no cost to participants, up to 20% become no-shows.

There are four universities in the area, so one event is planned each year at each university. Logistically, this permits more parents and children to attend since the universities are dispersed throughout the county.

Initially, feedback surveys were collected to assess the structure of the program. These results were very favorable for the overall program and provided insight into the most effective activities and types of speakers to enlist. While the anecdotal feedback was positive, more serious evaluations became critical in determining the effectiveness of the intervention.

### *The Study and Its Limitations*

The survey (included in Appendix A) had four components: two questionnaires for students (pre and post) and two questionnaires for parents (also pre and post). Both the student and parent versions of the questionnaire were completely anonymous. The first component (the Pre-Questionnaire) was administered immediately before the event began, and the second component (the Post-Questionnaire) immediately after the conclusion. In order to measure the change possibly engendered by the intervention, the same six questions were posed on the pre- and post-versions, although the order was shuffled to discourage participants from visually reproducing their earlier survey responses. Each question was answered using a nine-point Likert scale (also labeled Strongly Disagree (1) to Neutral (5) to Strongly Agree (9)). The student and parent versions of the survey were identical on three of the six questions (#4-6 on the pre-surveys) and different on the other three (#1-3 on the pre-surveys). This overlap allowed for the study of attitudinal similarities across student-parent pairings in addition to the analysis of pre/post changes within a given group. The post-surveys for each group also included some questions that sought written responses; this additional information (found in the Qualitative Results and Discussion sections) added texture to the Quantitative Results section below.

Before beginning an analysis of the data, it is worth noting some of the limitations of this study so that the results to follow may be read from the appropriate viewpoint. First, it is crucial to mention that this intervention was not a randomized, controlled experiment. Girls and their parents self-select for participation, and hence, may arrive with feelings about engineering which are not representative of the general populace. More importantly, their susceptibility to change may also not be representative of a random sample of people. While this limitation does somewhat weaken the applicability of the research findings, there is still much to be learned from the exploration of a group of individuals who are willing to take the initiative to enroll in a day of engineering enrichment. Indeed, the incoming attitudes of participants (students' and adults') were not uniformly positive, and hence, the value of the intervention can be explored across a fairly large spectrum of prior beliefs.

Second, the academic view on Likert response scales is not uniformly positive. Many questions surrounding their use are troubling: Is there inter-respondent agreement on the meaning of a given rating? Do respondents view the scale markings as equally spaced? How many scale markings best measure respondents' true feelings? In this paper, a variety of interpretations will be overlaid on the Likert scales: at times, they will be viewed as ordinal data, and, at other times, as continuous data (depending on the tests being used). While this study has limitations compared to an ideal study with a larger randomized sample set, the authors hope that in parsing these data with different methodological lenses all readers can find some valuable insight within some scope of applicability.



## ***Quantitative Results***

For future reference, the student and parent questions are presented below (based on the order of the Pre-Questionnaires). In the notation to follow, S and P refer to “Student” and “Parent” respectively. Thus, the notation SQ2 means “Student Quantitative (question) 2”, while PQ4 means “Parent Quantitative (question) 4”.

The six prompts (referred to as “questions” throughout) from the students’ version of the survey were as follows:

- SQ1. I find engineering topics to be interesting.
- SQ2. I would like to study engineering in school.
- SQ3. I want to become an engineer when I grow up.
- SQ4. I feel like engineers are hard to relate to.
- SQ5. I see women as leaders in engineering.
- SQ6. I have a good sense for what an engineer does each day.

The parents’ survey prompts are shown below. Note that questions 4-6 are identical for students and parents:

- PQ1. I have an appreciation for engineering.
- PQ2. I know what path my daughter should take in order to become an engineer.
- PQ3. I consider engineering as a possible career path for my daughter.
- PQ4. I feel like engineers are hard to relate to.
- PQ5. I see women as leaders in engineering.
- PQ6. I have a good sense for what an engineer does each day.

The above questions were devised so that they mapped onto the three overarching objectives of the intervention. Those linkages are shown below. Each broad category has two student and two parent questions that seek to measure the effectiveness of the intervention in the given category.

Engineering Awareness: SQ1, SQ6, PQ1, PQ6  
Pathway: SQ2, SQ3, PQ2, PQ3  
Philosophy: SQ4, SQ5, PQ4, PQ5

The quantitative results below will be organized into two overarching categories: *across-time* comparisons and *across-group* comparisons. The first category measures how attitudes change for a fixed group (either students or parents) from the pre-surveys to the post-surveys. That is, the analysis is confined to a certain group, and the effect of the intervention over time is explored. Within this type of investigation, one might ask, for example, whether students’ views on a particular question change from the pre- to the post-survey. The second type of comparison (across-group) looks at a fixed point in time and searches for relationships between the student and parent groups at that time. Within this type of investigation, one might ask, for example, whether students and their parents have similar attitudes when they arrive and take the pre-survey. The below figure shows the overall investigatory plan: horizontal arrows represent *across-time* comparisons (i.e., the group is fixed) and vertical arrows represent *across-group*

comparisons (i.e., the time being considered is fixed). The interim across-group analysis examines the correspondence in changes in the pre and post surveys across parent-student pairs.

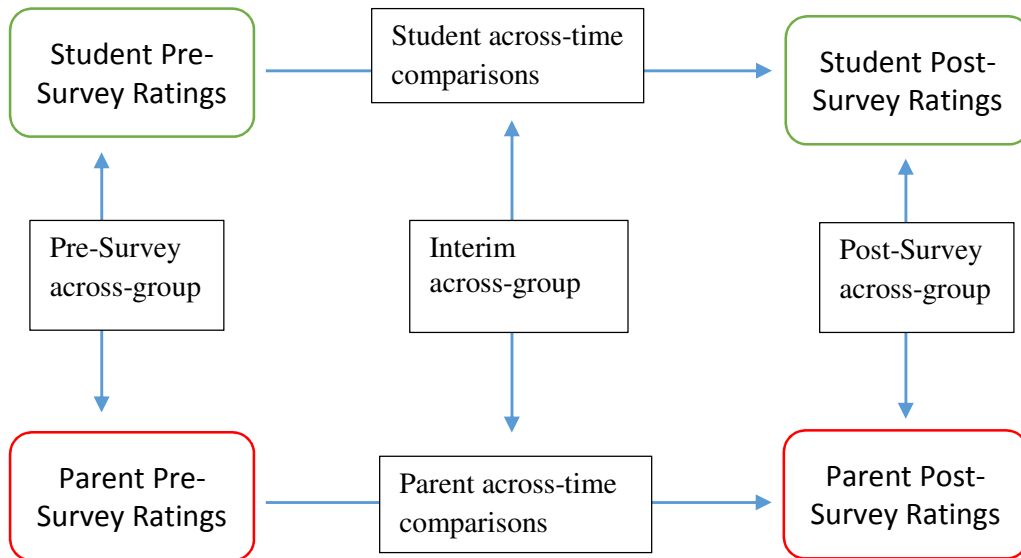
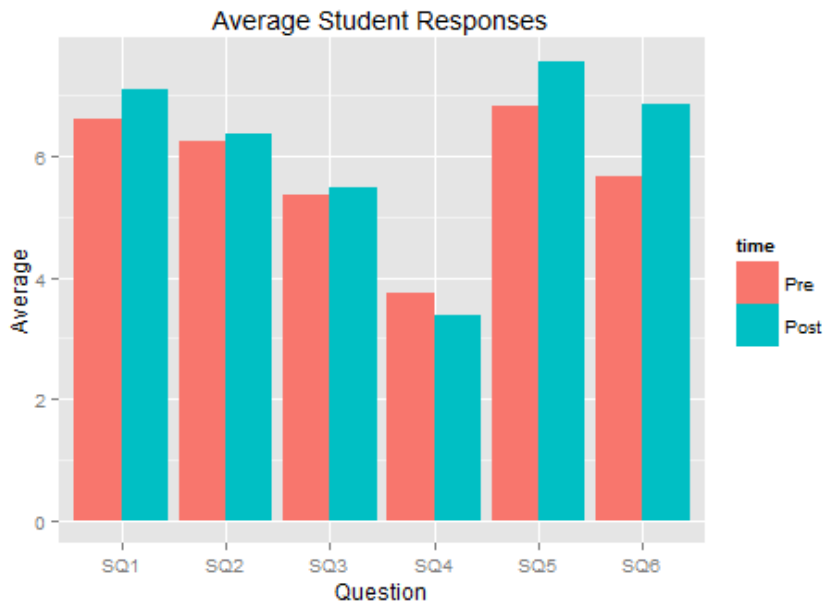


