Synthesis of K-12 outreach data on women in engineering

Emily Barnes , Rowan University

Emily Barnes is an undergraduate student of Rowan University's Engineering Program. She has a focus in Chemical Engineering. As a participant in various outreach programs throughout the years, she has gained an interest in their structures and effectiveness in recruiting women to join Engineering fields. She selected engineering as her major after gained excitement from college courses in advanced Mathematics and Chemistry.

She hopes to continue her education in Chemical Engineering in Graduate School and one day participate in outreach programs as a working Professional Engineer.

Mr. Nicholas Lenzi
Dr. Katherine G Nelson, Rowan University

Katie just recently finished a postdoc at ASU and is currently working as temporary faculty int he college of engineering at Rowan University. Her research interests include complexity learning, cognition, and motivation.

Understanding impacts of Women in Engineering K-12 Outreach Programs

Introduction

The percentage of women that are employed as engineers (14.5% as of 2015) has gone up since 1985, when women made up only 5.7% of the engineering population [1]. Be that as it may, the percentage of women in engineering has plateaued between 13-15% since the early 2000s and severely underrepresents the percentage of women that make up the US population [2, 3]. Given the lagging and plateaued underrepresentation of women in engineering, questions have emerged that are aimed at both understanding why women choose different fields and determining what can be done about to get them into engineering [4].

One possible solution for the underrepresentation of women is targeted programs to expose younger girls (K-12) to engineering [5, 6, 7]. Engineering is not a core topic in most public high schools so young girls are not even aware that engineering exists, let alone given any opportunities to foster their engineering interest [19]. Engineering outreach programs seek to remedy this by providing opportunities for K-12 students to experience engineering. Generally, these programs are developed and run to engage and excite their target K-12 audience [8]. However, the lack of female engineers indicates that these programs may not effectively appeal to female students, or promote their future success in engineering in ways that are equal to male students.

Research Purpose

A review of outreach literature indicates that, generally, STEM outreach programs report their success in terms of achieving their goals. Goal attainment is measured in ways such as an increase in participant knowledge, a change in attitude and perceptions towards engineering, and a general change in attitude towards college education [14, 15]. However, these positive outcomes have not manifested in an increase in female attrition in engineering programs. As such, the purpose of this paper is to review the literature on outreach programs to understand what is going on. Specifically, we wanted to know:

- What are the general themes for the outreach programs related to gender, focus, and mission.
- How are these themes similar or different across the different outreach programs

To answer these questions, we chose to conduct a systematic literature review on recent literature on engineering education outreach programs. Systematic literature reviews have been recommended in engineering education research to synthesize existing work so that it can better inform practice and identify new potential areas for research [9]. We collected literature primarily from peer-reviewed journal articles and analyzed the characteristics of K-12 outreach programs.

Methods

We define K-12 engineering outreach programs as programs or activities that engage K-12 populations in engineering. Typically, outreach programs seek to supplement the lack of engineering taught in normal school curricula; however, this paper classifies STEM schools, high schools with a focus on STEM topics, as engineering outreach as they expose students to engineering in a K-12 setting. Engineering outreach programs also cover a variety of topics and at different depths: some expose students to general engineering whereas others focus on specific branches and associated topics of engineering such as the Relevant Education for Math and Science program specifically focusing on industrial engineering and A. P. Preciado Babb's outreach activity focusing on thermodynamics [17, 18]. For the purpose of this work, these programs are aggregated together because few specific engineering domain outreach programs exist.

Data Collection

Engineering outreach papers were collected through Google Scholar and ProfSearch, a Rowan University search query that gathers results from online databases subscribed to by the University. The chosen papers were scholarly, peer reviewed papers, published by journals or found in conference proceedings from the year 2000 to present. Given the broad scope of this study, chosen papers included all types of engineering outreach programs that targeted a variety of audiences. A total of 30 papers were collected initially and reduced to 25 due to scoping. Out of scope papers were those that either did not concern outreach programs focused on engineering education or that did not target K12 students or teachers. A bibliography was created of these papers as well as a spread sheet which included pertinent, high-level information that would help in later paper classification. Table 1 summarizes the high-level categories used in the spreadsheet.

