

Engineering Workshops for Middle School Girls

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Engineering Workshops for Middle School Girls (Research to Practice)

Strand: Principles of K-12 Engineering Education and Practice

Abstract

The lack of female participation in the field of engineering is somewhat astonishing. One study found that only 11% of professional engineers are women.¹ According to the American Association of University Women (AAUW), there are multiple possible factors that contribute to this phenomenon, including societal bias and the environment of the STEM classroom. As a society, it seems to be a natural assumption that the subjects of math, science, and engineering are traditionally “male” subjects. Research has been done to show how “stereotypes can lower girls’ aspirations for science and engineering careers over time.”² In order to eliminate societal bias, the environment and manner in which STEM subjects are taught to girls must change. “If girls grow up in an environment that cultivates their success in science and math with spatial skills training, they are more likely to develop their skills as well as their confidence and consider a future in a STEM field.”² This project was designed to target middle school-aged girls who are approaching high school with interactive engineering projects. This project explores whether exposing middle school girls to engineering in a supportive environment increases their chances of studying STEM subjects later in their careers.

This project included organizing and hosting three different engineering workshops for approximately twenty middle school girls to introduce them to the subject of engineering in a supportive environment. At each engineering workshop, the girls were introduced to engineering by doing an activity that involved creativity and problem solving skills. Each of the three workshops focused on a different discipline of engineering and the students were able to take home what they created. For electrical engineering, the students created an interactive miniature pinball machine while for chemical engineering the students learned chromatography principles to make tie-dye shirts. The mechanical engineering session resulted in the construction of small trebuchets capable of launching clay balls. In addition to using students' creativity and problem solving skills, the goal of the project was for girls to see themselves as potential engineers after each session. To measure the success of this project, each of the girls participating was given a survey before and after each session asking them to express their interest in engineering on a scale of 1 to 5. For all sessions combined, those students "somewhat interested" to "very interested" in engineering increased by 23%. Based on these surveys and student comments, we are confident that the middle school girls understand more of what an engineer does and can see themselves as future engineers.

Introduction

While traditional Western cultural assumptions view engineering as a masculine domain, historian of technology Ruth Oldenziel reminds us that “[t]here is nothing inherently or naturally masculine about technology.”³ Rather, Oldenziel traces the historical development of engineering and technology as gendered domains by presenting their “maleness” as a socially constructed and relatively recent phenomenon. Oldenziel’s work provides a broader historical and theoretical context to support a variety of engineering educators advocating “feminist pedagogy.” The phrase “feminist pedagogy” is a loose term describing any educator seeking to incorporate the values of feminism into students’ learning experience. Eschenbach et al. describe common feminist beliefs as a conviction that “gender should not be a distributive mechanism or a basis for social hierarchy, or a means whereby some parts of people get stunted and other parts get overdeveloped.” Educators engaged in feminist pedagogy seek to question the hierarchies and power structures imbedded in traditional engineering epistemologies professional practices, and teaching processes.⁴

Although feminist scholars share the goals of increasing equity and eliminating gender hierarchies in STEM education, disagreement remains as to the best methods for drawing and retaining women in STEM fields. Early feminist critiques of STEM education focused on increasing the number of girls entering STEM fields by eliminating the social conditions, such as gender stereotypes, that discouraged girls from entering these fields.⁵ For example, Stephen Brush has noted a number of these societal factors including the portrayal of engineers in textbooks as always male, studies showing female mathematical inferiority, the association of engineering with supposedly masculine machinery, high school counseling steering girls away from STEM fields among, and the combative and overly-competitive nature of science and engineering education.⁶ Henry Etzkowitz has proposed a process of “hierarchical segregation” in which girls are discouraged from STEM fields at several stages of the career line beginning with gender identities which have designated STEM fields as unfeminine.⁷

Focusing on the undergraduate education stage of Etzkowitz’s hierarchy, Elaine Seymour conducted a 3-year ethnographic study of female attrition from STEM fields at seven colleges and universities. Seymour concluded that:

The hostility women encounter from some SME faculty, and from many of their male peers, is a direct consequence of their intrusion upon a traditional process whereby young men are selected and prepared to enter an elite fraternity. The more the faculty treat the demonstration of particular “masculine” characteristics as an essential part of “becoming a scientist,” [or an engineer] the more resistance to their participation women will experience.⁸

Seymour noted the sentiment of one female engineering student indicative of the views of many females she interviewed in her study who stated “If women survive, it’s partly because someone noticed they had the talent, and encouraged them in the first place.”