Figure 1. Overview of the Quantitative Analysis

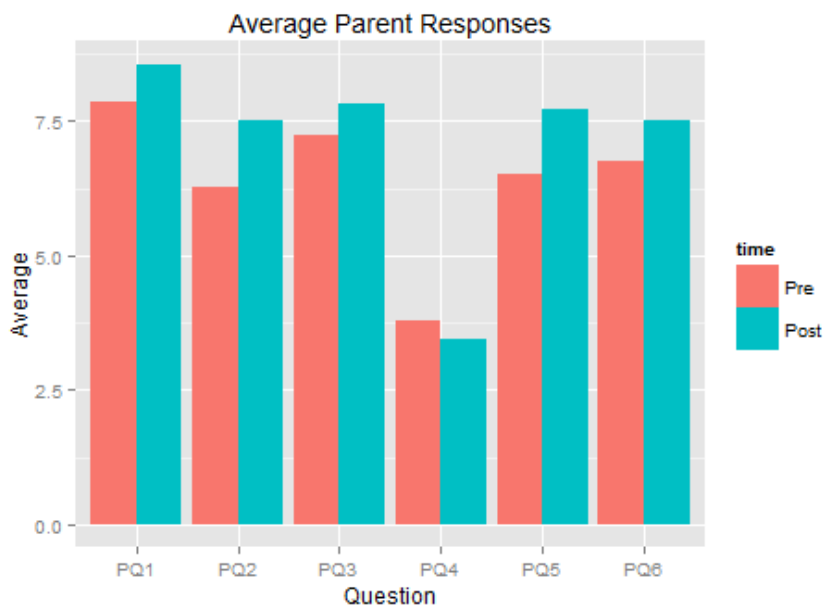
#### *Across-Time Comparisons (Measures of Central Tendency)*

We begin by exploring the changes seen in the student group from the pre-survey to the post-survey. Figure 2 reveals the average ratings given on each question (using the numeric version of the Likert scale ranging from 1 to 9; i.e. from strongly disagree to strongly agree) for both the pre- (light bars) and post-surveys (dark bars). Note that all prompts except SQ4 are worded with positive language; as such, one would hope to see post-survey results decline for SQ4 and increase for the others. Indeed, this is precisely the case. Bar heights represent the average of the 42 students that fully completed both surveys and included the same anonymous ID number on both so that they could be linked. This across-time analysis can also be done for the parents. The average results from those 36 parents that completed both the pre- and post-surveys and included the anonymous linking ID number are shown below in Figure 3.



Student Question Number	Wilcoxon p-value
SQ1	p = 0.01748
SQ2	p = 0.24580
SQ3	p = 0.24890
SQ4	p = 0.17690
SQ5	p = 0.00062
SQ6	p = 0.00213

Figure 2. Average Likert responses (9-point scale) for students' (n = 42) pre- and post-surveys (left side). p-values of paired differences across-time for each question using the Wilcoxon Signed-Rank Test (right side).



Parent Question Number	Wilcoxon p-value
PQ1	p = 0.00023
PQ2	p = 0.00083
PQ3	p = 0.00323
PQ4	p = 0.04669
PQ5	p = 0.00005
PQ6	p = 0.00477

Figure 3. Average Likert responses (9-point scale) for parents' (n = 36) pre- and post-surveys (left side). p-values of paired differences across-time for each question using the Wilcoxon Signed-Rank Test (right side).

One question concerning these data is whether they are statistically significant, or whether the observed changes are simply the result of chance. Given that the student and parent response distributions of the pre-surveys were not normal, the non-parametric Wilcoxon Signed-Rank Test was employed to see if a shift in the medians of the pre- and post-distributions occurred. The use of this test operates under the assumptions of randomness, independence, paired samples, ordinal data, and that the population distribution of the differences about the median is symmetrically distributed. If the population is chosen to be the set of girls/parents that would enroll in such an intervention, then these requirements are met. Under a null hypothesis that the intervention engenders no change (that is, the pre- and post-medians are identical, or that the difference in medians is 0), the one-sided alternative hypothesis is that the intervention creates an upward shift in those prompts worded positively (all but Q4), and a downward shift in the prompt worded negatively (Q4). This setup affords a one-sided Wilcoxon test, and running the test on each pairing of pre- and post-ratings for students (and then parents), one finds the p-values listed on the right side of Figures 2 and 3. With this test, and all others described in this paper, low p-values signify statistical significance. Most of these p-values are statistically significant at the 0.05 level, suggesting that the null hypothesis is to be rejected. That is, there is strong evidence that the intervention is capable of raising the median response on student questions SQ1, SQ5, and SQ6, parent questions PQ1, PQ2, PQ3, PQ5, and PQ6, and lowering the median on PQ4.

*Across-Time Comparisons (Switcher Tables)*

A different and useful way to explore the Likert response data is to dichotomize respondents based on a threshold level, and then explore how these binary placements change between the pre- and post-surveys. If effect, this creates a 2x2 contingency table:

Summary of Pre/Post-Surveys	Post-survey < threshold level	Post-survey >= threshold level
Pre-survey < threshold level	Maintainers (-)	Switchers (+)
Pre-survey >= threshold level	Switchers (-)	Maintainers (+)

Figure 4. Structure of the 2x2 Dichotomized-Response Contingency Table

As the above table indicates, those participants that begin and end below the threshold have not experienced a shift in attitude strong enough to move them past the threshold level; these participants are labeled “Maintainers (-)” above – that is, they hold on to their below-threshold views. Some participants, however, will arrive with an uninspired attitude and leave quite inspired (depending on where the threshold is set); these are the positive switchers, Switchers (+) above. Similarly, some arrive with a positive outlook and either maintain this, Maintainers (+), or leave with an outlook that falls below the threshold, Switchers (-). Most interventions aim to create the positive switcher, and the below statistics will both report findings of this type and show the statistical significance of these findings.

Two things are critically important in this analysis. The first is choosing a threshold level. While a neutral score (5) seems the natural choice, the goal of this intervention was not to move participants from a place of lukewarm negativity to lukewarm positivity. The goal, rather, was to inspire girls to consider engineering as a future career. Here, the nine-point Likert scale is particularly useful, for it contains four different degrees of positivity (6-9). As such, two different threshold values are studied below:  $T = 6.5$  and  $7.5$ . The first value effectively separates the negative, neutral, and first positive options (1-6) from the 3 highest positive options (7-9). This choice is more likely to capture those participants that begin uninspired and move to a medium-strength positivity. The threshold of  $7.5$ , in contrast, reports switchers only in those cases that responders achieve a very high degree of positivity after the intervention (or begin quite inspired and end up less excited, if they drop below the threshold). In an imprecise sense, the smaller threshold helps pinpoint those who have begun warming to the idea of engineering, while the higher level identifies those that have become truly excited.

The second issue is one of assessing statistical significance. Once a question (Q1-Q6), participant group (student/parent), and threshold ( $6.5/7.5$ ) have been set, one may form the  $2 \times 2$  contingency table. To assess whether the distribution of results in the table is significant, a non-parametric, exact test known as McNemar's Test is used<sup>[23]</sup>. This test compares the proportions of respondents that fall into a given category (here, above the threshold, or equivalently, below the threshold) before and after the intervention. Note that this test requires the data be paired. McNemar's Test has two major benefits over the usual statistical techniques leveraged on contingency tables. First, it is non-parametric, so data need not come from a population with a pre-assumed distribution. Second, given that the test is exact, it can handle tables with small individual (or total) cell counts. Under the null hypothesis that the intervention has no effect, one would expect to see roughly identical proportions of respondents above the threshold before and after. Here, the alternative hypothesis is one sided, that the intervention engenders a higher proportion of responses above the threshold after than before.

Below one finds the contingency tables (Figures 5-8) and p-values for each combination of factors: question (Q1-Q6), participant group (students or parents), and threshold level ( $6.5$  or  $7.5$ ). On SQ4/PQ4, which is worded negatively, the pre- and post-survey values were symmetrically flipped about the neutral response so that the same threshold levels made sense. Here, the notion of a positive switcher remains desirable – it equates to a respondent that leaves strongly disagreeing (that engineers are hard to relate to) while arriving with a less severe view.

The first observation to make of these data is that in all cases, the intervention (overall) has done more good than harm (i.e., Switcher (+) is greater than or equal to Switcher (-) across all questions and thresholds that were studied). Furthermore, many of the p-values suggest rejecting the null hypothesis. That is, there is strong evidence that the intervention was capable of reshaping a proportion of responses in relation to a variety of attitudinal measures. In total, 12 of the 24 p-values below are statistically significant at the 0.05 level. Many of these are from parent contingency tables: overall, it appears that parents were far more willing to use the strongest components of the Likert scale and hold positive views.

<b>SQ1</b>	Post < T	Post >= T
Pre < T	12	7
Pre >= T	4	19
McNemar's Test p-value: 0.274		

<b>SQ2</b>	Post < T	Post >= T
Pre < T	17	5
Pre >= T	4	16
McNemar's Test p-value: 0.5		

<b>SQ3</b>	Post < T	Post >= T
Pre < T	23	4
Pre >= T	3	12
McNemar's Test p-value: 0.5		

<b>SQ4</b>	Post < T	Post >= T
Pre < T	14	11
Pre >= T	5	12
McNemar's Test p-value: 0.105		

<b>SQ5</b>	Post < T	Post >= T
Pre < T	10	10
Pre >= T	1	21
McNemar's Test p-value: 0.006		

<b>SQ6</b>	Post < T	Post >= T
Pre < T	14	12
Pre >= T	4	12
McNemar's Test p-value: 0.038		

Figure 5. Table for: **Students**; Threshold Level: **T = 6.5** (lower level = 1-6, upper level = 7-9)

<b>PQ1</b>	Post < T	Post >= T
Pre < T	1	5
Pre >= T	0	30
McNemar's Test p-value: 0.031		

<b>PQ2</b>	Post < T	Post >= T
Pre < T	7	11
Pre >= T	2	16
McNemar's Test p-value: 0.011		

<b>PQ3</b>	Post < T	Post >= T
Pre < T	4	8
Pre >= T	1	23
McNemar's Test p-value: 0.020		

