FiERCE: Empowering Girls in Engineering Through Role-Models and Mentoring

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Abstract

Leveraging current research indicating that the presence of mentors and role-models are instrumental to the recruitment and retention of females in engineering, the primary purpose of this study was to examine the effect of role-models and mentors on the attitudes and self-confidence of middle school girls towards engineering. Participants were cohorts of middle school aged females, paired with Penn State University (PSU) female undergraduate engineering students. The study was conducted by exposing participants to a consistent series of activities that fostered creative thinking, problem solving, and real-world engineering, all while encouraging and facilitating interaction amongst the cohorts. The results outlined below focus mainly on the impact of the program on the middle school students. Comprehensive assessments were embedded into every aspect of the program in order to evaluate program effectiveness and outcomes. Regular, structured interactions between the participants resulted in statistically significant increases in both the interest and confidence in engineering amongst the young students as well as the positive influence of mentors and role-models.

Keywords: STEM Outreach, K-12 Outreach, Females in Engineering, Role Models, Mentoring, Diversity

Introduction

Current literature is flooded with research and reports on the science, technology, engineering and math (STEM) “crisis”, often citing now-familiar statistics. More specifically, statistics regarding the state of girls and women in STEM are also frequently mentioned and, despite 20 years of research, remain somewhat alarming. [1-3] Particularly relevant statistics are that in 2013 only 19.2% of bachelor’s degrees in engineering were awarded to women, women remain underrepresented in the STEM workforce, where 13% of practicing engineers are female, and women comprise only 14% of tenure track faculty.[3]

Much research has been done to elucidate the factors behind the numbers. An American Association of University Women (AAUW) study concludes that social and environmental factors contribute to the underrepresentation of women in engineering, and that girls’ achievements and interest are shaped by the environment around them.[4,5] Supporting research identifies social pressures such as sexism, discrimination, isolation and lack of role models as pressures that leave female students rejecting the field of engineering.[6,7] Another major factor that plays a prominent role in retention of women in engineering is self-efficacy. Female students typically start college with a lack of confidence in their abilities as compared to their male counterparts despite comparable academic skills, and women typically transfer out of engineering earlier and with a higher GPA than men as a result of their self-doubt.[8-11] In addition, between 5th and 9th grade, gifted girls, perceiving that smarts aren't sexy, hide their accomplishments, indicating a strong argument towards providing girls with a segregated environment while pursuing STEM interests.[12] Key findings with respect to increasing student interest in STEM indicate that the most important methodologies for high impact programs involve exploring STEM long term,[13] inspiring career exploration,[14] and exposing participants to role-models. Although hands-on activities generate an interest in STEM, it is the interaction with role-models that is instrumental in generating a lasting interest in technical careers.[14-18]

Program Implementation

In order to develop and deliver a high impact program following the key methodologies outlined above, the first stage of the project involved identifying a cohort of 56 middle school girls and pairing them with 10 female undergraduate engineering students ranging from freshmen through seniors.

In order to recruit PSU students, an initial explanatory email was sent to all female undergraduates registered as either engineering majors or pre-majors. A meeting was held to explain the program and invite students to participate. In addition, the undergraduates earned independent study credit for participating in the project. As a result of recruitment efforts, ten PSU students signed up to participate in the project.

Participants were asked to complete an early assessment of attitudes and confidence level regarding STEM before activities began, and comprehensive assessments were embedded into every aspect of the program to evaluate efficacy.

It was quickly realized that the project, because of its scope and importance, would benefit from a name, hence the program became known as FiERCE: Females in Engineering, Role-models Can Empower! Throughout the course of the FiERCE program, the Penn State mentors, middle school students, and engineers when available, met bi-weekly to engage in purposeful hands-on activities. The activities were organized to provide the students with a structured introduction to engineering in a fun, interactive way. Table 1 summarizes the major activities.

Table 1: Outline of Major Activities

Activity	Description
Kick-Off Event	Visit to Penn State Berks during National Engineers Week. Building tour, Lego Competition
Career Exploration	Panel discussion involving career exploration
Engineering Challenge	Zip Line - Problem-Solving Activity
CAD Workshop and Design Activity	Introduction to Computer Aided Design Project teams design boats and model using CAD software for Float-Your-Boat Challenge.
3D Printing	3D printing workshop and activity. Students 3D print the boats they designed and modeled.
Float-Your-Boat Challenge	Major engineering design challenge
Career Exploration, Brain Games	Career discussion and interactive brain-game activity

Engineering Challenge	Save Slimey - Problem-Solving Activity
Introduction to Real-World Engineering Problem	Students are introduced to a long-term, real-world engineering challenge
Meet The Client	Students are introduced to their clients, who have presented them with a problem they would like solved. Teams of students become the engineers who must solve the problem with the guidance of their mentors.
Brainstorming, Concept Selection	Teams brainstorm ideas and identify a solution.
Presentation to Clients	Student teams meet with their clients, present solutions for final approval.
Design and Build Solution	Teams, with the guidance of their mentors, order parts and build and test their products.
Final Product Showcase	In a major event, students present their final products at a showcase held at Penn State. Students present both the product and a poster outlining their work. All stake-holders are invited to attend including parents and teachers.