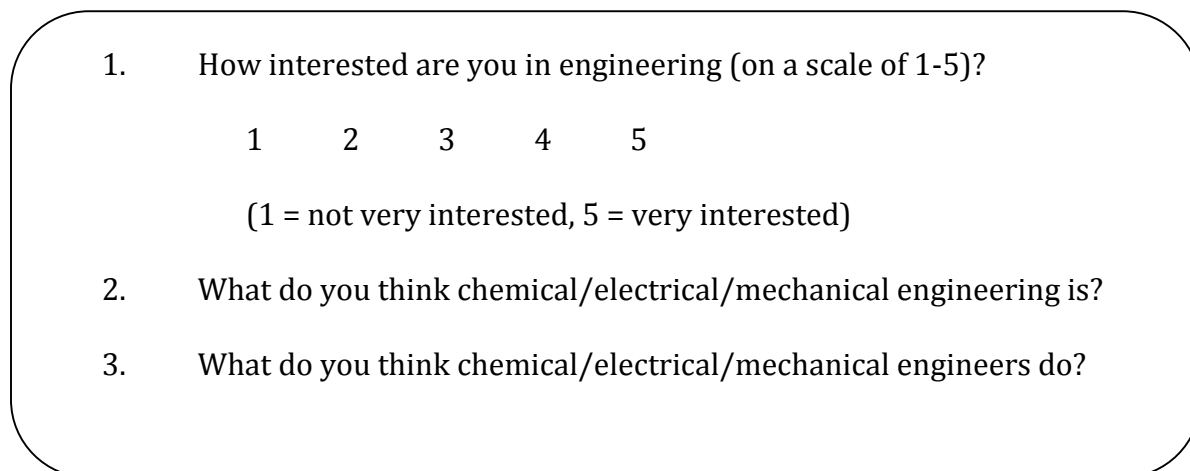
More recent feminist educators have advocated going beyond mere participation of women to challenging the dominant practices of engineering by incorporating feminist epistemologies.⁹ There is thus a dispute as to whether a uniquely female way of thinking about and doing science and engineering exists, and whether this female epistemology should be incorporated into feminine epistemologies. Other feminist scholars have resisted an essentialist female approach to engineering, arguing that it ignores differences among women and their experiences.¹⁰ Testing the view that more than simple increases in the quantity of female participation in traditional engineering practices is necessary to render the profession more welcoming to women, Salter and Persaud interviewed 142 upper-class women majoring in engineering to test the ‘chilly’ classroom dynamic inhibiting active participation of women in traditional co-ed engineering classrooms. While their study is not conclusive, they did find that women felt discouraged to participate in what they call ‘thinking oriented’ engineering classrooms and that this lack of participation hampered their learning.¹¹ Typical survey comments reflected fears among women of being rebuked and criticized by their professor and peers and general anxiety from an overly-competitive atmosphere among the students.¹¹

In this study, we aim to add to this body of literature regarding engineering pedagogy as it relates to the attraction, retention, and ultimate success of women in the field by providing one real-world model. Acknowledging the view that more than simple participation of women is necessary to challenge the hierarchies and power structures imbedded in traditional engineering processes, this study seeks to determine if introducing middle school girls to hands-on engineering in a friendly, respectful, and all-female environment increases interest in pursuing a career in engineering. In addition to contributing to the literature above, this study aims to actively disrupt Etzkowitz’s hierarchy of segregation by creating interest in girls at the very beginning of their academic careers when they are forming gender and career identities.

Engineering Workshops

Three engineering workshops for middle school girls were organized, designed, and implemented by the first author as part of her Anne Gary Pannell Merit Scholarship at Sweet Briar College. A Pannell Scholar must complete a scholarly or creative project related to her interests during her sophomore year. The goal of the project was to introduce middle school girls to the subject of engineering in a supportive environment. At each engineering workshop, approximately twenty girls completed an activity that involved creativity and problem solving skills. Many girls attended all three and others attended individual sessions according to their schedules and interests. Current Sweet Briar College engineering students (all female) and one

faculty member (also female) were present at each workshop to guide and assist the girls. In addition to using creativity and problem solving skills, the girls were encouraged to see themselves as potential engineers during each session. Workshops began with an interactive discussion with the faculty member to gauge students' perceptions of engineering and engineers. To measure the success of this project, each of the girls participating was given a survey before and after asking them to express their interest in engineering on a scale of 1 to 5 and knowledge of the particulate engineering field (Figure 1). These surveys were used to show how much each participant learned about engineering and how many of them see themselves as future engineers.