<b>PQ4</b>	Post < T	Post >= T
Pre < T	10	9
Pre >= T	4	13
McNemar's Test p-value: 0.133		

<b>PQ5</b>	Post < T	Post >= T
Pre < T	7	10
Pre >= T	0	19
McNemar's Test p-value: 0.001		

<b>PQ6</b>	Post < T	Post >= T
Pre < T	6	8
Pre >= T	1	21
McNemar's Test p-value: 0.020		

Figure 6. Table for: **Parents**; Threshold Level: **T = 6.5** (lower level = 1-6, upper level = 7-9)

<b>SQ1</b>	Post < T	Post >= T
Pre < T	17	8
Pre >= T	2	15
McNemar's Test p-value: 0.055		

<b>SQ2</b>	Post < T	Post >= T
Pre < T	24	4
Pre >= T	4	10
McNemar's Test p-value: 0.5		

<b>SQ3</b>	Post < T	Post >= T
Pre < T	29	3
Pre >= T	1	9
McNemar's Test p-value: 0.313		

<b>SQ4</b>	Post < T	Post >= T
Pre < T	22	6
Pre >= T	5	9
McNemar's Test p-value: 0.5		

<b>SQ5</b>	Post < T	Post >= T
Pre < T	17	9
Pre >= T	1	15
McNemar's Test p-value: 0.011		

<b>SQ6</b>	Post < T	Post >= T
Pre < T	26	5
Pre >= T	2	9
McNemar's Test p-value: 0.227		

Figure 7. Table for: **Students**; Threshold Level: **T = 7.5** (lower level = 1-7, upper level = 8-9)

<b>PQ1</b>	Post < T	Post >= T
Pre < T	2	10
Pre >= T	0	24
McNemar's Test p-value: 0.001		

<b>PQ2</b>	Post < T	Post >= T
Pre < T	16	9
Pre >= T	1	10
McNemar's Test p-value: 0.011		

<b>PQ3</b>	Post < T	Post >= T
Pre < T	11	10
Pre >= T	1	14
McNemar's Test p-value: 0.006		

<b>PQ4</b>	Post < T	Post >= T
Pre < T	19	8
Pre >= T	2	7
McNemar's Test p-value: 0.055		

<b>PQ5</b>	Post < T	Post >= T
Pre < T	14	10
Pre >= T	0	12
McNemar's Test p-value: 0.001		

<b>PQ6</b>	Post < T	Post >= T
Pre < T	16	6
Pre >= T	2	12
McNemar's Test p-value: 0.145		

Figure 8. Table for: **Parents**; Threshold Level: **T = 7.5** (lower level = 1-7, upper level = 8-9)

One approach to further study these tables is to rank questions from largest to smallest p-values for each Figure above. This helps suggest which questions, and hence, overarching objectives (Engineering Awareness, Pathway, Philosophy), are more or less resistant to attitudinal alteration.

	Highest p	Decreasing p-values				Lowest p
RANKING	1st	2nd	3rd	4th	5th	6th
Stu, 6.5	SQ2 and SQ3 (tie)	SQ1	SQ4	SQ6	SQ5	
Stu, 7.5	SQ2 and SQ4 (tie)	SQ3	SQ6	SQ1	SQ5	
<b>Stu Average</b>	<b>SQ2</b>	<b>SQ3</b>	<b>SQ4</b>	<b>SQ1</b>	<b>SQ6</b>	<b>SQ5</b>
Par, 6.5	PQ4	PQ1	PQ6 and PQ3 (tie)		PQ2	PQ5
Par, 7.5	PQ6	PQ4	PQ2	PQ3	PQ1 and PQ5 (tie)	
<b>Par Average</b>	<b>PQ4</b>	<b>PQ6</b>	<b>PQ3 and PQ1 (tie)</b>		<b>PQ2</b>	<b>PQ5</b>

Figure 9. Questions Ranked from Highest p-value to Lowest p-value Based on Figures 5-8

The “Stu, 6.5” row of this table was constructed by ordering the questions in Figure 5 from highest to lowest p-value. After doing the same for “Stu, 7.5”, each question was assigned a rank score for each row – e.g. question 5 (SQ5) in “Stu, 6.5” is rank 6; questions 2 and 4 in “Stu, 7.5” are each rank 1.5, the average of ranks 1 and 2. These rank scores were added and then used to order the questions in the “Stu, Average” row. This ordering suggests that SQ2 and SQ3 more difficult to effect a change in students. This makes sense given that these two questions (“I would like to study engineering in school” and “I want to become an engineer when I grow up”) represent positions of strong belief that take many years to change and have far-reaching implications. Other beliefs are much easier to modify in children: SQ5 (“I see women as leaders in engineering”), for example, can be changed by introducing young girls to female engineers in the field that are doing revolutionary work. Thus, it seems as if those questions that mostly require exposure or knowledge (SQ1, SQ5, SQ6) are easier to positively change in shorter time spans.

The parent surveys showed some similar trends: PQ2 and PQ5 (“I know what path my daughter should take in order to become an engineer” and “I see women as leaders in engineering”) are mostly about gaining knowledge and seeing positive examples of women, which can be changed in short time spans. The parent results differ from the student results on PQ4 and PQ6 (recall questions 4-6 are the identical for student and, while questions 1-3 are different). This could be the result of the entrenchment of beliefs that occurs during maturation and is worthy of further exploration. See the Discussion section for further analysis of these data.

#### *Across-Group Comparisons*

Turning now to the vertical arrows in Figure 2, we explore the relationships that exist across groups for fixed points in time. Here, three questions are particularly important: Do students



and their parents *arrive* with similar viewpoints about the world of engineering? Do they *leave* with similar views? Do their attitudinal changes that result from the intervention look similar? (That is, if a parent experiences a large positive change because of an intervention, is it reasonable to expect his/her daughter will also?)

These correlations can be partially explored by looking at how students and their parents responded to questions SQ4/PQ4, SQ5/PQ5, and SQ6/PQ6.

Q4. I feel like engineers are hard to relate to.

Q5. I see women as leaders in engineering.

Q6. I have a good sense for what an engineer does each day.

These three questions were identical on the student and parent questionnaires. Thus, for a particular time (say, the pre-survey), one may link a particular student's response,  $S$ , to her parent's response,  $P$ , and plot the point  $(S,P)$  on a two-dimensional grid (where each axis runs 1-9, the possible Likert response scores). Doing this for each student-parent pairing creates a scatterplot. If student and parent attitudes were perfectly (linearly) correlated, we would expect these data to fall on a straight line. Thus, we may use the Pearson correlation coefficient to measure how well the data resemble a straight line, i.e. how well student and parent attitudes correlate. We may do this for each question (4-6) and each time (pre, interim, and post), generating a scatter plot and correlation coefficient in each case. Correlation values close to 1 (agree) or -1 (disagree) suggest strong linear correlations; values close to 0 suggest virtually no linear correlation.

The assumption of linearity may also be weakened (e.g., if the data nicely line up on a quadratic or higher degree curve) by using transformations to one or both of the variables. Here, a different approach is taken (because no clear transformations are visible in the scatterplots): the Spearman Rank coefficient is used to measure the degree of monotonic correlation between student and parent responses. This approach is not hamstrung by the assumption of linearity and looks more generally to see how closely the data follow a monotonically increasing (or decreasing) function. This approach should not be viewed as superior to the Pearson coefficient, but rather, as supplemental, and particularly helpful at uncovering monotonic relationships that may not be linear (or clearly transformational-linear). Below are the scatterplots, Pearson correlations, and Spearman-Rank correlations for each fixed time and question (across groups). Note that the data for the pre- and post-time frames can simply be read off from participant surveys, while the data for the interim time frame are the differences between the pre- and post-surveys (post minus pre); this explains why the axes are different for these scatterplots.

The interesting results in the below data are not that the two scatterplots (Pre-SQ6/PQ6, Diff-SQ5/PQ5) show a weak linear correlation, but rather, the wealth of examples that show basically *no* linear correlation. If one instead looks for a (possibly non-linear) monotonic relation between student and parent responses using the Spearman Rank correlation coefficient, the results are similarly weakly correlated. This finding is valuable not because it reveals deeply connected opinions of parents and their children, but rather, quite the opposite: whether coming in, leaving, or undergoing change during the event, there appears to be little connection between self-reported beliefs of family members. This finding is quite surprising and will be discussed later in the Conclusion.