A short lecture was delivered prior to each activity to introduce the content and eliminate the need for prerequisite knowledge. Once the lecture was completed, the PSU mentors were each responsible for a group of 3-5 students and directed the activity for their group. Activities ranged from short, isolated activities that could be completed in a single session, to much more complex activities such as 3D modeling and printing that involved significant interaction with and guidance from the PSU mentors. As can be seen in Table 1, the activities were designed to emphasize creativity and problem solving in an organic way. Each of the "problem-solving" activities began with an introduction to the physics principles being explored that week. Following the introduction, the mentors and students brainstormed possible solutions. Each activity incorporated a testing station, where the students could explore the effects of various relevant variables. For example, in the zip-line challenge, the testing station consisted of a rig to evaluate the effect of weight on speed of the gondola as it traveled down the zip line. The testing stations were designed to guide student thinking with respect to significant variables, without explicitly providing the necessary information. This form of delivery was very effective in developing their creative thinking and problem solving skills as directed toward a tangible outcome.

The "Introduction to Real-World Engineering" design problem mimicked real-world engineering by introducing the girls to an open-ended problem to solve for a client, rather than a guided solution. The clients were teachers in the middle school who identified problems in their classroom (ranging from computer cords getting tangled to the problem of young students not being able to reach the whiteboard). The fact that the teachers were the clients enhanced the projects because the girls had a familiarity with the client and environment, could relate to the problems, and saw an immediate benefit of their solutions. The presence and mentoring of the

Penn State students was instrumental to the success of the projects. The final solutions were showcased in an evening event at Penn State Berks, to which parents, teachers, and administrators were invited. At this event, students presented the process and products, which neatly tied up the entire program by having them demonstrate not only the technical aspects of their work, but also the soft skills required in the engineering profession.

Evaluation and Outcomes

Because this was a sustained program conducted over a period of time, the students were able to explore STEM long-term. The importance of this cannot be underestimated, as single events with random volunteers expose students to engineering, whereas this long-term program immerses them in engineering and allows relationships between the mentors and mentees to build. Validation of the effectiveness of the program was attained through a series of assessments, which were obtained from a combination of published surveys[19] as well as questions specific to the FiERCE program. Survey questions asked the middle school participants to rate their responses to a series of forty-six questions on a scale of 1-7 where 1 = strongly disagree and 7 = strongly agree. Identical surveys were distributed prior to the start of the program as well as at the conclusion. A sampling of survey questions are shown in Table 2, with average survey response scores indicated. Additional questions exhibited similar results. Questions ranged from student views on math, science and engineering, to 21st century skills to perceptions about engineering. Independent t-tests gave a two-tailed P value less than 0.05, which is considered to be statistically significant.

Table 2: Pre and Post Program Responses (Middle School Students)

Survey Statement	Pre and Post Survey Percent Change
I would consider choosing a career that uses math	21%
I would consider a career in science	8%
I would consider a career in engineering	12%
I believe I can be successful in a career in engineering	10%
I like to imagine creating new products	15%
I don't answer questions in class because I'm afraid I'll get the answer wrong	-29%
The males in my classes are more confident than the females	-18%
Engineers and scientists are nerds	-20%
I think engineering is a career for males	-24%

There are several survey responses that merit discussion. It is interesting to note that the percent change in the interest in a career in math is much higher than that of science. From the data it can be seen that the students had a much lower interest in math at the start of the program. By careful selection of activities, students were able to establish the real-world application of math, resulting in increased interest. In addition, increases in both the consideration of a career in engineering as well as the confidence of a successful career in engineering were statistically significant as well. What is most thought-provoking is that the largest changes were not specific to choice of career, but unveiled themselves in the questions regarding perceptions. Perceptions with respect to their abilities as compared to their male counterparts, their confidence, and their opinion of engineers all improved dramatically. All of the perception questions are most directly influenced by the partnering of these young female students with strong female undergraduate role-models.

Program Outcomes

To address and assess the goals of the program, the students responded to additional survey questions with the following outcomes, as shown in Table 3.

Table 3: Assessment of Program Goals

Goal	Outcomes
Identify a measurable increase in interest in studying STEM.	89% of respondents indicated that this program made them like science more than they did prior to the program, 29% of those respondents indicating that they did not like science at all prior to the program but have now developed an interest.
Confirm that the program taught the students how STEM applies to real-world problems.	78% of students indicated that the program made them think more about how things work, 70% responded that the program made them more of a problem solver, and 70% of students felt it made them apply knowledge rather than just memorize it.
Foster a positive environment that will provide a measurable increase in attitudes and confidence toward STEM by way of mentors and role-models.	93% of students felt positive about their relationships with the PSU mentors, with 82% reporting that working with the mentors made them more confident about doing engineering work. 100% of the Penn State students felt that they were able to serve as positive role-models to the middle school girls. 100% of the PSU undergrads indicated that this program increased their confidence in their career choice, and provided them with validation of their skills

Create a multi-dimensional approach to mentoring	100% of the PSU students indicated that in addition to the mentoring relationship they developed with the undergraduates, they also developed mentoring relationships within their PSU cohort.

