# A Four-Year Study of a Female Engineering Outreach Program

## The Influence of Math Ability on Female Students' Career Decisions for Engineering

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## Abstract

The under-representation of women in engineering has encouraged universities to reach out to students during the formative school years. To show whether an outreach program is effective, determining whether there is correlation between participant interest and ability is critical, as it may possibly provide greater insight on how to improve the program. Women Engineers at the Beach , an innovative program of outreach offered at California State University, Long Beach, has been re-designed based on the findings from a correlation study which analyzed archival data of students over a four-year period. The study investigated whether a relationship existed between students' math ability and students' interest in engineering as a career choice.

## Introduction

Lack of career awareness by school teachers and counselors appears to be the prominent source of concern for outreach programs that strive improve the condition of women in engineering. According to a national study done by the Noel-Levitz education consulting firm, data collected from students from 302 college institutions showed that almost 50% of freshmen lacked confidence expected for college-level math and science (2008). Interestingly, an earlier report showed female students reporting lower levels of confidence in math and science, but conversely, their study skills and motivation to finish college rivaled that of their male counterparts (2007). The TIMSS 2007 report also revealed that no significant differences between boys and girls in math performance exist. Competing with old notions that boys are better at math than girls, Boaler (2005) contended that this stereotype contradicts the existing performance data which in fact show an increase in achievement by girls on the SAT math section. Hence, the dearth of women in engineering programs cannot be attributable to weak academic performance in math or science alone, and other factors must be examined.

## Problem statement

Outreach programs recognize the importance of intervention, but only a limited few attempt to look for causal factors via the application of research. Scarce resources and minimal funding for outreach, coupled by the nature of a discipline that still struggles to attract women, intensify the need for assessing programs for their effectiveness. While the climate for women has steadily changed over the past 20 years, the profession has yet to experience the kind of momentous institutional change seen in the gender overhaul of the legal and medical professions, also once dominated by men. Davis and Gibbin (2002) reported that while there is strong response from the engineering community to reach out to women, the nature of disjointed efforts often discourage women from entering the profession. Efforts to study the gender disparity in engineering are ambitious and pave the way for outreach legitimized by research; this study endeavors to take that route.

## The purpose and importance of the study

This study examined the efficacy of a female-exclusive engineering outreach program called, Women Engineers at the Beach . The program promotes engineering awareness to young girls and helps cultivate their desire for engineering career selection. Archival data mined from the first four years of the program was used to determine whether math ability had any influence on students' career decisions for engineering. Results have significant impact on the future program re-design as well as setting the tone for other women in engineering initiatives.

## Background

### Description of the program

Research has confirmed that factors affecting women's career choice for engineering have more to do with awareness and interest and less with ability. Studies have provided undisputable data regarding gender differences in math and science achievement and reveal no correlation between biological factors and ability. Career decisions of women are largely influenced by socio-cultural expectations. With this in mind, Women Engineers at the Beach focuses on how participants receive and process information and how their interest can be sustained.

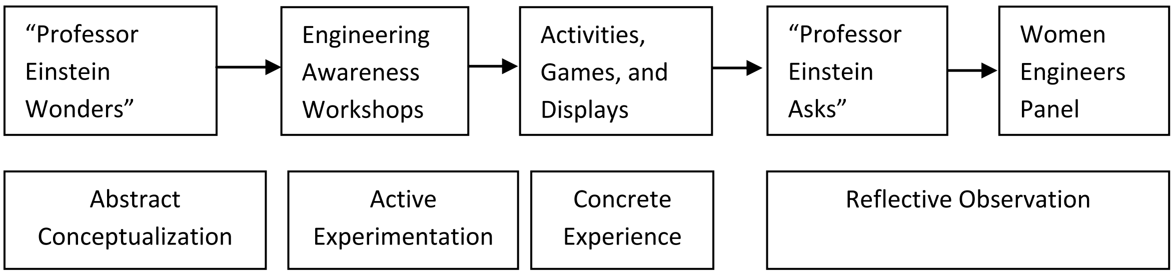

Figure 1. Outreach design based on Kolb’s Experiential Learning theory.