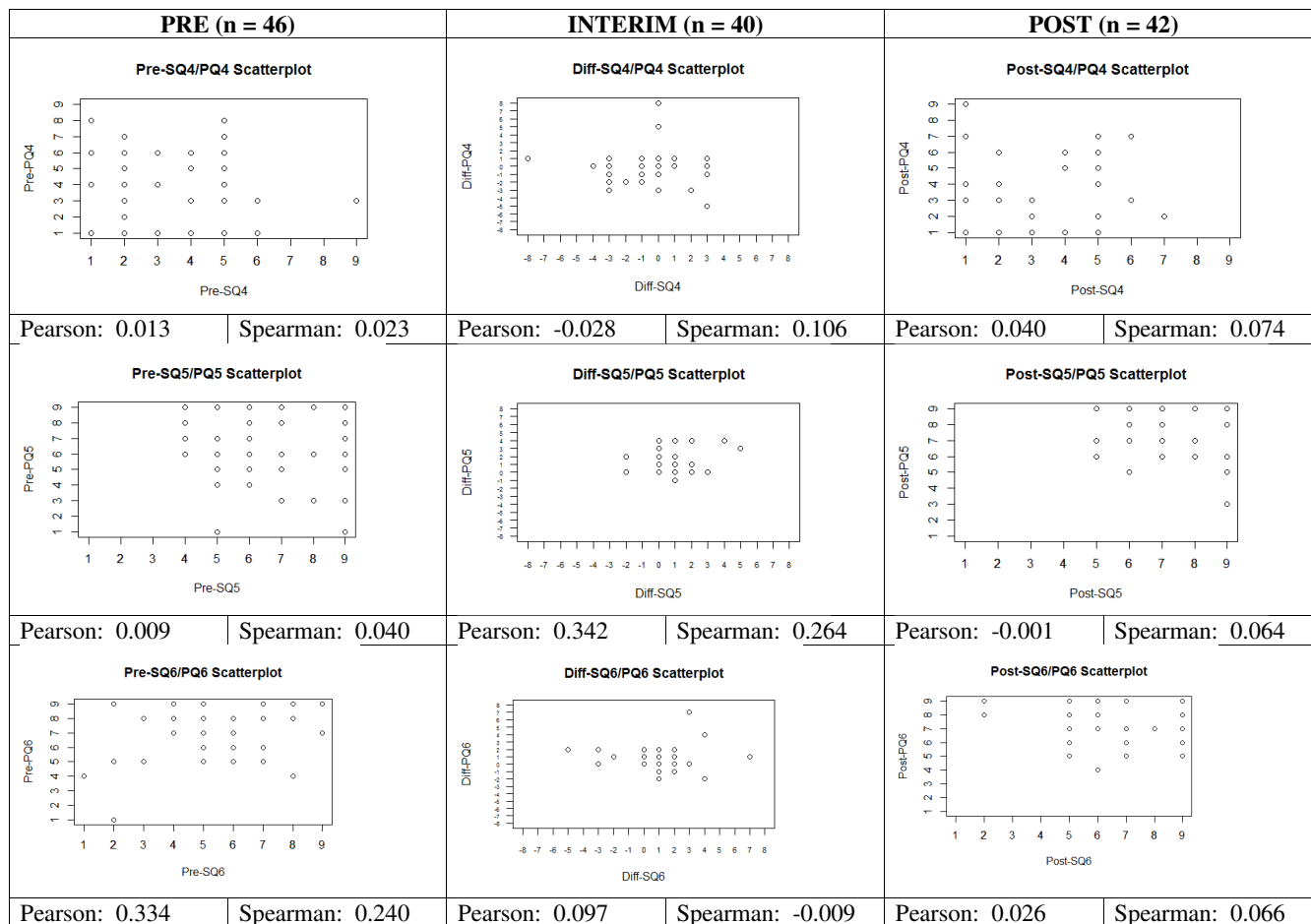


Figure 10. Scatterplots and Correlation Coefficients of Across-Group Comparisons for Fixed Questions and Times

## ***Qualitative Results***

In addition to the quantitative, Likert-style questions discussed above, both student and parent post-surveys included two additional sections: one gathering basic demographic data, and the other asking a series of qualitative questions designed to add texture to the numerical data. The questions for students were:

SW1. Has this program changed your view of *females* in engineering? YES/NO

SW2. If so, how? If not, why not?

SW3. Has this program changed your view of engineering? YES/NO

SW4. If so, how? If not, why not?

Here, SW2 stands for “Student Written (question) 2” and is a follow-up to SW1. The parent format was similar but featured different prompts:

PW1. Has this program changed your view of *females* in engineering? YES/NO

PW2. If so, how? If not, why not?

PW3. Has this program changed how you will encourage your daughter to continue exploring engineering topics? YES/NO

PW4. If so, how? If not, why not?

As with the quantitative questions, these prompts were also mapped to the three overarching objectives discussed previously. Note that, given the open-ended nature of the prompts, some questions mapped onto multiple categories:

Engineering Awareness: SW3/4, PW3/4

Pathway: SW3/4, PW3/4

Philosophy: SW1/2, PW1/2

The responses given to these questions were particularly insightful (for both students and parents); specific examples are given in the Discussion section. It is important to understand the value of these results: they provide richness and support for the quantitatively significant results seen in the preceding section.

Before tying the results of both analyses together, the results of the demographic data are reported for completeness. These are not discussed further and could be the source for future investigations. For example: Are students of certain ages more susceptible to attitudinal change in certain areas?, Do girls from multilingual households arrive with different views on engineering?, etc.

Students were asked to self-report their ages, grades, racial identity, and language(s) spoken at home. Parents were only asked to provide their racial identities and language(s) spoken at home.

Age in Years	10	11	12	13	14
Count	4	7	11	15	1
Percentage	10.5%	18.4%	28.9%	39.4%	2.6%

Figure 11. Ages of Student Participants (n = 38)

Grade	5	6	7	8
Count	4	7	11	16
Percentage	10.5%	18.4%	28.9%	42.1%

Figure 12. Grade-Level of Student Participants (n = 38)

Race	Asian	Black	Multiracial	White
Count	6	3	5	22
Percentage	15.8%	7.9%	13.2%	57.9%

Figure 13. Self-reported Racial Identity of Student Participants (n = 38)

Language	English	Chinese	Portuguese	Vietnamese	Bilingual	Trilingual
Count	24	1	1	1	6	2
Percentage	63.2%	2.6%	2.6%	2.6%	15.8%	5.3%

Figure 14. Language(s) Spoken Primarily at Home According to Students (n = 38)

Race	Asian	Black	Hispanic	Multiracial	Other	White
Count	5	1	1	5	2	18
Percentage	15.6%	3.1%	3.1%	15.6%	6.3%	56.3%

Figure 15. Self-reported Racial Identity of Parent Participants (n = 32)

Language	English	Bilingual
Count	27	5
Percentage	84.4%	15.6%

Figure 16. Language(s) Spoken Primarily at Home According to Parents (n = 32)

## Discussion

In this section, the results of the previous analyses will be used to assess the efficacy of the intervention as delineated by the overarching objectives: Engineering Awareness, Pathway, and Philosophy. In exploring attitudinal changes, the goal is not simply to determine whether or not viewpoints have shifted, but also why and how they have shifted. For these latter goals, the qualitative data were investigated using the technique of Grounded Theory<sup>[21,22]</sup>. In brief, this technique involves making iterative passes through data and assigning coding schemes to help develop an overarching structure or framework for what was observed. Said simply, the qualitative data are crucial in building a schema for the type of belief reformation achieved, while the quantitative data are critical in gauging the probabilistic significance of these alterations. The three major objectives will be discussed in turn.

### Engineering Awareness

This objective was explored via the following questions from the student and parent questionnaires. (p-values from above have been transferred here for easier reference.)

Student Summary	p-value	Parent Summary	p-value
SQ1 – Pre/Post change	0.01748	PQ1 – Pre/Post change	0.00023
SQ1 – Switcher 6.5	0.274	PQ1 – Switcher 6.5	0.031
SQ1 – Switcher 7.5	0.055	PQ1 – Switcher 7.5	0.001
SQ6 – Pre/Post change	0.00213	PQ6 – Pre/Post change	0.00477
SQ6 – Switcher 6.5	0.038	PQ6 – Switcher 6.5	0.020
SQ6 – Switcher 7.5	0.227	PQ6 – Switcher 7.5	0.145
SW3/4	N/A	PW3/4	N/A

Figure 17. Summary of Questions Relating to the Engineering Awareness Objective

These p-values are statistically significant, suggesting the intervention was effective in reshaping both students' and parents' attitudes about the field of engineering. Indeed, as Figure 9 from earlier indicates, SQ1 and SQ6 were among the lowest p-value questions in the composite ranked switcher table analysis. When the results for this topic are compared with Pathway and Philosophy (to follow), it is clear that this topic is particularly susceptible to change, while the others show less willingness to adopt a long-term career strategy or change in a belief system. This trend might occur because reshaping Engineering Awareness is largely a matter of information sharing – particularly, the kinds of engineering that exist, the lifestyle of an engineer, daily responsibilities, etc. The other topics, in comparison, require internally remapping some portion of one's belief structure and considering long-term career planning.

To further understand these statistically significant changes, the qualitative data were explored via Grounded Theory. This technique was successful in bringing three main themes into focus for prompts SW3/4.

SW3. Has this program changed your view of engineering? YES/NO

SW4. If so, how? If not, why not?

Below are quotes supporting these major themes and providing evidence for the types of attitudinal transformations that occurred under the umbrella of Engineering Awareness. The first of these, that engineering can actually be fun, might be surprising for those who make their living doing or teaching STEM-related topics. This viewpoint, however, may not come naturally to children, as seen by the responses below, all of which were accompanied with an answer of YES (that their views of engineering had changed during the day). Similar to the notion of fun is that of interest, which suggests, perhaps, a greater degree of intellectual engagement with the field. In this regard, students frequently made reference to particular demonstrations (liquid nitrogen flowers, fuel cells, designing boats, etc.) with which they connected. In each of these demonstrations, efforts were made to present engaging ideas *and* share the age-appropriate science behind those ideas. Finally, many students shared that they left with a more thorough view of the subfields found within engineering. The nature of what an engineer does each day (office work versus field work) also seemed to be a topic of importance to some students. In Figure 18, the notation S134 denotes the student participant with random ID #134.