Overall, the survey results validate the significant impact the program had with respect to the effects of a sustained program as well as the effects of role-models and mentors on the attitudes and confidence with respect to the STEM fields. A statistic of particular interest is that 90% of students responded that they were surprised by how this program made them more interested in STEM and more confident in their abilities. This astonishing statistic speaks to the important problem that early on, young girls assume that they do not have an interest in STEM and it may take a concentrated effort to change that perception.

Conclusions

A long-term program to expose young girls to mentors and role-models in order to increase their interest and confidence in the engineering field was developed. The program was implemented by exposing students to a consistent series of activities that fostered creative thinking, problem solving, and real-world engineering, all while encouraging and facilitating interaction amongst cohorts of females in various stages of development. The compellingly positive effect, as determined by both assessments and observation, of the PSU mentors on the middle school girls indicates that this program was an overwhelming success and achieved its goals.

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Laura A. Bayerle is the Technology Coordinator at St. Ignatius Loyola Regional School, and serves as co-director of the FiERCE program. She has long been a defender of the importance of developing critical thinking skills in all students. She is a firm believer that no one should be discouraged from a career path, and sees this time as especially important to encourage girls to follow their dreams. Bayerle has a degree in Biology, with a concentration in Biotechnology.

References

1. National Science Foundation, National Center for Science and Engineering Statistics. 2017. Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017. Special Report NSF 17-310. Arlington, VA. Available at www.nsf.gov/statistics/wmpd/.
2. National Science Board. 2016. Science and Engineering Indicators 2016. Arlington, VA: National Science Foundation (NSB-2016-1
3. Yoder, B. L. (2015). Engineering by the numbers. American Society for Engineering Education, Washington, DC. https://www.asee.org/papers-and-publications/publications/college-profiles/15EngineeringbytheNumbersPart1.pdf
4. Hill, Catherine. "Why So Few? Women in Science, Technology, Engineering, and Mathematics." AAUW: Empowering Women Since 1881, AAUW, 2013, www.aauw.org/research/why-so-few/.
5. Belec, Hannah M. "10 Ways to Get More Women into Engineering and Tech." AAUW: Empowering Women Since 1881, AAUW, 26 Mar. 2015, www.aauw.org/2015/03/26/add-women-engineering-and-tech/.
6. Grandy, J. (1998). Persistence in science of high-ability minority students. Journal of Higher Education, 69(6), 589-620.
7. Li, Q., Swaminathan, H., & Tang, J. (2009). Development of a classification system for engineering student characteristics affecting college enrollment and retention. Journal of Engineering Education, October, 361-76.
8. Lord, S., Camacho, M., Layton, R., Long, R., Ohland, M., & Wasburn, M. (2009). Who's persisting in engineering? A comparative analysis of female and male Asian, black, Hispanic, native American, and white students. Women and Minorities in Science and Engineering, 15, 166-190.
9. Bottomley, L., Rajala, S., & Porter, R. (1999, November). Women in engineering at North Carolina State University: An effort in recruitment, retention, and encouragement. Paper presented at 29th ASEE/IEEE Frontiers in Education Conference, San Juan, Puerto Rico.
10. Hartman, H., & Hartman, M. (2006). Leaving engineering: Lessons from Rowan Universit'ys College of Engineering. Journal of Engineering Education, January, 49-61.
11. Jaeger, B., Freeman, S., Whalen, R., & Payne, R. (2010). Successful Students: Smart or Tough? ASEE 2010.
12. Gurian, Anita. "Girls with Low Self-Esteem: How to Raise Girls with Healthy Self-Esteem." Education.com, 24 Apr. 2014. Web.
13. Mosatche, H. S., & Lawner, E. K. (2010a). Access for Young Women: Curriculum for girls' leadership and promotion of gender equity in math and science.Queens, NY: Queens Community House.
14. Women in STEM: A Gender Gap to Innovation, ESA Issue Brief #04-11. U.S. Department of Commerce Economics and Statistics Administration: Washington, DC, 2011.
15. Dasgupta, N.; Asgari, S. Seeing is Believing: Exposure to Counterstereotypic Women Leaders and its Effect on Automatic Gender Stereotyping. J. Experimental Social Psychology 2004, 40 (5), 642−658.
16. Gibson, D. E. Role Models in Career Development: New Directions for Theory and Research. J. Vocational Behavior 2004, 65 (1), 134−156.
17. Karukstis, K. K.; Gourley, B. L.; Wright, L. L.; Rossi, M. Mentoring Strategies to Recruit and Advance Women in Science and Engineering. J. Chem. Educ. 2010, 87 (4), 355−356.

18. Bamberger, Y. M. Encouraging Girls into Science and Technology with Feminine Role Model: Does This Work? J. Sci. Educ. Technol. 2014, 23 (4), 549−561.
19. Friday Institute for Educational Innovation (2012). Student Attitudes toward STEM Survey – Middle and High School Students, Raleigh, NC: Author.