Table 1: Overview of the high-level information found for each article.

Category	Description
Title	The title of the article
Authors	The authors of the article
Date	When the article was published
Population	The target population of the outreach program.
Research Questions	The research questions of the article, if applicable.
Method	How data was collected – quantitative, qualitative, or both.
Type of Outreach	Description of the outreach program.
Outreach Mission	The mission statement or stated goals of the outreach program.
Findings	The findings of the article.
Anything Else	Any other interesting information found in the article.

Organization Methods

After the papers were imputed into the spreadsheet, the authors met to discuss how to group the papers together along different themes. Papers were first separated by whether they concerned outreach programs that were all-inclusive (both boys and girls) or specifically for girls. Then, the papers were further organized around higher-level themes of target audience, time of occurrence, and mission statement or program goals.

By Target Audience

Each engineering outreach program had a targeted population. Three different groups of target audiences emerged from the data and through our discussions: Elementary K-4, Middle 5^{th}-8^{th}, and High School 9^{th}-12^{th}. Two additional categories were added: one to capture programs that targeted K12 teachers directly or through proposed teaching methodology to improve student understanding of engineering, and the other for programs that targeted both middle and high school students.

By Time of Occurrence

The literature was also grouped based on when the programs occurred. Multiple levels were used and were as follows:

- Macro level – During the literature review, it was observed that outreach programs occurred in class as either a standalone project available to teachers or to incorporate outreach into curricula, or as an out-of-class program that exists on its own. At the macro level, programs are thus divided into two categories: in class or out of class.
- Micro level – This organization further breaks down the macro level taxonomy into more specific temporal categories, as demonstrated in Table 2.

Table 2: The temporal categories used for micro level organization.

Category	Description
In School – Full Year	STEM-focused schools or outreach programs that seek to change year-round curricula
In School – Single Activity	Standalone activities that are either distributed to teachers to be conducted in class or that are conducted in class by an outreach program
Out of School – Afterschool	Programs that occur after the school day
Out of School – Weekends	Programs that occur on weekends
Out of School – Summer	Programs that occur during the summer

By Mission Statement or Program Goals

The final organizational method was based on mission statements, or if unavailable, the goals of the outreach programs. Three themes were observed:

- A focus on real-world applications or the use of practical applications in class
- To influence the career decisions of those that partake in the program
- To improve teacher knowledge in STEM to thus improve its instruction to K12 students.

Results and Discussion

As shown in Figure 1, just under half (44%) of the papers targeted high school students. K12 teachers were the next most targeted group (24%) followed by middle school (16%), high school and middle school (12%), and lastly elementary school (4%). By gender, 75% of middle school outreach programs were targeted at girls.