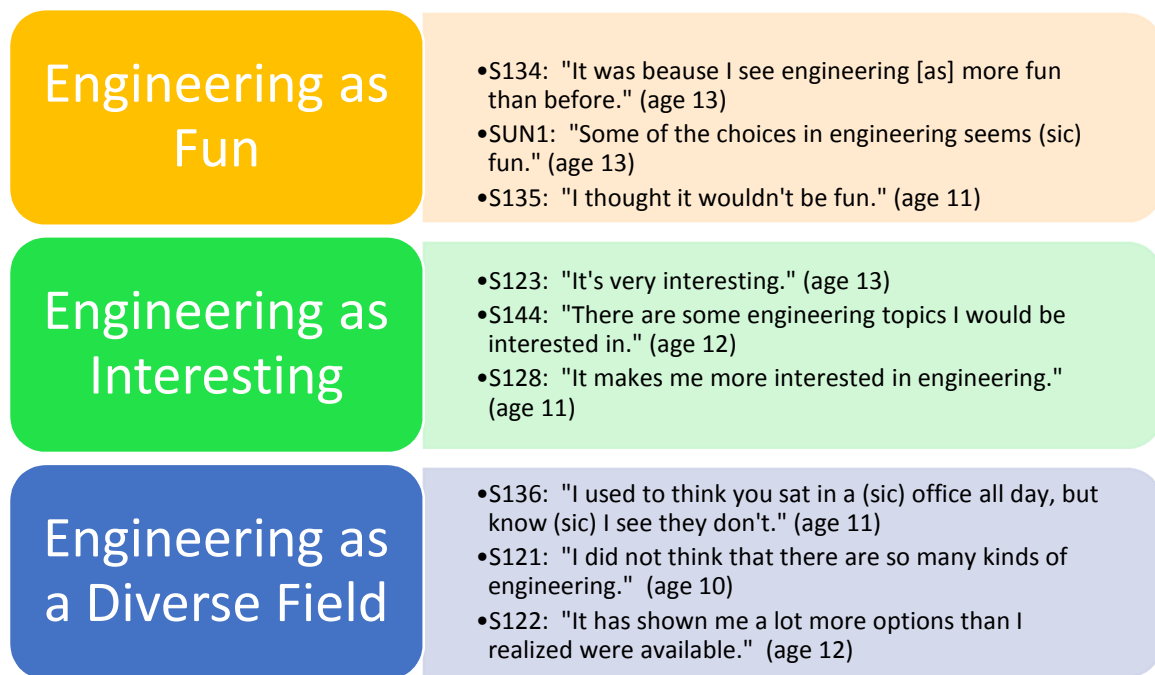


Figure 18. Student Themes in SW3/4 Relating to the Engineering Awareness Objective

Parents encountered a slightly different prompt for PW3/PW4, and hence the major themes in their replies were not identical to students' replies.

PW3. Has this program changed how you will encourage your daughter to continue exploring engineering topics? YES/NO

PW4. If so, how? If not, why not?

One of these related to Engineering Awareness was particularly salient and similar to the student response:

## Engineering as a Diverse Field

- P144: "It has exposed me to different career paths to begin these conversations."
- P136: "I will explore the diversity of the engineering field to see what may be a good fit for both daughters."
- P119: "There are more fields of engineering than I was aware of."

Figure 19. Parental Theme in PW3/PW4 Relating to the Engineering Awareness Objective

### Pathway

This objective focused on building a mental map of the steps necessary to becoming an engineer, including course-work selection, exposure to a college campus, familiarity with laboratory settings, and building knowledge of the financial rewards and challenges.

Student Summary	p-value	Parent Summary	p-value
SQ2 – Pre/Post change	0.24580	PQ2 – Pre/Post change	0.00083
SQ2 – Switcher 6.5	0.5	PQ2 – Switcher 6.5	0.011
SQ2 – Switcher 7.5	0.5	PQ2 – Switcher 7.5	0.011
SQ3 – Pre/Post change	0.24580	PQ3 – Pre/Post change	0.00323
SQ3 – Switcher 6.5	0.5	PQ3 – Switcher 6.5	0.020
SQ3 – Switcher 7.5	0.313	PQ3 – Switcher 7.5	0.006
SW3/4	N/A	PW3/4	N/A

Figure 20. Summary of Questions Relating to the Pathway Objective

The above data are interesting in that the parent results are all statistically significant while none of the students' results are (at the 0.05 level). This trend is also reflected in Figure 9: student views on SQ2 and SQ3 seem particularly difficult to alter, while parents are especially susceptible to this type of messaging. This is somewhat expected, for parents are more likely to see and plan for the educational big picture, while students are focused on discovering what is personally interesting. This does not suggest, however, that pathway goals should be ignored for students. If parents are not part of an intervention, then this information is even more important for students. Further work is needed to discover how to engender a long-range outlook in students – one that is aware of the roadblocks ahead and contains the best thinking on how to navigate these. In addition, continuing work of this kind is essential from the parent side of the equation, for these results suggest that even short-term interventions can help create strong parent-advocates for kids who have yet to awaken to the future potential or career pathway.

Students infrequently discussed this objective, and so the parent responses became the primary source for thematic content. Interestingly, two major themes arose which were not part of the original Pathway category. The first was perhaps the most basic and crucial of ideas: the parental belief that his or her daughter *could* actually become an engineer – that this pathway was one *available* to his or her child. Once on this pathway, the second theme could be realized:

what resources (e.g., teachers, mentors, role models, websites, books, scholarships) were available.

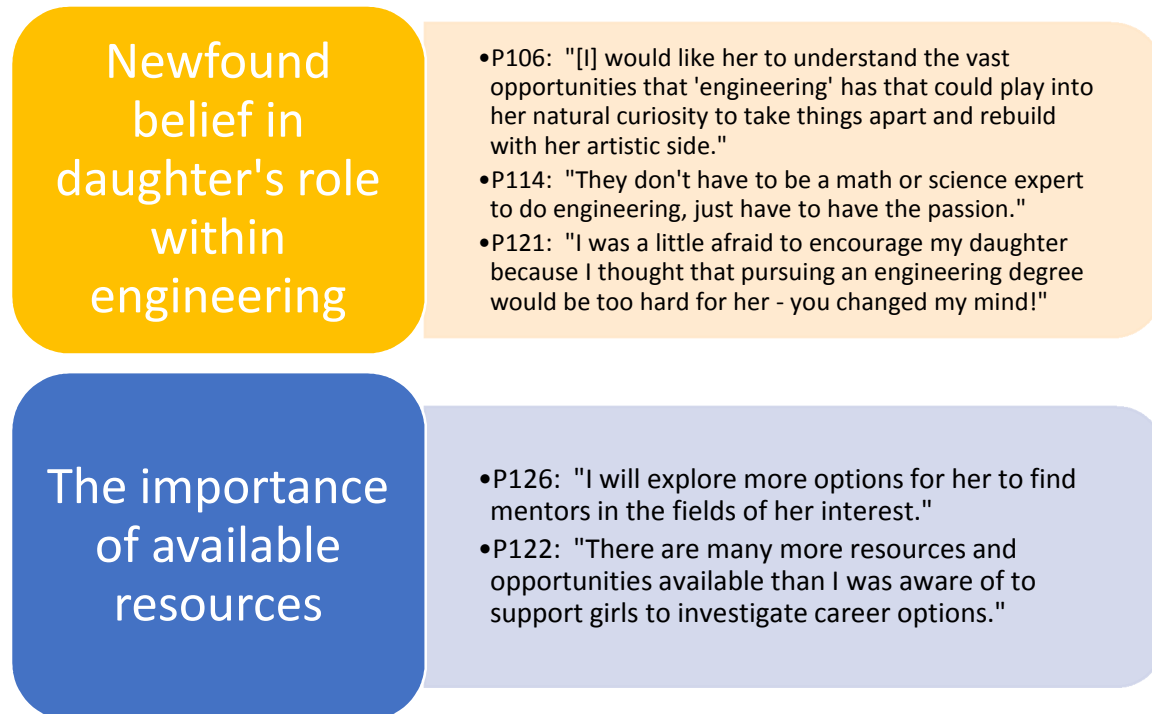


Figure 21. Parental Themes in PW3/4 Related to the Pathway Objective

*Philosophy*

The notion of exciting middle school girls to enter the field of engineering was central to the mission of this intervention. This challenge, however, required more than simply exposing girls to the field. Given the deep historical and social challenges women have faced in technical fields (see Background), project organizers worked to incorporate positive experiences and messaging in as many ways as possible. The results of female role-modeling are evident in the quantitative and qualitative results seen below. The numerical data pertinent to this category are found in Figure 22.

Student Summary	p-value	Parent Summary	p-value
SQ4 – Pre/Post change	0.17690	PQ4 – Pre/Post change	0.04669
SQ4 – Switcher 6.5	0.105	PQ4 – Switcher 6.5	0.133
SQ4 – Switcher 7.5	0.5	PQ4 – Switcher 7.5	0.055
SQ5 – Pre/Post change	0.00062	PQ5 – Pre/Post change	0.00005
SQ5 – Switcher 6.5	0.006	PQ5 – Switcher 6.5	0.001
SQ5 – Switcher 7.5	0.011	PQ5 – Switcher 7.5	0.001
SW1/2	N/A	PW1/2	N/A

Figure 22. Summary of Questions Relating to the Philosophy Objective



SW1/2 and PW1/2 were particularly helpful in understanding how the statistically significant changes observed came about. Turning first to the parents, belief reformation seems to have occurred on two separate planes: high-level and low-level change. The former relates to attitudes about general roles for women and participation by women in engineering, while the latter is concerned with specific examples of engineers. Overall, parent's responses seemed to reference negative historical precedents and preconceptions more than student responses. Evidence supporting these attitudinal changes is contained in Figure 23.