1. How interested are you in engineering (on a scale of 1-5)?

1 2 3 4 5

(1 = not very interested, 5 = very interested)

2. What do you think chemical/electrical/mechanical engineering is?

3. What do you think chemical/electrical/mechanical engineers do?

Figure 1. Sample survey given to the middle school girls both before and after the workshops.

In the chemical engineering workshop, the girls learned about chromatography and used these principles to create tie-dyed t-shirts. The students learned that chromatography is a technique used to separate mixtures in many different fields of science and engineering. They then created their own t-shirt designs using permanent markers and rubbing alcohol. The students first drew on their shirt with permanent markers and then applied rubbing alcohol to the ink with an eyedropper. Due to the principles of chromatography, the ink of the permanent markers separates to create a rainbow of colors on the t-shirt. Plastic cups and rubber bands were used to contain the rubbing alcohol once it flowed through the fabric of the shirt (Figure 2).



Figure 2a: Colorful designs were created on this shirt by applying the principles of chromatography using permanent markers and rubbing alcohol.



Figure 2b: The t-shirts were placed over a plastic cup and a rubber band was used to wrap the shirt around the brim of the cup in order to contain the rubbing alcohol once it flowed through the fabric of the shirt.

The electrical engineering workshop included an introduction to basic circuits and construction of an interactive miniature pinball machine game. The students first briefly learned about circuits and electricity. Then they created several simple circuits with batteries, LEDs, resistors, buzzers, and alligator clips (Figure 3). Next, the students used their knowledge of

circuits to construct a miniature pinball machine game, which was comprised of two basic circuits (one to light an LED and one to sound a buzzer) wired to a foam core box. When playing the game, the student tilted the box in order to roll a conductive metal ball around to connect two exposed wires and complete the circuit to either light the LED or sound the buzzer (Figure 4). A battery was used as the power source and alligator clips were used to connect each of the circuits. Tape was used to keep all of the electrical elements in place.

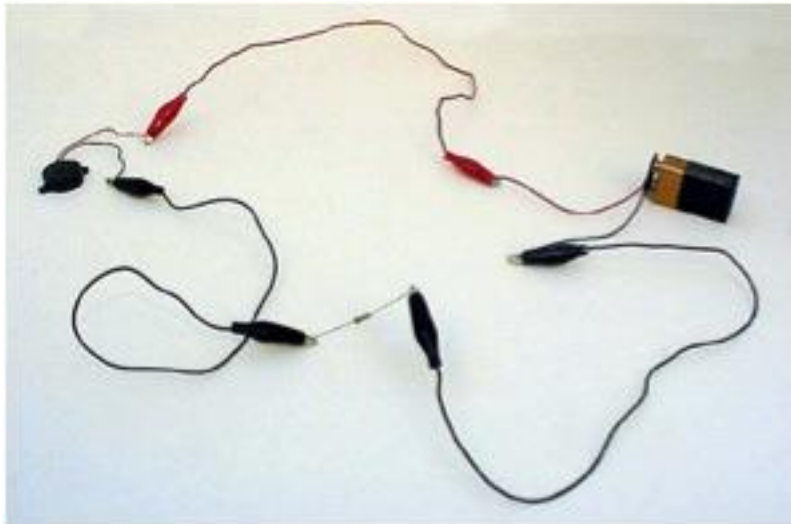


Figure 3: Before constructing the miniature pinball machine games, each student created a basic circuit.



Figure 4a: Top view of the pinball box, showing an LED in the upper left corner and a conductive ball.