### Program participation

While Women Engineers at the Beach appreciates the many ways that outreach can stimulate personal drive and encourage a respect for accumulated knowledge for all students, it is sensitive to the constraints caused by limited funding. To maximize resources and funding, the program is careful to select those students who will most benefit; these include students who perform at grade-level math or higher. It also values those types of behaviors observed in high achievers, thus, it also promotes to the gifted and talented population.

### Experiential Learning Theory

It is not sufficient for students to simply have an experience but rather, they need to extend their learning by reflecting on what they saw and did. Kolb (1983) purported that natural learning involves four stages, and that immediate and real experience was necessary: abstract conceptualization (thinking about an idea), active experimentation (doing something with an idea), concrete experience (applying new knowledge using new skills to real-world situations), and reflective observation (connecting new knowledge and new skills to real-world relevant situations in a critical way wherein new constructs of thinking are developed). His Experiential Learning Theory (ELT) maintained that the learner could enter the cycle at any stage as long as he/she moves through it in sequence (1983). The apparent value of Kolb’s (1983) ELT was applied to both the over-arching outreach program design as well as the individual “Engineering Awareness” workshops. Figure 2 illustrates how ELT was used to re-design the workshop format and pedagogy.

Figure 2: “Engineering Awareness Workshop” configured on the basis of Kolb’s Theory.

| **Learning Stage** | **“Harnessing the Power of the Electron” workshop (Electrical Engineering)** |
|---|---|
| Abstract Conceptualization | Students view facts/ questions about electrical engineering in “Professor Einstein Wonders” PowerPoint. Students provided with basic understanding of electrical engineering and may have questions. |
| Active Experimentation | Students attend workshop where they are introduced to Ohm’s and Kirchhoff’s Law. Students learn how to measure voltage across circuit elements using a voltmeter, ammeter. Students work in groups of 3-4. Some discovery learning takes place, monitored by instructor. |

| | |
|---|---|
| Concrete Experience | Students see examples of electrical engineering, practice their learning during “Activities, Games/Display” period. Students answer real-world questions at “Question Stations” for EE workshop. Questions focus on electricity in the home and daily life provide relevance. |
| Reflective Observation | Students attend the “Women Engineers Panel” to listen to how engineer uses her knowledge of EE at work/home. Students ask questions and think about their own learning via survey. |

Scope and breadth of the study

An understanding of basic outreach theory, wherein a target population is identified and mechanisms for monitoring and control have been developed, has contributed greatly to development of the program. A few emergent theories also support the merit of female exclusivity in outreach. Foremost is the theory of "spotlighting", articulated by McLoughlin. McLoughlin (2005) stated that despite good intentions, singling women out by gender would cause them anxiety. However, she also asserted that “spotlighting” done corretcly can be effective. The conceptual framework for this study is founded on the premise that serving female students who perform better in math within the climate of a female-exclusive program would rival other outreach formats that serve lower-performing students within mixed-gender groups.

Research questions

How does math ability influence female students’ interest in engineering?

What correlation exists between female students’ math ability and interest in engineering?

Population and Sample

The population included 2,400 female students, from grades six through 12, recruited from schools located within a 30-mile radius of California State University, Long Beach for the years spanning 2001 to 2004.

Measurement tool

The measurement tool used was an eight-question survey administered to students before and after program participation. Four questions assessed the effectiveness of the program: Question 1: “Do you know what engineering is?” Question 5: “Are you now more familiar with engineering?” Question 6: “Would you be interested in this career?” Question 8: “Would you like to come again?”

Research design

$O_1$ X $O_2$

The research design employed was the pre-test post-test experimental paradigm, with X representing the intervention (the program), $O_1$, initial observation (response prior to intervention), and $O_2$, final observation (response after intervention). Specifically, $O_1$ refers to students’ background knowledge of engineering prior to program participation, and $O_2$, students’ perceptions of engineering following program completion.

Results

The tables below display math level, science course and special program enrollment for students served from 2001 to 2004.