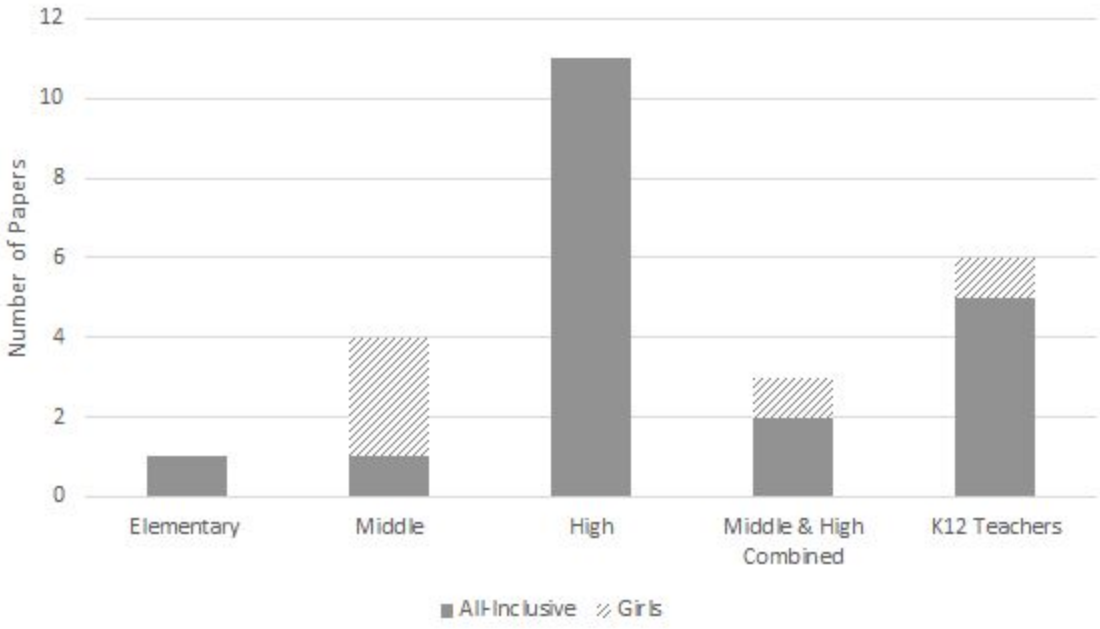

Figure 1: The 25 engineering outreach program papers sorted by their respective target audiences.

Similarly, as demonstrated in Figure 2, just under half (44%) of the programs occurred as summer programs. This is followed by STEM schools and programs that seek to change curriculum (24%), in school single activities (20%), out of school weekend programs (8%), and finally, after school programs (4%). When this time of occurrence data was overlaid with target audience data there is a fairly even distribution with high school summer programs (20%) being the only category that stands out.

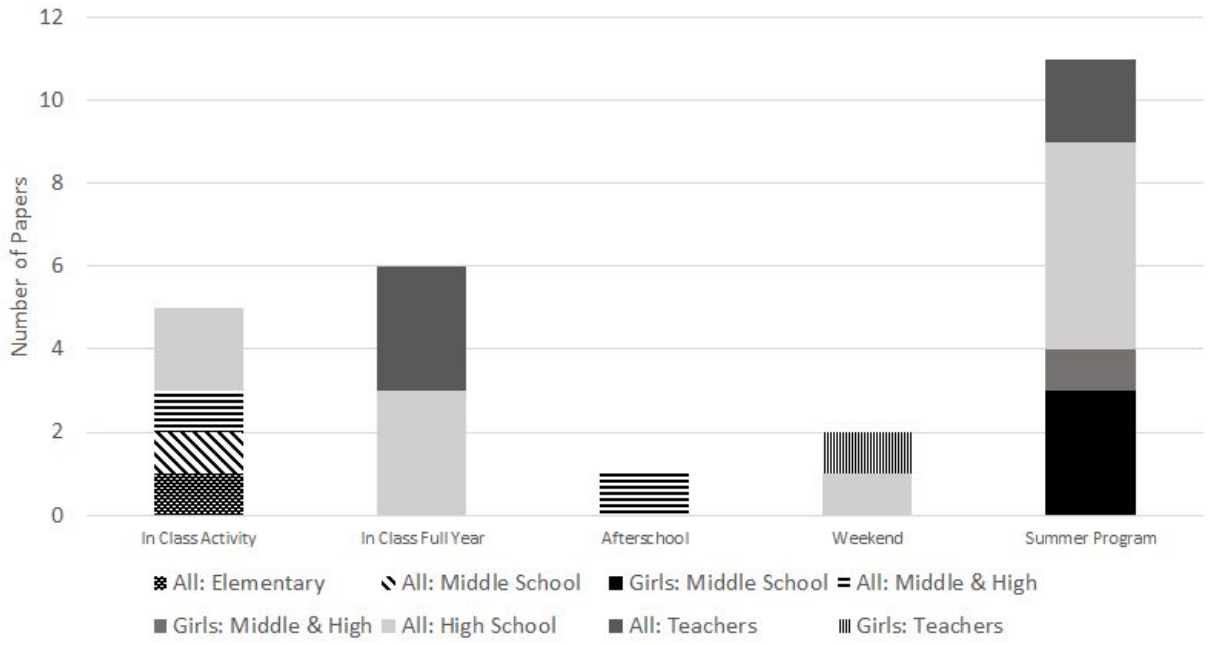

Figure 2: An overlay of the target audience and time of occurrence data. This data is further divided by all-inclusive and girl-focused programs.