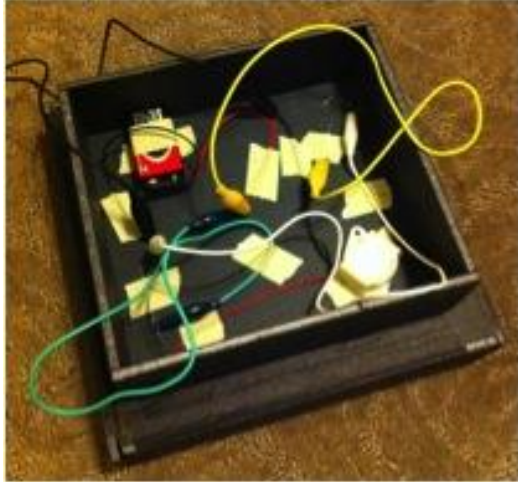


Figure 4b: Bottom view of the pinball box, showing the electrical components.

The final workshop used the construction of miniature trebuchets to explain mechanical engineering concepts. The students first learned about simple machines and the history of the trebuchet. The students were also shown how a trebuchet acted as a lever to launch projectiles. Each student constructed her own miniature trebuchet from a kit purchased from Pitsco Education (Figure 6).¹² The trebuchets were made from basswood with washers as the weights and clay balls as the projectiles. Parts of the trebuchet kits, such as the sling, were constructed before the workshop to ensure that the girls had enough time to build the entire trebuchet within the time of the workshop. Once constructed, the students tested their trebuchets. They were encouraged to experiment with different weights and differed sized projectiles to see what would result in the farthest projectile distance. This workshop was filmed by a local television station to highlight Sweet Briar College's role in educating women engineers.



Figure 6. Trebuchet kit.

Student Feedback

The goal of these workshops was for the middle school girls to be introduced to engineering and for them to see themselves as potential engineers. To quantify this, all students were given a survey to complete before and after the workshop (Figure 1). Prior to the sessions, the girls had some idea of what engineers do, but the descriptions were very task-based and highly associated with more traditional ideas of science (Figure 7). After the workshops, responses were more holistic and service-oriented (Figure 8). In the pre-activity discussions, engineering was described as a creative discipline designed to help people and make the world a better place by applying scientific and mathematical principles. Current Sweet Briar College students also casually discussed their engineering class projects with the middle school girls during the activities.

- “they study science and perform these activities”
- “create designs or things like that”
- “they try to fix broken things...”
- “I don’t know”
- “work in labs”
- “mix things”

Figure 7. Student perceptions of what engineers do prior to the workshops

- “awesome things”
- “...do well they help people, solve problems, and be creative”
- “they can fix problems with their great thinking skills”
- “create things while finding solutions to problems and helping people”
- “test things and stuff”

Figure 8. Student perceptions of what engineers do after the workshops

The first survey question was used to evaluate a change in the middle school girls’ interest in engineering as a result of the workshops (Figure 9-11). For all sessions combined, those students “somewhat interested” to “very interested” in engineering increased by 23%. Based on these surveys and the student responses to the additional questions, it is clear that the middle school girls understand more of what an engineer is and that many of them can see themselves as future engineers.