PW1. Has this program changed your view of *females* in engineering? YES/NO  
 PW2. If so, how? If not, why not?

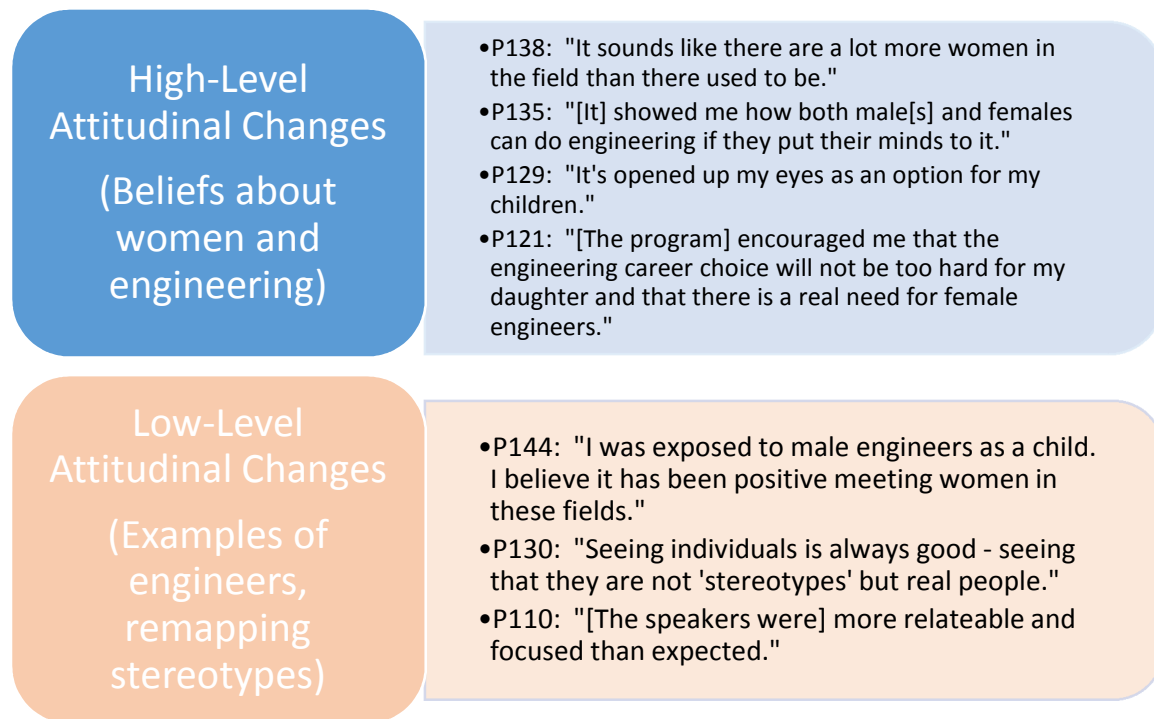


Figure 23. Parental Themes Found in PW1/2 Relating to the Philosophy Objective

The student responses found in SW1/2 were also enlightening.

SW1. Has this program changed your view of *females* in engineering? YES/NO  
 SW2. If so, how? If not, why not?

Here, one encountered belief reformation along a hierarchy. When organized horizontally, this hierarchy appeared as an arrow of self-actualization:

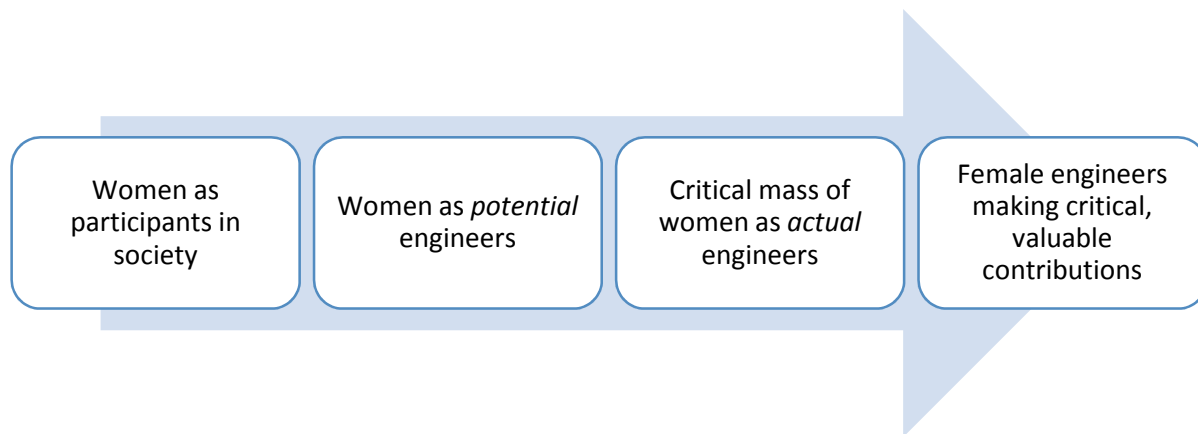


Figure 24. Belief Progression of Student Responses to SW1/2

It is reasonable to believe that participants arrive to an intervention like Girl’s Day Out with disparate views on engineering, women, and women’s roles in engineering. The first category in Figure 24 describes the initial philosophical barrier overcome by those students who arrived with the least developed notions of women’s equality. This component of attitudinal reformation is particularly powerful, for the others are predicated on it. Indeed, many students were able to gain this first foothold in Figure 24:

S123: “I now know that it’s not only men who are allowed in science.” (age 13)

S144A: “Yes, because I thought females couldn’t really do anything (didn’t have the power).” (age 10)

S147: “Because I know women can do anything men can do!” (age 10)

S115: “It has taught me that you can do whatever you want if you want to.” (age 13)

The transition to seeing women as potential engineers is movement beyond the recognition that women deserve an equal place in society (a global, social barrier) to the stance that women deserve a place in engineering (a subject-specific, local barrier). Through their responses, girls described an academic space in which they might theoretically participate:

S121A: “It showed me that women can be engineers.” (age 13)

S108: “Females should be majors in engineering more because they could make a difference in this world.” (age 13)

S128: “Yes, because I used to think females just weren’t right [for] engineering. After this [intervention], I changed my opinion, and this job would be great for any gender.” (age 11)

The above viewpoint does not yet have the depth of feeling that accompanies greater experience with engineers and awareness of what they do. The below evidence suggests an even deeper level of progress in viewing the relationship between females and engineering:

S107A: “It showed me that many women major in engineering.” (age 13)

S137A: “Now I know that there are actually women in engineering.” (age 13)

S137: “I [was] surprised (sic) to hear there are a lot of females in engineering...” (age 13)

The most developed views came from those students who accepted the value of women, the possibility and existence of women engineers, but moreover, found these contributions to be

valuable. In their totality, these four viewpoints suggest that women should have a role, that this role can be in engineering, that there are women doing this, and that these women truly matter. With such a belief network, many of the internal, philosophical barriers to becoming an engineer have been removed:

S114: “I saw how big of a roll (sic) women play in engineering and how many oppertunities (sic) there are.” (age 13)

S130: “It showed how women really can become leaders in engineering.” (age 13)

S138: “Before I knew that women could be and are engineers, but I realized that they are just as strong, if not stronger, in engineering.” (age 14)

S125: “This programe (sic) has changed my opinion by showing me just some of the incredible oppertunities and discoveries that females are making in engineering.” (age 13)

### ***Conclusion***

The aim of this paper has been to explore, via both quantitative and qualitative analyses, the effects of an intervention on a group of middle school girls and their parents across three broad objectives: Engineering Awareness, Pathway, and Philosophy. The results from this investigation suggest that even a single-day event can be effective in reshaping attitudes (Philosophy), exposing young minds to the world of engineering (Engineering Awareness), and beginning to develop a vision for how a young person might become a member of this community (Pathway). Indeed, awareness seemed to be the easiest objective to reach: 8 of the 12 p-values from Figure 17 (combining Wilcoxon’s and McNemar’s tests) were significant. This category also revealed four themes (Engineering as Fun, Engineering as Interesting, and both student and parent views of Engineering as a Diverse Field). As mentioned before, this result is not surprising, for exposure and information-sharing are fairly simple when contrasted with belief reformation and engendering a long-term vision.

Reshaping views on Pathway was more difficult. Here, fewer p-values were statistically significant, and parents showed far more positive movement on questions than their daughters (which tended to remain unchanged). While this is to be expected to some degree – because parents are probably more likely to take a long-term view on their children’s futures – it raises an interesting question for future research: How can this student/parent pathway disparity be minimized, and is it even possible for interventions on this time scale? The quantitative results for the Philosophy questions were also mixed, although they showed significant positive movement in beliefs. The results were buttressed by the rich texture that sprang from the qualitative analysis: while parents experienced change on two scales (High-Level and Low-Level), their daughters appeared to move along a hierarchy, progressing toward a more sophisticated and inclusive role for women in society and engineering. This finding was especially promising, for it revealed that even short-time-scale interventions can effectively advance young girls’ views on the role of females and engineering.