Table 1: Number of students by math level, with respect to science course enrollment.

| Grade | Grade-level math | Grade-level math in science | % Grade-level math in science | Above grade-level math | Above grade-level math in science | % Above grade-level math in science |
|---|---|---|---|---|---|---|
| 6 | 248 | 105 | 42.3% | 99 | 82 | 82.8% |
| 7 | 133 | 67 | 50.4% | 203 | 178 | 87.7% |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | 134 | 52 | 38.8% | 205 | 185 | 90.2% |
| 9 | 199 | 101 | 50.8% | 136 | 115 | 84.6% |
| 10 | 99 | 45 | 45.5% | 289 | 267 | 92.4% |
| 11 | 153 | 87 | 56.9% | 195 | 175 | 89.7% |
| 12 | 65 | 32 | 49.2% | 275 | 236 | 85.8% |

Table 2: Number of students by math level, with respect to special program participation.

| Grade | Grade-level math | Grade-level math in special programs | % Grade-level in special programs | Above grade-level math | Above grade-level math in special programs | % Above grade-level math in special programs |
|---|---|---|---|---|---|---|
| 6 | 248 | 101 | 40.7% | 99 | 92 | 92.9% |
| 7 | 133 | 54 | 40.6% | 203 | 197 | 97.0% |
| 8 | 134 | 62 | 46.3% | 205 | 187 | 91.2% |
| 9 | 199 | 93 | 46.7% | 136 | 126 | 92.6% |
| 10 | 99 | 44 | 44.4% | 289 | 271 | 93.8% |
| 11 | 153 | 69 | 45.1% | 195 | 182 | 93.3% |
| 12 | 65 | 30 | 46.2% | 275 | 261 | 94.9% |

Table 3: Survey responses for years spanning 2001 to 2004.

| Item | Denoted as | Question | "Yes" | "No" | % "Yes" |
|---|---|---|---|---|---|
| Question 1 | Q1 | Do you know what engineering is? | 166 | 2,265 | 6.8% |
| Question 2 | Q2 | Did you enjoy the workshop? | 2,332 | 99 | 95.9% |
| Question 3 | Q3 | Was the presenter clear? | 2,002 | 429 | 82.4% |
| Question 4 | Q4 | Did the presenter answer all your questions? | 1,990 | 441 | 81.9% |
| Question 5 | Q5 | Are you now more familiar with engineering? | 2,222 | 210 | 91.4% |
| Question 6 | Q6 | Would you be interested in this career? | 1,916 | 515 | 78.8% |
| Question 7 | Q7 | Do you have any engineers in your family? | 376 | 2,055 | 15.5% |
| Question 8 | Q8 | Would you like to come again? | 2,210 | 221 | 90.9% |

Table 4: Math-level in relation to engineering interest and desire for repeat outreach.

| Grade level | Total No. students | Students at grade-level math | | | Students above grade-level math | | |
|---|---|---|---|---|---|---|---|
| | | No. Students | No. and % "Yes" Q6 | No. and % "Yes" Q8 | No. Students | No. and % "Yes" Q6 | No. and % "Yes" Q8 |
| 6 | 347 | 248 | 150 (60.5%) | 212 (85.5%) | 99 | 92 (92.9%) | 99 (100%) |
| 7 | 336 | 133 | 85 (63.9%) | 110 (82.7%) | 203 | 194 (95.6%) | 203 (100%) |
| 8 | 339 | 134 | 100 (74.6%) | 105 (78.4%) | 205 | 195 (95.1%) | 197 (96.1%) |
| 9 | 335 | 199 | 104 (52.3%) | 160 (80.4%) | 136 | 195 (91.9%) | 126 (92.6%) |
| 10 | 388 | 99 | 72 (72.7%) | 81 (81.8%) | 289 | 255 (88.2%) | 270 (93.4%) |
| 11 | 348 | 153 | 85 (55.6%) | 126 (82.4%) | 195 | 165 (84.6%) | 187 (95.9%) |
| 12 | 340 | 65 | 33 (50.8%) | 51 (78.5%) | 275 | 227 (82.5%) | 255 (92.7%) |

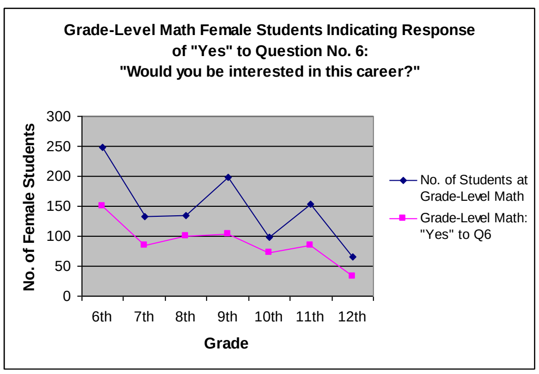


Figure 2. Graph of grade-level math students' response to Q6.