There is a fairly even distribution between the outreach programs by mission statement (see Figure 3). All teacher-focused outreach programs share the same goal of improving K12 teacher competency in STEM. A similar number of programs for the middle school and high school audiences targeted influencing career decision. Few programs in middle school focused on practical or real world applications, whereas the greatest number of programs for high school students were those that focused on practical or real world applications. Also, summer programs predominantly sought to influence career decisions (32% combining both all inclusive and girl programs) whereas single school activities focused on practical real-world applications (16%).

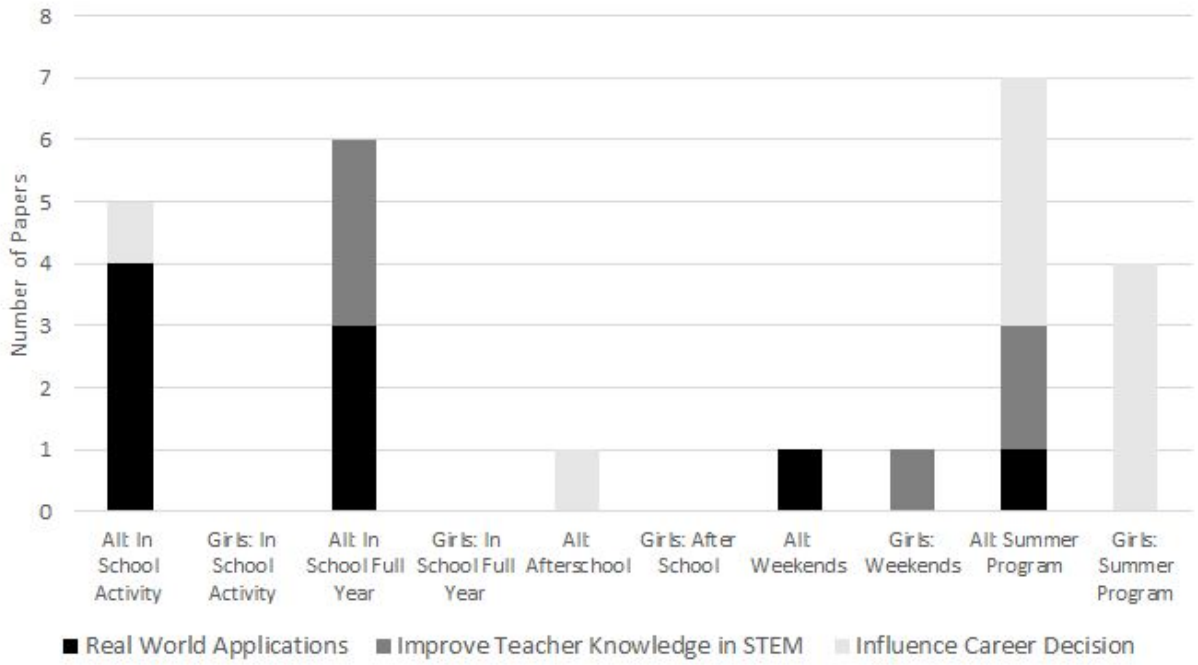

Figure 3: An overlay of the mission statement and time of occurrence data. This data is further divided by all-inclusive and girl-focused programs.

General Discussion

This study demonstrated that high school outreach programs primarily occur during the summer with a focus on real world applications, that middle school-focused programs primarily targeted girls and focused on influencing career, and that almost no outreach targeted elementary school students.