It is also valuable to return to the across-group analysis seen in the scatterplots of Figure 10. Quick scans of these data seem to suggest no discernable relationship between the beliefs of parents and their children. Indeed, the valuable finding in these data is not that a simple linear correlation exists (as might be expected), but rather, that *virtually no linear, transformational-linear, or monotonic correlation exists*. This finding is especially important. In one sense, it is a

blessing, for it means there is hope in reaching out to those students whose parents hold negative views of STEM disciplines: the beliefs of a young girl are not rigidly tied to those of her parents. In another sense, it is a curse, for if a student has parents who are scientists, engineers, or STEM enthusiasts, then the student will not necessarily share in those beliefs. Thus, *each* student must be inspired irrespective of his or her parents' beliefs.

As is often the case, a study of this type raises numerous questions and concerns requiring further study. First, it is important to collect additional data and ensure the results seen above hold for larger sample sizes. In this study, approximately 35 to 45 data points were used (depending on the analysis in question and the completeness of data required). With additional data, regression analyses could be run to explore the effects of age, race, and at home language-use on the post-survey results (or pre-surveys or change differentials). Are students from multilingual homes more likely to arrive with positive views on engineering? Are younger students more susceptible to the changes created by such an intervention? Can some order be found in the scatterplots of Figure 10 if certain subsets of the data are selected? Can any relationships between student and parent attitudes be determined and then leveraged in designing future interventions? In addition, the results of this paper explore attitudinal changes that are present immediately after the intervention. Do these newfound beliefs persist in the long term? How can the positive benefits of Girl's Day Out be disentangled from the myriad other influences that shape complex decision making related to STEM careers? These questions require additional data and more sophisticated analyses.

At the end of this paper, two appendices are included: a copy of the surveys used for this investigation (Appendix A), and a roadmap, so that others may step beyond the words and ideas of this article and create a STEM intervention of their own (Appendix B). The findings above offer hope to students and educators all around this country: hope that the unique talents of young women may be leveraged in advancing the fields of STEM; hope that the massive shortfall of scientists and engineers facing this country may be ameliorated by the inclusion of an underrepresented group; and hope that young girls may look to a goal that was previously only a distant vision and see a clear, welcoming, and realizable future. As teachers and parents and researchers, we must not underestimate the potential of our impact, lest we weaken the impact of the potential of the young women across this land. Our job is to hear that call from President Obama, to show "young people what it is that your work can mean, and what it means to you." Hopefully this paper can inspire others to this ideal – to find the conviction, the energy, and the passion to reach out to the girls around the world and open their minds to the beauty and wonder that is STEM.

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**Appendix A – Student and Parent Surveys**

**GIRL'S DAY OUT: STUDENT PRE-QUESTIONNAIRE**

You are about to take part in a survey that we are conducting it in order to get a better understanding of *your* views on engineering before and after completing our program. The survey should take only a few minutes to complete, and the results will be used to conduct research studies to assess the effectiveness of the program. Please do NOT write your name on this survey, just your ID number in the upper right corner. This will keep your identity secret but allow us to match your responses with the post-Questionnaire. Please answer these questions as honestly as you can. On the below questions, *circle* the choice that best represents your opinion.

1. I find engineering topics to be interesting.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

2. I would like to study engineering in school.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

3. I want to become an engineer when I grow up.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

4. I feel like engineers are hard to relate to.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

5. I see women as leaders in engineering.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

6. I have a good sense for what an engineer does each day.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

## GIRL'S DAY OUT: STUDENT POST-QUESTIONNAIRE

You are about to take part in a survey that we are conducting it in order to get a better understanding of *your* views on engineering before and after completing our program. The survey should take only a few minutes to complete, and the results will be used to conduct research studies to assess the effectiveness of the program. Please do NOT write your name on this survey, just your ID number in the upper right corner. This will keep your identity secret but allow us to match your responses with the pre-Questionnaire. Please answer these questions as honestly as you can. On the below questions, *circle* the choice that best represents your opinion.

1. I see women as leaders in engineering.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

2. I would like to study engineering in school.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

3. I feel like engineers are hard to relate to.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

4. I have a good sense for what an engineer does each day.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

5. I find engineering topics to be interesting.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

6. I want to become an engineer when I grow up.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree



Has this program changed your view of *females* in engineering? (circle one)      YES    NO

If so, how? If not, why not?

Has this program changed your view of engineering? (circle one)      YES    NO

If so, how? If not, why not?

Some Info About You:

Age: \_\_\_\_\_      Grade in School: \_\_\_\_\_

Please check any boxes that you associate with your racial identity:

- |   |   |
|---|---|
| <input type="checkbox"/> Asian              | <input type="checkbox"/> Black or African American        |
| <input type="checkbox"/> Hispanic or Latino | <input type="checkbox"/> Native American or Alaska Native |
| <input type="checkbox"/> White non-Hispanic | <input type="checkbox"/> Other (please specify: _____)    |

Language(s) spoken primarily at home: \_\_\_\_\_

## GIRL'S DAY OUT: PARENT PRE-QUESTIONNAIRE

You are about to take part in a survey that we are conducting it in order to get a better understanding of *your* views on engineering before and after completing our program. The survey should take only a few minutes to complete, and the results will be used to conduct research studies to assess the effectiveness of the program. Please do NOT write your name on this survey, just your ID number in the upper right corner. This will keep your identity secret but allow us to match your responses with the post-Questionnaire. Please answer these questions as honestly as you can. On the below questions, *circle* the choice that best represents your opinion.

1. I have an appreciation for engineering.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

2. I know what path my daughter should take in order to become an engineer.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

3. I consider engineering as a possible career path for my daughter.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

4. I feel like engineers are hard to relate to.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

5. I see women as leaders in engineering.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

6. I have a good sense for what an engineer does each day.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

## GIRL'S DAY OUT: PARENT POST-QUESTIONNAIRE

You are about to take part in a survey that we are conducting it in order to get a better understanding of *your* views on engineering before and after completing our program. The survey should take only a few minutes to complete, and the results will be used to conduct research studies to assess the effectiveness of the program. Please do NOT write your name on this survey, just your ID number in the upper right corner. This will keep your identity secret but allow us to match your responses with the pre-Questionnaire. Please answer these questions as honestly as you can. On the below questions, *circle* the choice that best represents your opinion.

1. I consider engineering as a possible career path for my daughter.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

2. I feel like engineers are hard to relate to.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

3. I know what path my daughter should take in order to become an engineer.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

4. I have a good sense for what an engineer does each day.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

5. I have an appreciation for engineering.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

6. I see women as leaders in engineering.

1	2	3	4	5	6	7	8	9
Strongly Disagree				Neutral				Strongly Agree

Has this program changed your view of *females* in engineering? (circle one)      YES    NO

If so, how? If not, why not?

Has this program changed how you will encourage your daughter to continue exploring engineering topics? (circle one)      YES    NO

If so, how? If not, why not?

Please check any boxes that you associate with your racial identity:

Asian

Black or African American

Hispanic or Latino

Native American or Alaska Native

White non-Hispanic

Other (please specify: \_\_\_\_\_)

Language(s) spoken primarily at home: \_\_\_\_\_

## ***Appendix B – Roadmap***

### **Timeline/Checklist**

#### **3 Months Prior to Event**

- Contact interested community and student organizations
- Finalize location/date/rooms
  - Prepare rain contingency

#### **2 Months Prior to Event**

- Open Registration
- Begin advertisement of event
- Secure Keynote Speaker(s)
- Finalize Parent Program/Student Panel
- Call for volunteers

#### **1 Month Prior to Event**

- Continue advertising of event
- Finalize campus/lab tours
- Confirm sufficient volunteers
- Define STEM activities

#### **Week Prior**

- Close Registration
- Assign girls to groups
- Submit lunch/food order
- Send reminder email to participants
- Send reminder email to volunteers/speakers/panel
- Collect supplies/equipment required for registration and activities

#### **Day Prior**

- Finalize and collect in one location all supplies and equipment required

#### **Day of Event**

- Volunteers arrive at least 1 hour prior to start of event
  - Provide volunteers nametags
- Place clear, large signage to parking location and walking to check-in
- Check-in girls/parents
  - Provide nametags and group assignments
- Distribute and collect surveys at beginning/end of event
- Plan for volunteers to leave 1 hour later than end of event for cleanup

#### **After Event**

- Review surveys
- Discuss and record lessons learned and ways to improve

## **Category Descriptions**

### *Event Location:*

- Description/Organization: The event has been held at a local college campus to enable girls and parents to experience campus life. The event can easily be held at any other location.
- Best Practices:
  - Main ingredient is sharing the enjoyment of STEM
  - Ensure enough space for activities and parent program

### *Student Organizations:*

- Description/Organization: If event is held on a college campus there are numerous STEM student organizations and clubs looking for outreach opportunities. Empowering the students can help build leadership and organizational skills.
- Potential Student Organizations: SWE, WIC, SHPE, MAES, AWIS, NSBE, ASCE, ASME

### *Registration:*

- Description/Organization: Registration is required for participants to attend the event. The cost of the event is usually free to participants with local industry and organizations picking up the expenses for rooms, food, and supplies. Since there is no fee to attend, up to 20% become no-shows.
- Best Practices:
  - Registration should include at minimum: parent name, parent email, parent phone, child name, food allergies, total number of participants in family
  - Use of services like Eventbrite or Google Docs can aid in the registration process

### *Advertising:*

- Description/Organization: Advertising for the event is normally done through a local science advocate organization, Girl Scouts, and/or directly contacting partner schools of the university.
- Best Practices:
  - When planning, check for conflicts with other events
  - Girl Scout Troops are a great way to get information to girls and parent
  - Make the advertisement exciting and of visual interest

### *Keynote Speaker:*

- Description/Organization: A short time is allotted at the beginning of the event for one or two female STEM professionals to tell their story. Topics could include: their childhood, how they became interested in STEM, support or lack thereof to complete a STEM degree, and how they juggle parenthood and work. Speakers are found from the local industry and should be engaging and relatable. Ensuring the speaker directs the presentation to the middle school level and can convey the fascination and worth of her work is imperative. At times, a panel of a few college students and/or STEM professionals is employed in place of a keynote.