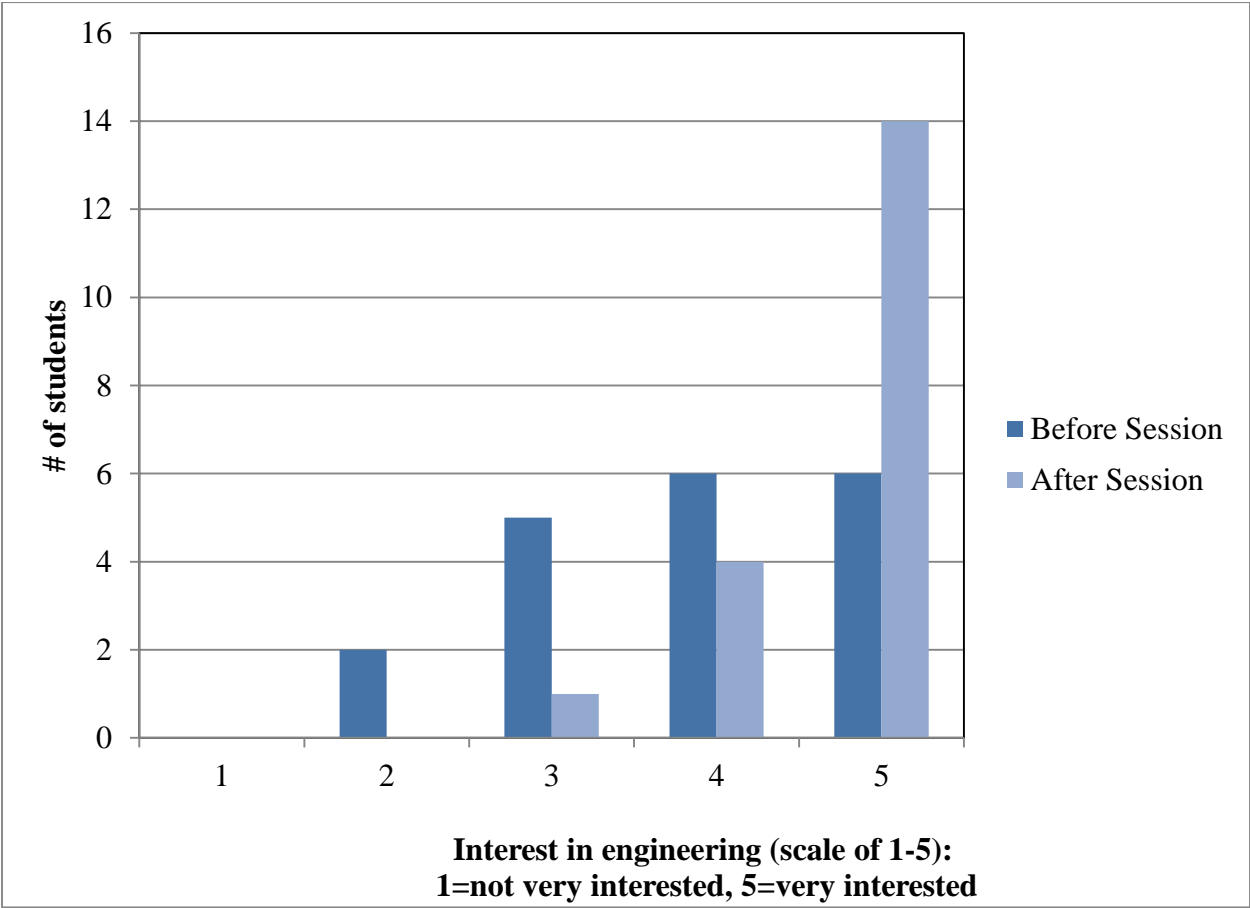


Figure 9. Interest in engineering before and after chemical engineering workshop