Influencing career decision was a priority for the bulk of the middle school outreach programs in comparison to programs that targeted high school students. This indicates that middle school programs are aware of and interested in making engineering more appealing to participants as opposed to only incorporating real world or practical applications of engineering in their programs. There are both negative and positive consequences to this. When middle school students think about their future careers, their career choice is influenced by the gender stereotypes of job fields such as STEM [10]. These stereotypes include both the perception that engineers are socially awkward and male and that women are not interested in technical or abstract topics such as physics [11]. As such, career-oriented programs could unintentionally alienate girls in those programs. For example, Adventure Engineering is a day camp that utilizes "adventure-driven scenarios" in order to teach math and scientific concepts. Of the four groups

that took part in this program, it was found that the male students in three of these four groups had a negative stereotype of women [12]. Other studies have also found evidence of this negative stereotype existing among middle schoolers. Shaprio, M. et al. (2015) asked middle school students to rank their top five career choices; then, to do the same thing again but to imagine they were the opposite gender. Were no biases to exist, the rankings should be the same in both instances. Middle school boys chose STEM jobs as their top career choice but as their fourth choice when imaging they were girls. Similarly, middle school girls chose STEM as their 4th choice of career but as their second when imagining they were boys [10]. Similarly, Bian, L. et al. (2017) found that "girls as young as 6 years old are less likely than boys to label people of their own gender as 'really, really smart" [13 **Page 1]**. It is apparent that a gender bias exists as early as middle school and could have an impact on middle school girls pursuing an education or career in engineering.

On the positive side, and building from what we know about girls' choice to pursue STEM before high school, programs that focus on helping influence career decisions toward engineering may offer female students an option toward engineering that they would not have considered previously. However, the bulk of programs we observed were targeted for high school students, well past the time when girls have begun to lag behind their male peers related to math and science scores [20], and state that boys are smart but girls have to work hard [13] (which could lead to girls' attributions about limited performance resulting from limited ability). So, even though the middle school programs are focused to possibly promote girls interest in engineering, the lack of middle school programs overall raises a concern.

Taken together, the synthesis of research here demonstrates that outreach programs have to make some changes expose girls to engineering before they are being outperformed by the boys in their classes, and that all-inclusive programs need to be designed in a way to better limit bias (bias that the girls feel, and bias that the boys have).

Limitations and Next Steps

Many of these papers were conducted by different organizations and designed by different teams of individuals, there were some clear differences in how data was collected and we were challenged at time to qualitatively compare the different programs. For example, the research methods were not similar across programs so the data from one program to another differed.

Conclusion

The present data shows that even though many programs are getting young women more interested in engineering, there is still work to be done to better encourage women to find a place in engineering. In our literature review, we found that outreach programs primarily targeted high school students through summer programs and exposed them to real world or practical

applications. Elementary students were hardly targeted. Furthermore, most all-inclusive student programs occurred after girls are becoming disinterested in STEM whereas programs that specifically targeted girls made career influence a priority and targeted girls at an age when girls science and math scores begin to lag behind boys' scores. This review of literature demonstrates the needs to focus all-inclusive programs on career choice at a time that is most advantageous for girls' pursuit of engineering as a career option.