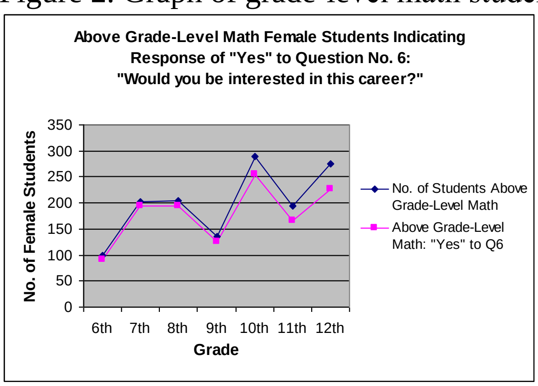


Figure 3. Graph of above grade-level math students' response to Q6.

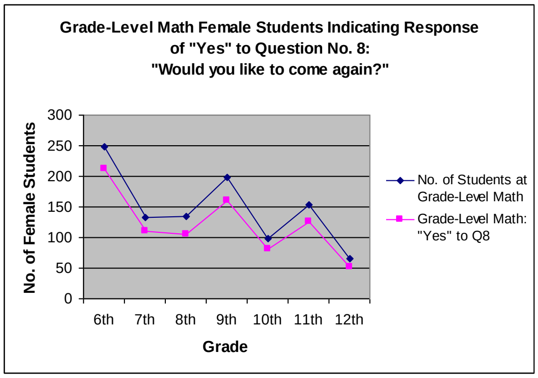


Figure 4. Graph of grade-level math students' response to Q8.

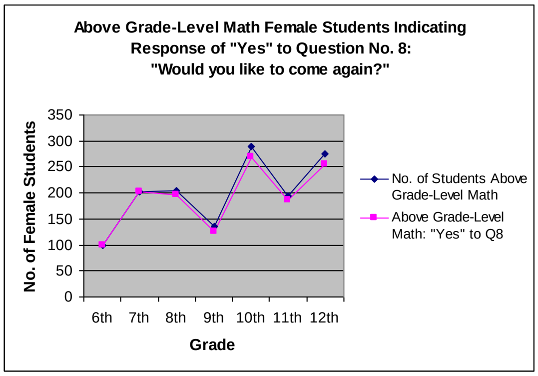


Figure5. Graph of above grade-level math students' response to Q8.

## Data Analysis

### The Pearson Product-Moment Correlation Coefficient

The Pearson product-moment correlation coefficient, r, is a measure of how well a linear equation describes the relation between two variables, X and Y. In this study, X and Y are represented by the independent and dependent variables of math level and student interest, respectively. It is defined as the sum of the products of the standard scores of the two measures divided by the degrees of freedom.

$$r = \frac{N\sum XY - (\sum X)(\sum Y)}{\sqrt{N\sum X^2 - (\sum X)^2}\sqrt{N\sum Y^2 - (\sum Y)^2}}$$

Figure 6: The Pearson Product-Moment Correlation formula.

Table 5: Value of r for grade-level math responses to Q6.

| Grade | X | Y | |
|---|---|---|---|
| 6 | 248 | 150 | r = 0.94 |
| 7 | 133 | 85 | |
| 8 | 134 | 100 | |
| 9 | 199 | 104 | |
| 10 | 99 | 72 | |
| 11 | 153 | 85 | |
| 12 | 65 | 33 | |

As an example, the below computation used data from Table 4 regarding the responses of grade-level math students to Q6 to generate the correlation coefficient, r.