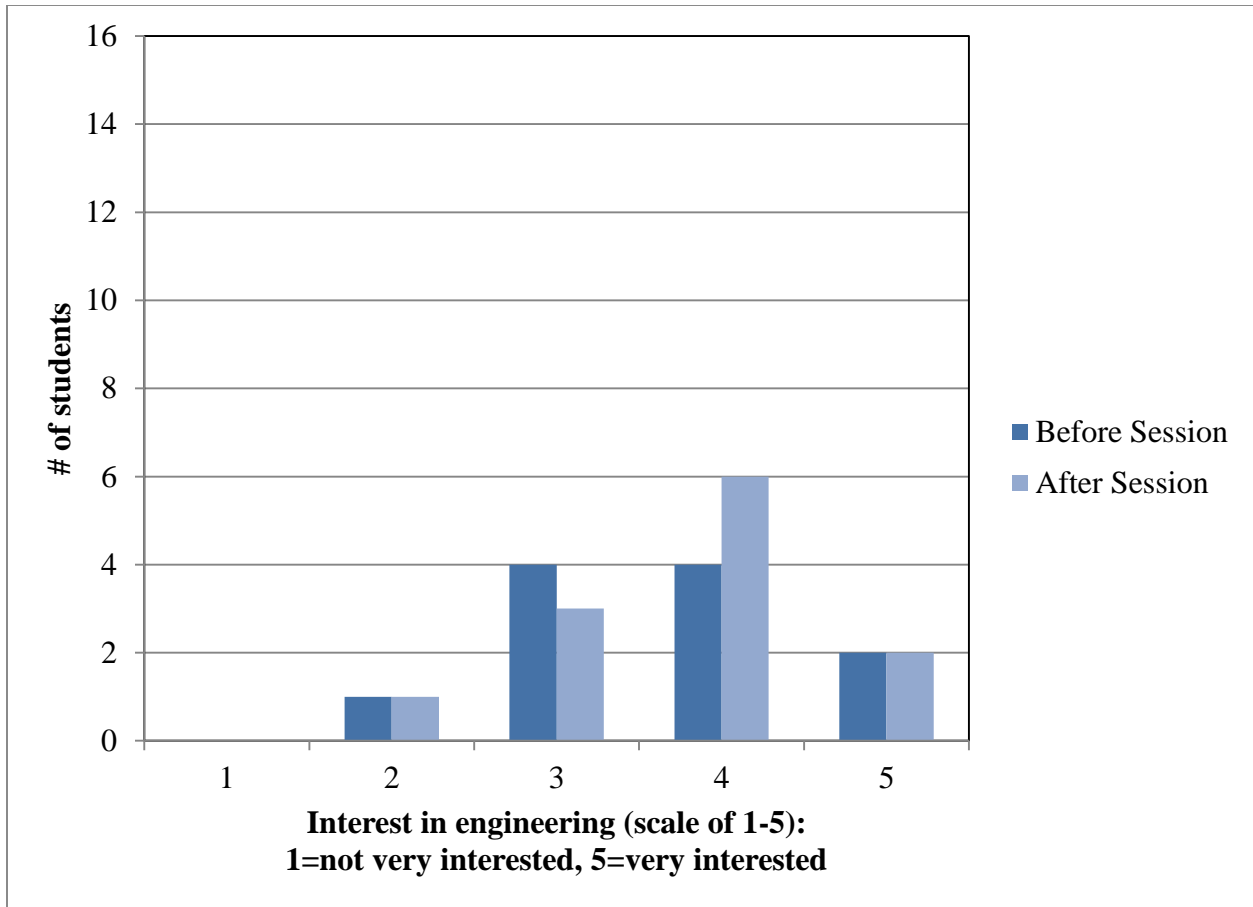


Figure 10. Interest in engineering before and after electrical engineering workshop