- Best Practices:
  - Keep it short: 10 minutes max. Otherwise, the girls will lose interest.
  - Change it up: Mix in videos, demonstrations, activities, more than one speaker, etc.
  - Keep the parents and girls together for this part.

*Parent Program/Student Panel:*

- Description/Organization: Parents are able to hear from College Advisors who provide information on requirements to get their daughters to college and financial planning. Additionally, a student panel is put together from diverse STEM students, who share their personal experiences and permit the parents to ask questions of interest. Parents also get to experience the campus and lab tours.
- Best Practices:
  - Prep the speakers and panelists before the event (not day of)
  - Less is more! Number of panelists should not exceed 5
  - Do NOT have each panelist answer every question
  - Leave a majority of the time for questions from parents, but have topics in case they run out of questions
  - Inform parents of other programs to help inspire girls in STEM and college progression

*Volunteers:*

- Description/Organization: Volunteers can come from the community, industry, and the college campus. Need to ensure they are trained on the best message to present to girls. The AAUW report “Why so few?” provides some recommendations to breaking stereotype threats and counteracting bias.
- Best Practices:
  - Energize – Volunteers should bring excitement and energy of their passion for STEM
  - Along with required volunteers it is best to have:
    - Extra people not assigned to fill in as needed
    - Assigned roamers to facilitate help
    - Assigned timekeeper to keep to the schedule
    - Assigned lunch runners (if required)

*Emails to Volunteers and Participants:*

- Volunteers:
  - 2 months prior – send call for volunteers
  - 1 week prior – reminder email with times, locations, and responsibilities
  - Provide guidance on how to be inspiring to the girls
- Participants:
  - Immediately after registration complete – send generic email to participants with welcome and indication of more information to follow
  - 1 week prior – reminder email including detailed parking map and directions to venue and sign-in, food if any to be served, and weather details: jacket or sunscreen

### *Group Dynamics:*

- Description/Organization: The program begins and ends with the parents and girls together. Most of the day consists of a separate student and parent track. Girls are split into smaller groups to encourage more verbalization and communication with female college students as well as to provide a more convenient environment for activities. One female college student may have 6-10 girls in a group.
- Best Practices:
  - Keep the groups to 6-10 girls with an enthusiastic college student
  - Stay in groups through rotations and lunch

### *Campus/Lab Tours:*

- Description/Organization: The girls (and parents in a separate group) are taken on a campus tour to get familiar with the college campus. The tour should show girls and parents parts of the campus and labs that most people do not get to see. Girls and parents should feel like they are getting the behind-the-scenes tour. Engineering labs that have sparked the most interest include: concrete canoe, robotics, soil erosion, materials research, solar energy, and structural.
- Best Practices:
  - Don't make it a marathon – make the walking reasonable
  - Make the girls/parents feel special
  - Don't come across as a commercial for the university

### *STEM Activities:*

- Description/Organization: Science and engineering demonstrations and builds allow the girls to explore the STEM path in a real-world environment. A more detailed description of the activities that have been effective is included in the following section.
- Best Practices:
  - Timed rotations works best (10-15 minutes at each table)
  - Themed tables – have numerous demos or activities with a central focus at each table.
  - Make it fun and relevant to real world applications
  - Best if activities can tie in to work that your company performs

## **Potential Activity Descriptions**

### **Math Empowerment**

All teams need to attend this table. Math puzzles and how math can be fun. Visualize how cool math tricks can actually be easily understood.

### **Resonance**

Acoustics is the interdisciplinary science that deals with the study of sound, ultrasound, and infrasound. Acoustics was not studied in a scientific manner until Pythagoras took an interest in the nature of musical intervals. Sound waves have different frequencies which we can hear as different notes or pitches. For humans, hearing is limited to frequencies between about 20 Hz



and 20,000 Hz. The different activities show the different frequencies possible and the effect they have on materials. Some of the resonance demos we have found to work best are below.

- **Chladni Plates:** This shows resonance in the form of a vibrating plane. This two-dimensional demonstration shows that instead of nodes being points (as they are on a string), the patterns of the sand form lines that lie on the nodes whereas sand bounces off any area that is an antinode. Various shapes can be formed.
- **Wine Glass:** When the frequency of the vibration created from alternating kinetic and static “slip-stick” friction between your fingers and the rim match the natural frequency supported by the glass, it resonates.
- **Tibetan Singing Bowl:** The same phenomena that occurs with the wine glass also occurs with wood against brass causing the same “slip-stick” phenomena.
- **Chinese Water Bowl:** Exact replica of the bowl found on the outskirts of Beijing, China, dated at around 500 B.C. This holds a standing wave created by the frequency added by the “slip-stick” friction between skin and brass. If the timing of friction is close enough to the natural frequency of the bowl, and if the standing waves on the surface of the water become great enough, then jets of water will erupt.
- **Musical tubes:** These tubes were made to resonate at certain musical notes. Let the students hear the different pitches and explain how the different lengths support different size waves. You can try playing different songs having each student holding a different tube so they each have a note to play.

### **Light**

Students see how prisms are used to split up light into a rainbow (ROYGBIV). Also we can take the colors and add them to get white light. A virtual image can appear to exist, but really only exists from the reflection of the mirrors. Laser communication systems are fun as well. Students can learn about waves and signals while observing the information from a camera and microphone being sent across a laser beam.

### **Liquid Nitrogen**

Liquid nitrogen is the liquid produced industrially in large quantities by fractional distillation of liquid air. The temperature of liquid nitrogen is  $-321^{\circ}$ . Liquid nitrogen must be kept in a special container, like a thermos (Dewar), to keep it from reverting to a gaseous state. Liquid nitrogen is used in cryogenics, food processing, and other science experiments.

### **Recycling**

Reduce, reuse, recycle! Come learn about the process of recycling. The planet is depending on you. Find ways how *you* can reduce, reuse, and recycle.

### **Liquefaction**

Soil liquefaction describes the behavior of soils that, when loaded, suddenly go from a solid state to a liquefied state, or having the consistency of a heavy liquid. Learn about soil, water, and earthquakes. Geotechnical engineers and environmental engineers work to ensure the ground is safe for building homes and structures.

### **Physics of Balls**

If two balls of different weights are dropped from the same height, which ball will fall to the ground the fastest? Explore the theories and experimentation of Galileo and Aristotle and learn about the conservation of energy. Also learn about the coefficient of restitution, also known as the “bounciness” of materials. Did you know different sports materials were designed to perform a certain way? Cylinders and bases are available from CENCO.

### **Air and Pressure**

Air is made up of atoms, and air has mass, so air has “weight” and the weight of air results in pressure. With bell jars (available from PASCO), students are able to explore the effects of pressure by creating a vacuum in this small apparatus. This is especially exciting when a marshmallow is put in a bell jar and the air is pumped out. Because a marshmallow is mostly sugar and air, the air pockets (like a balloon) will expand if the outside air pressure is reduced. Some of the air will escape from the cavities within the marshmallow (like a popped balloon), so when air is allowed back into the bell jar, the marshmallow will collapse.

### **Straw Rockets**

Rocket launchers can be purchased from Pitsco.com. Students are able to explore the concepts of aerodynamics and flight by building simple rockets out of straws, paper fins and a clap cap. They get experience in research and development by testing and redesigning their rockets based on how their rockets and others’ performed. It is a fun and easy activity for all ages. Once the launchers are purchased, the supplies are cheap and easy to find.

### **Robot**

Remote controlled robots have always had the best feedback of all the demos and activities. We have access to many unique and one-of-a-kind robots from our Lab, but fun ones can be purchased. Don’t be afraid to go out to the community and look for companies or organizations that are willing to bring out their robots as well.

### **Microbial Fuel Cell**

Most equipment and sensors which require power and underwater components usually utilize battery power. This requires replacement or recharging which can be time consuming and sometimes dangerous. A microbial fuel cell converts chemical energy directly into electricity. Bacteria serve as the catalyst to convert the substrate into electrons. KEEGO manufactures a small container for educational use to show the effects and utility of microbial fuel cells.

### **Foil Boats**

Students are asked to design a boat out of a single foil sheet that will be able to hold the most pennies in a tub of water. The foil can be designed into a boat of any shape. Cargo (pennies) is added slowly until the boat sinks. This is a great opportunity to discuss properties of boats and touch on key vocabulary – buoyancy, density, mass, etc.