$$r = \frac{7\{(248x150)+(133x85)+(134x100)+(199x104)+(99x72)+(153x85)+(65x33)\} - \{(248+133+134+199+99+153+65) \text{ x } (150+85+100+104+72+85+33)\}}{SQR\{7(248^2+133^2+134^2+199^2+99^2+153^2+65^2) - (248+133+134+199+99+153+53)^2\} \text{x } SQR\{7(150^2+85^2+100^2+104^2+72^2+85^2+33^2)-(150+85+100+104+72+85+33)^2\}}$$

$$r = 0.94$$

Table 6: Value of r for grade-level math responses to Q8.

| Grade | X | Y | |
|---|---|---|---|
| 6 | 248 | 212 | |
| 7 | 133 | 110 | |
| 8 | 134 | 105 | r = 1.00 |
| 9 | 199 | 160 | |
| 10 | 99 | 81 | |
| 11 | 153 | 126 | |
| 12 | 65 | 51 | |

Table 7: Value of r for above grade-level math responses to Q6.

| Grade | X | Y | |
|---|---|---|---|
| 6 | 99 | 92 | |
| 7 | 203 | 194 | |
| 8 | 205 | 195 | r = 0.98 |
| 9 | 136 | 125 | |
| 10 | 289 | 255 | |
| 11 | 195 | 165 | |
| 12 | 275 | 227 | |

Table 8: Value of r for above grade-level math responses to Q8.

| Grade | X | Y | |
|---|---|---|---|
| 6 | 99 | 99 | |
| 7 | 203 | 203 | |
| 8 | 205 | 197 | r = 1.00 |
| 9 | 136 | 126 | |
| 10 | 289 | 270 | |
| 11 | 195 | 187 | |
| 12 | 275 | 255 | |

Guilford's Guidelines

Guildford's Guidelines were used to interpret values of r, ranging from – 1.00 to + 1.00.

Table 9: Guildford's Guidelines

| r value | Interpretation |
|---|---|
| ± 0.90 – 1.00 | Very high correlation; very dependable relationship |
| ± 0.70 – 0.90 | High correlation; marked relationship |
| ± 0.40 – 0.70 | Moderate correlation; substantial relationship |
| ± 0.20 – 0.40 | Low correlation; definite but small relationship |
| > 0.20 | Slight; almost negligible relationship |

Explanation of the data arrays

While the thrust of this study focused on inquiring about students' level of math competency in relation to students' interest in pursuing engineering, the survey also included questions intended to gather students' prior knowledge of engineering as well as their opinion about their overall experience of the program; these questions may be of worth in the future work that would involve qualitative studies. The continual collection of this data is also intended to increase the sampling size so that future studies will benefit from a smaller margin of error with which generalizations to the larger population may be made. Table 3 shows responses to the eight-question survey as collected over a period of four years. Question 1 revealed that no more than 6.8% of students had prior understanding of what the engineering field involved. By contrast, students reported gaining more knowledge of engineering following program participation, confirmed by the 91.4% response rate to question 5. Questions 2, 3, and 4 inquired about students' opinion about the Engineering Awareness workshop; 95.9% of students reported that they enjoyed their workshop experience, 82.4% reported that they felt the workshop presenter was clear, and 81.9% of students reported that their questions were answered within the time-frame of the workshop. Students' perception of the workshop presenter differed by about 10% as compared to their perception of the workshop, in general. Since no supplemental questions were included to solicit more detail from the students as to what they meant, inference that responses might hint to the quality of the speaker cannot be confirmed. Interestingly, question 7 showed that 15.5% of students had engineers in their family; this particular data point might be later investigated to determine the influence of family career pursuits and or pressures on students' career decision-making. Aside from gauging students' level of interest, the survey also asked whether students had desire to return for repeat program participation. It was found that 90.9% of students wanted to return; this data provided the program director a willing and eager group of students for which the program was made available in succeeding semesters.

Question 6 as a positive indicator of interest in engineering

The rate of "Yes" responses from students performing at grade-level math was significantly lower than those performing above grade-level math, at 61.5% versus 90.1%, respectively, as displayed on Table 4. Those performing above grade-level math responded at a rate 28.7% higher than those at grade-level math. The response rate of students performing above grade-level math was unexpectedly impressive, but it is reasonable to expect that students who perform above grade-level would be more academically prepared to appreciate the mathematical-logical quality of an engineering-specific outreach program. Graphical analysis indicates a downward trend in expressed interest for students who performed at grade-level math, while an upward trend is seen for those performing above grade-level math, as displayed in Figures 2 and 3, respectively. The line-graph on Figure 18 represents increase in engineering interest as a function of performance in above grade-level or mathematics.