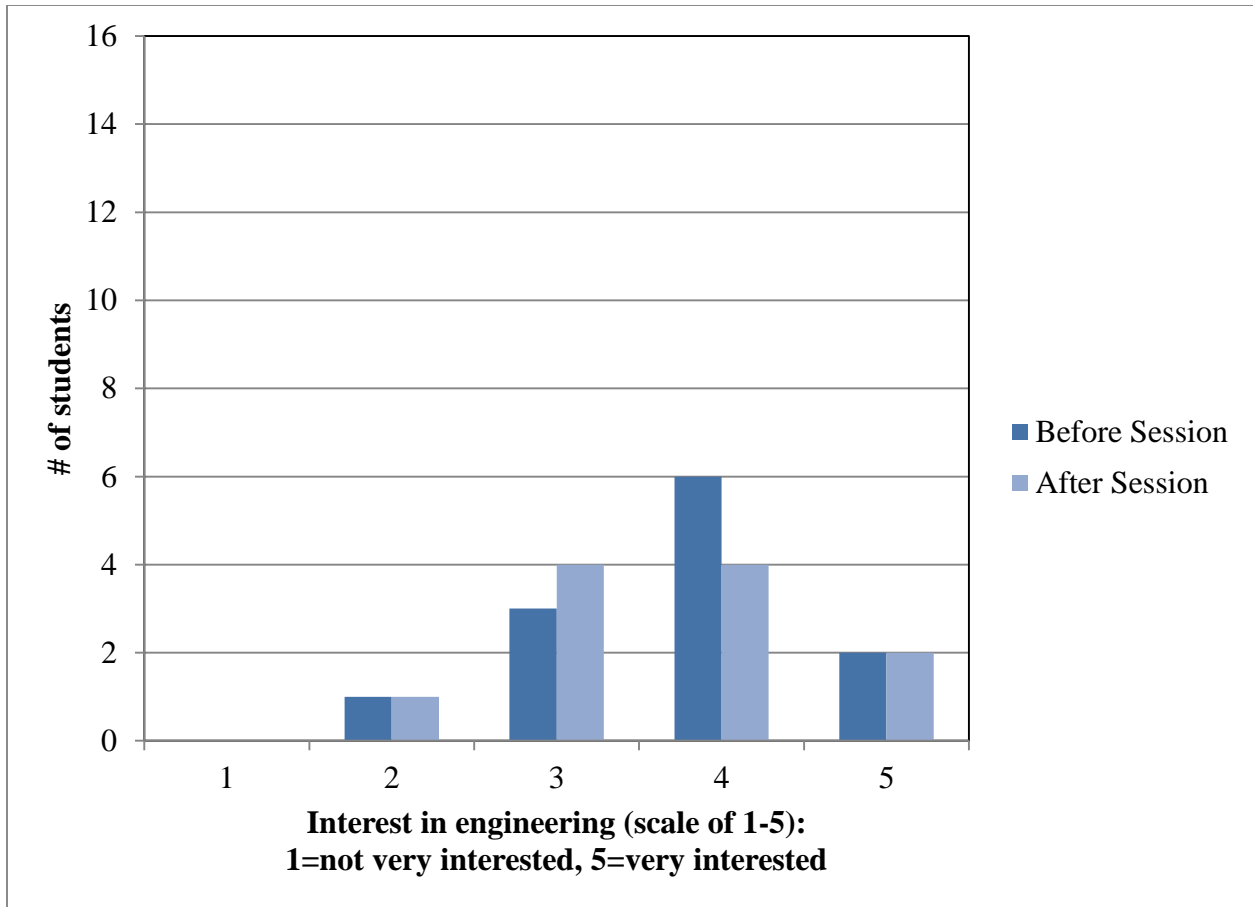


Figure 11. Interest in engineering before and after mechanical engineering workshop

Comments from parents were overwhelmingly positive and indicated that the girls remained engaged with the topics and activities after the workshops ended (Figure 12).

- “Thank you, for implementing the Engineering work-shops!!! My daughter loved mixing different colors and watching how they formed patterns.”
- “Your program has sparked my daughter’s interest!!!!”
- “She has really enjoyed these and I love that she’s having fun learning!”
- “She has had a WONDERFUL time! We are actually going to make the T-shirt chromatography tonight for her birthday party : -)”

Figure 12. Parent responses to workshops

Discussion

The results of this study suggest that providing middle school girls with a supportive, hands-on, all-female learning environment increased interest in engineering as a future career. We recognize that the study, designed and implemented by a sophomore engineering student, may not conclusively show a causal link between these environmental factors and interest among middle school students. Nevertheless, we think the survey results still lend credence to the argument among some feminist scholars that increasing female interest in engineering and continuing success of women in the field requires more than mere participation in traditional engineering education. By providing a non-competitive all-female environment embracing a holistic approach focused on values such as creativity and “helping people,” the middle school girls experienced engineering without the hierarchies and power structures imbedded in traditional engineering practices. Learning environments with female mentors and leaders which are targeted specifically at middle school girls have consistently been found to increase or maintain students’ confidence and interest in STEM subjects and sense of empowerment.¹³⁻¹⁶ Researchers have noted, however, that sustaining this interest beyond the observed activity is critical.¹³ In a long-term study, Tyler-Wood et al. found that even younger girls (4th and 5th graders) in an ongoing afterschool science program with female high school students as mentors showed stronger self-efficacy in STEM fields well into high school and college.¹⁷

More importantly, the study may reflect that when engineering and technology are presented as gender neutral or even as feminine, girls are free to explore engineering without grappling with the traditional gender stereotypes associated with engineering or machinery. Hands-on activities and projects with other girls foster peer support and acceptance of engineering ability as a part of self-identity.^{15, 18, 19} While this study does not seek to definitively answer the more philosophical question of whether a unique female epistemology exists or a female way of thinking about engineering, it does suggest that a holistic approach and goals that go beyond narrow design increases female interest at least among middle school-aged girls in an all-female learning environment. The positive comments from parents are encouraging for the future engineering goals of the middle school girls as parental (especially maternal) support has been shown to positively influence girls’ motivation in science and math.²⁰ At the very least, the study demonstrated that among a small sample of middle school girls, there is nothing inherently male about engineering or technology.