References

1. National Science Foundation, National Center for Science and Engineering Statistics, National Survey of College Graduates, 2015
2. Beede, D., Julian, T., Langdon, D., McKittrick, G., Khan, B., & Doms, M. (2011). *Women in STEM: A Gender Gap to Innovation* . Department of Commerce - Economics and Statistics Administration.
3. U.S. Census Bureau (2011). *Age and Sex Composition: 2010* Retrieved from https://www.census.gov/prod/cen2010/briefs/c2010br-03.pdf
4. Layne, P. (2016). The State of Women in Engineering - Why So Few? *Society of Women Engineers Annual Conference.* Nashville.
5. Weavers, L. K., Bautista, D. T., Williams, M. E., Moses, M. D., Marron, C. A., & Rue, G. P. (2011). Assessing an Engineering Day Camp for Middle-School Girls. J. Prof. Issues Eng. Educ. Pract. Journal of Professional Issues in Engineering Education and Practice, 137(3), 127-134. doi:10.1061/(asce)ei.1943-5541.0000046
6. Dubetz, T., & Wilson, J. A. (2013). Girls in Engineering, Mathematics and Science, GEMS: A science outreach program for middle-school female students. *Journal Of STEM Education: Innovations & Research*, *14*(3), 41-47.
7. Demetry, C., Hubelbank, J., Blaisdell, S. L., Sontgerath, S., Nicholson, M. E., Rosenthal, E., & Quinn, P. (2009). Supporting Young Women To Enter Engineering: Long-Term Effects Of A Middle School Engineering Outreach Program For Girls. *Journal of Women and Minorities in Science and Engineering J Women Minor Scien Eng, 15*(2), 119-142. doi:10.1615/jwomenminorscieneng.v15.i2.20
8. Safferman, A. G., Jeffers, A. T., & Safferman, S. I. (2004). Understanding K-12 engineering outreach programs. Journal of Professional Issues in Engineering Education and Practice, 130(2), 95-108. doi:10.1061/(ASCE)1052-3928(2004)130:2(95)
9. Borrego, M., Foster, M. J., & Froyd, J. E. (2014). Systematic Literature Reviews in Engineering Education and Other Developing Interdisciplinary Fields. *Journal of Engineering Education*, *103*(1), 45–76. https://doi.org/10.1002/jee.20038
10. Shapiro, M., Grossman, D., Carter, S., Martin, K., Deyton, P., & Hammer, D. (2015). Middle School Girls and the "Leaky Pipeline" to Leadership. *Middle School Journal*, *46*(5), 3–13. https://doi.org/10.1080/00940771.2015.11461919

11. Blosser, E. G. (2015, June), *Constructions of Gender in Three Campaigns to Recruit Women to Engineering: Is Outreach Combatting or Reinforcing Gender Inequality?* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.23738
12 . Mooney, M. A., & Laubach, T. A. (2002). Adventure Engineering: A Design Centered, Inquiry Based Approach to Middle Grade Science and Mathematics Education. *Journal of Engineering Education*, *91*(3), 309–318. https://doi.org/10.1002/j.2168-9830.2002.tb00708.x
13. Bian, L., Leslie, S.-J., & Cimpian, A. (2017). Gender stereotypes about intellectual ability emerge early and influence children's interests. *Science*, *355*(6323), 389. https://doi.org/10.1126/science.aah6524
14. Nadelson, L. S., & Callahan, J. (2011). A Comparison of Two Engineering Outreach Programs for Adolescents. Journal Of STEM Education: Innovations & Research, 12(1/2), 43-54.
15. McAfee, L., & Kim, A. (2007, June), Successful Pre College Summer Programs Paper presented at 2007 Annual Conference & Exposition, Honolulu, Hawaii. https://peer.asee.org/2792
16. Koller, E., Van Beek, L. M., Guzey, D. S., & Thomas, A. P. (2015). Implementing and Evaluating An E-Textile Curriculum In an Engineering Summer Program for Girls (Evaluation). *Proceedings Of The ASEE Annual Conference & Exposition*, 1-20.
17. Kuhl, M. E., Kaemmerlen, J., Marshall, M. M., Mozrall, J. R., & Carville, J. (2015). Extending K-12 industrial engineering outreach programs and accessibility using simulation. IIE Annual Conference. Proceedings, , 1315.
18. A. P. Preciado Babb, C. Saar, S. Friesen and J. Brandon, "Engaging high school students in an engineering thermodynamics project," *2014 IEEE Global Engineering Education Conference (EDUCON)*, Istanbul, 2014, pp. 222-228.
19. Zinth, J. D. (2007). *50-State Comparison: High School Graduation Requirements* . Education Commission of the States.
20. National Center for Education Statistics (2013). *The Nation's Report Card: Trends in Academic Progress 2012* (NCES 2013–456). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, Washington, D.C.