Question 8 as a positive indicator of desire to return for repeat program participation

The study found that the percentage of "Yes" responses from students performing at grade-level math (81.4%) was about 14.5% lower than responses from students who out-performed them in math (95.8%), as shown on Table 4. Notwithstanding the differences between higher-level math respondents to those performing at grade-level, the program was overall pleasing to most participants, as seen by the response rate of 88.6% for interest for program return.

With respect to interest in the engineering career, relative to the grade levels of six through 12, data showed that middle school participants (grades six through eight), performing at grade-level math, responded at 66.3% while high school students (grades nine through 12), performing at grade-level mathematics, responded at 57.9%. Similar lower rate was shown for students who performed above grade-level math. Middle school students responded at 94.5% while high school students, at 86.8% regarding interest in engineering. On either data points regarding interest, middle school students showed more interest with an increase of 8% over their high school counterparts. There was no significant difference between middle and high school participants with respect to desire to return to the program, 82.2% versus 80.8% (grade-level math) and 98.7% versus 93.7% (above grade-level math).

Explanation of the values of r, the Pearson Product-Moment coefficient

The values of r for all subgroups of data: 1) grade-level math responses to Q6, 2) above grade-level math responses to Q6, 3) grade-level math responses to Q8, and 4) above grade-level math responses to Q8, were computed as: 0.94, 1.00, 0.98, and 1.00 and displayed in Tables 5 through 8. Based on Guilford's Guidelines, Table 9, all values of r indicated "very high correlation; very dependable relationship". Thus, this study has established that math ability of female students has a strong relationship to the expressed interest in engineering.

Conclusions

"There is a growing acceptance within the engineering community that there needs to be major changes in the culture of engineering and as part of this, a greater participation of women." (McClean, C. 1977)

In 1990, a report entitled, Shortchanging Girls, Shortchanging America: A Call to Action, encouraged many schools across the country to provide gender-equitable opportunities for learning. Showing that women can be successful in areas that have traditionally been more popular among men is a good starting point. While many outreach programs have been effective in disseminating vast quantities of career information to female populations, few have focused on serving homogenous populations of female students based on criteria other than gender. This study examined the Women Engineers at the Beach program for its ability to inculcate awareness and interest in high-achieving students. Survey results from over 2,400 female students were examined with respect to math ability and how it correlated to interest in engineering careers. It found that only a small percentage of students possessed any prior background knowledge of engineering, indicated by a response of about 6.8%. This small percentage hailed from those students who performed above grade-level math as well as those who were already participating in special academic enrichment programs designed for pre-college success. The overwhelming number of students who reported having no prior knowledge of engineering, even amongst those who were enrolled in advanced mathematics courses, attests to the vastness of the problem regarding lack of engineering awareness in general. After having completed the program, the majority of students reported having learned more about engineering, indicated by a response of 91.4%. The results of this study demonstrated that the higher the level of math ability, the greater the inclination toward engineering career interest. Women Engineers at the Beach aims to influence the tendency of high-achieving female students toward selecting engineering careers.

The type of female students attracted by engineering-specific programs.

The study utilized a sample population of female students who were selected according to their ability in math. Many students were also enrolled in science courses that required advanced math ability, such as AP Chemistry, AP Physics, and Statistics. Students who performed higher in math were also shown to be those participating in special enrichment programs, including GATE (Gifted and Talented in Education), PACE (Program of Accelerated Curricular Activities), and AVID (Achievement Via Individual Determination). The premise that female students, who performed at grade-level math and beyond, were more academically prepared to handle and appreciate a program focused entirely on engineering, was established by this study.

The role of math level in female students' interest in engineering.