References

1. Fouad, Nadya A. and Singh, Romila. (2011) *Stemming the Tide: Why Women Leave Engineering*. University of Wisconsin-Milwaukee: Milwaukee, WI.
2. Hill, Catherine; Corbett, Christianne and St. Rose, Andresse. (2010) *Why so Few?: Women in Science, Technology, Engineering, and Mathematics*. American Association of University Women (AAUW): Washington, D.C.
3. Oldenziel, Ruth. (1999) *Making Technology Masculine: Men, Women and Modern Machines in America, 1870-1945*. Amsterdam University Press: Amsterdam.

4. Eschenbach, Elizabeth A.; Cashman, Eileen M.; Waller, Alisha A. and Lord, Susan M. (2005) Incorporating Feminist Pedagogy into the Engineering Learning Experience. 35th ASEE/IEEE Frontiers in Education Conference. Indianapolis, IN. October 19 – 22, 2005.
5. Lehr, Jane L. (2006) "Social Justice Pedagogies and Scientific Knowledge: Remaking Citizenship in the Non-Science Classroom." Dissertation. Virginia Polytechnic Institute and State University.
6. Brush, Stephen G. (1991) Women in Science and Engineering. *American Scientist* 79 (5): 404-419.
7. Etzkowitz, Henry; Kemelgor, Carol and Uzzi, Brian. (2000) *Athena Unbound: The Advancement of Women in Science and Technology*. Cambridge University Press: Cambridge.
8. Seymour, Elaine. (1995) The Loss of Women from Science, Mathematics, and Engineering Undergraduate Majors: An Explanatory Account. *Science Education* 79 (4): 437-473.
9. Harding, Sandra G. (1986) *The Science Question in Feminism*. Cornell University Press: Ithaca, NY.
10. Haraway, Donna. (1985) A Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s. *The Socialist Review*. 80: 65-106.
11. Salter, Daniel W. and Persaud, Anita. (2003) Women's Views Of The Factors That Encourage And Discourage Classroom Participation. *Journal of College Student Development* 44 (6): 831-844.
12. Pitsco Education. "Trebuchet." Web. 4 Oct. 2012. <<http://www.pitsco.com/Trebuchet>>.
13. Demetry, Chrysanthe; Hubelbank, Jeanne; Blaisdell, Stephanie; Sontgerath, Suznne; Errington Nicholson, Michelle ;Rosenthal, Elissa and Quinn, Paula. "Supporting Young Women to Enter Engineering: Long-Term Effects of a Middle School Engineering Outreach Program for Girls" *Journal of Women & Minorities in Science and Engineering* 15 (2009): 119-142.
14. Holmes, Stephanie; Redmond, Adrienne; Thomas, Julie and High, Karen. (2012) Girls Helping Girls: Assessing the Influence of College Student Mentors in an Afterschool Engineering Program. *Mentoring & Tutoring: Partnership in Learning* 20 (1): 137-150.
15. Baker, Dale. (2002) Good Intentions: An Experiment in Middle School Single-Sex Science and Mathematics Classrooms with High Minority Enrollment. *Journal of Women and Minorities in Science and Engineering* 8 (1): 1-23.
16. Edwards, L. (2002) "Creating a Virtual Community of Practice to Investigate Legitimate Peripheral Participation by African American Middle School Girls in Science Activities" Dissertation. University of Colorado at Boulder.
17. Tyler-Wood, Tandra; Ellison, Amber; Lim, Okyoung and Periathiruvadi, Sita. (2012) Bringing Up Girls in Science (BUGS): The Effectiveness of an Afterschool Environmental Science Program for Increasing Female Students' Interest in Science Careers. *Journal of Science Education and Technology* 21: 46-55.
18. Inman, Arline H.; Anderson-Rowland, Mary R.; Castro, Marcela; Zerby, Donna. (2003) Assessing the Evolution of Engineering Saturday Academies for Middle School and High School Women. WEPAN 2003 Conference. Chicago, IL. June 8 – 11, 2003.
19. Denner, Jill; Werner, Linda; Bean, Steve; Campe, Shannon. (2005) The Girls Creating Games Program. *Frontiers: A Journal of Women Studies* 26 (1): 90-98.
20. Leaper, Campbell; Farkas, Timea and Spears, Christia B. (2012) Adolescent Girls' Experiences and Gender-Related Beliefs in Relation to Their Motivation in Math/Science and English. *Journal of Youth and Adolescence*. 41 (3): 268-282.