57.6% of students performed at above grade-level math, while most students performed at grade-level math (73.5%). Although any student performing at grade-level math has the potential to succeed in engineering, students who out-perform their peers in math ability have greater potential to enter the engineering program more prepared. 61.5% of students performing at grade-level math responded "Yes" to Q6 (interested in selecting engineering as a career), while 81.4% expressed willingness to return for repeat participation in the program. More impressive, is the data reported by students who performed above grade-level math; these showed on average response rate of 90.1% as to indicating an interest in the engineering career, with a response of 95.8% expressing desire for program return. This data illustrates that the students enjoyed the program of outreach and wished to return.

Correlation between math level and students' interest in engineering.

The study showed undisputable correlation between female students' math ability and their inclination toward considering the engineering career. All values of r were computed as being above 0.90 on Guilford's Guidelines, and thus, were interpreted as having very high correlation, one in which the relationship between the independent (math ability) and the dependent variable (interest in engineering) was dependable and reliable. Therefore, it can be concluded that interest in engineering is intrinsically linked to math ability.

Although there are many models and approaches for engineering outreach, few are designed with a focus on established research. This study has determined that an effective model for a female-exclusive engineering-specific outreach must include the following components: 1) high-achieving students performing at grade-level math of higher, 2) program format and engineering-specific workshops based on Kolb's Learning theory, 3) math and science-based hands-on activities.

Study improvements and the future.

Although the study quantified the nature of math ability of female students as it relates to knowledge and interest in engineering through the experience of outreach, it has hopes of determining whether participation in the outreach program will transfer into steady increases in enrollment in academia at the institutional level. Currently, seven students, all junior-year engineering majors, have been identified as former participants of the Women Engineers at the Beach program. According to a six-year study of undergraduate women in engineering and science, conducted by the University of Washington, it was reported that individual tracking of students proved worthy in actually recruiting and retaining them in engineering (Brainard, 1991). As no formal mechanisms yet exist to identify past participants, the need to track students over time is evident and requires additional resources to enable a longitudinal study. Ultimately, more innovative models for outreach are needed to maximize students' native ability and fuel interest during the formative years, along with on-going support to retain the women who do enter the profession. Math preparedness coupled with purposeful program re-design was found to be effective in entrenching information in the young mind. These findings have helped the program to evolve over time and are responsible for much of its success. Anecdotal data has also provided inspiration for future studies that will explore whether female-exclusivity in engineering-specific outreach might heighten female students' interest in the profession and serve to reinforce the idea that engineering is a rewarding career for women.

References

American Association of Engineering Societies. 1996. “Engineering and Technology Enrollments (Fall 1982 – Fall 1996), *Engineering Workforce Commission.* Washington, D.C.

Boaler, J. 2005. “No difference in achievement in math and science for high school girls” (http://ed.stanford.edu/suse/faculty/displayFacultyNews.php?tablename=notify1&id=276), Retrieved on February 14, 2009.

Brainard, S. & Carlin, L. 1991. “A Six-Year Longitudinal Study of Undergraduate Women in Engineering and Science.” *Journal of Engineering Education*, 1998, pp. 369-375.

Davis, L., and R. Gibbin. 2002. Raising Awareness of Engineering Washington, D.C.: The National Academies Press.

Engineering Workforce Commission of the American Association of Engineering Societies, Inc. 1997. “Engineering and Technology Degrees Granted.” New York: N.Y.

International Association for the Evaluation of Educational Achievement, Trends in Mathematics and Science Study, 2007.

McLoughlin, L.A. 2005. Spotlighting: emergent gender bias in undergraduate engineering education. Journal of Engineering Education 94(4), 373-382.

National Academy of Engineering (NAE), 2008, Changing the Conversation: Messages for Improving Public Understanding of Engineering, The National Academies Press, Washington, D.C.

National Center for Education Statistics. *Digest of Education Statistics*, 2007 (http://nces.ed.gov/programs/digest/d07), retrieved on February 1, 2009.

Noel-Levitz, Inc. “National Freshman Attitudes Report.” Iowa City, IA: Noel-Levitz, 2007.

Noel-Levitz, Inc. “National Freshman Attitudes Report.” Iowa City, IA: Noel-Levitz, 2008.

Scientists and Engineers Statistical Data System of the Division of Science Resources Studies, National Science Foundation, 2007.

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