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Empowering the Next Generation of Women Engineers: Early Outreach and Mentorship through Targeted STEM Programs

Prof. Abas Sabouni, Wilkes University

Professor Abas Sabouni joined the Department of Electrical Engineering at Wilkes University in 2013. He received his Ph.D. in Electrical and Computer Engineering from the University of Manitoba, Winnipeg, Canada, in 2011. From 2011 to 2013, he served as a postdoctoral fellow in the Biomedical Engineering Department at École Polytechnique de Montréal and the Montreal Neurology Institute, and as a research associate in the Department of Electrical and Computer Engineering at Concordia University in Montreal, Quebec, Canada.

Additionally, he held visiting scholar positions at the University of California, San Diego in 2014, and Harvard University in Boston in 2017. He is currently a Professor of Electrical Engineering and Chair of the Mechanical and Electrical Engineering Department at Wilkes University. He also serves as Director of the graduate program in Electrical Engineering and Co-Director of the Bioengineering master's program.

Dr. Sabouni is a Senior Member of IEEE and serves on the Board of Directors for the Applied Computational Electromagnetics Society (ACES). He is a highly esteemed educator who has been recognized multiple times for his outstanding contributions to undergraduate teaching and research. His numerous honors include the 2021 Carpenter Award for Teaching and Student-Centered Research, the 2020 Alumni Mentoring Award, the 2020 Wilkes University President's Award, the 2017 Outstanding Scholarship Award, the 2017 Outstanding Adviser Award, the 2017 and 2025 O'Hop Last Lecture Awards, the 2016 Outstanding New Faculty Award, the 2014 Outstanding Interdisciplinary Teaching Award, the 2013 Postdoctoral Fellowship Award, the 2013 Natural Sciences and Engineering Research Council of Canada Award, and the 2008 IEEE Antennas and Propagation Society Honorable Mention Award.

Mahsa Khamechi, Wilkes University

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Abstract

This paper presents a structured outreach initiative designed to address gender disparities in engineering by engaging middle and high school girls through a hybrid model of hands-on learning, mentorship, and virtual challenges. With participation from 120 students, the program featured projects in biomedical, structural, and renewable energy engineering. Evaluation using a mixed-methods approach, including surveys, journals, interviews, and rubric-based project assessments, revealed statistically significant gains in student confidence, interest in engineering careers, and STEM-related engagement at home. The findings suggest that such targeted early interventions can positively shape engineering identity and motivation. While further longitudinal study is needed to assess long-term impact, the short-term results provide valuable insights for inclusive engineering education practices.

I. Introduction

Engineering plays a vital role in addressing real-world challenges; however, a significant gender imbalance persists in the field, particularly in disciplines such as electrical engineering. Nationally, women constitute only 15.5% of electrical engineering graduates, a stark contrast to their representation in environmental (57.8%) and biomedical engineering (51.5%) programs [1][2]. Despite ongoing diversity initiatives, engineering remains one of the most gender-imbalanced disciplines within STEM [3]. This disparity stems from a combination of factors, including pervasive societal stereotypes, a lack of visible role models, and limited early exposure to engineering concepts. Although women perform comparably to men in high school mathematics and science courses, their underrepresentation in engineering, especially electrical engineering, indicates that academic preparedness alone does not account for the gender gap. Early and sustained interventions are therefore essential to fostering interest and retention among young women in engineering pathways.

This paper presents strategies aimed at encouraging female students to pursue and persist in engineering education, with an emphasis on outreach programs at the middle and high school levels. These efforts are aligned with the mission of the American Society for Engineering Education (ASEE) Women in Engineering Division (WIED), which advocates for increased participation and retention of women in STEM. Evidence suggests that aligning engineering education with themes of societal impact can be especially effective. In the U.S., women comprise the majority of medical school students, reflecting a broader interest in careers that contribute to human well-being [4]. To attract more female students to engineering, and electrical engineering in particular, it is crucial to emphasize the field's role in improving quality of life through innovations in medical devices, communication systems, and sustainable energy technologies [5].

National initiatives such as the Society of Women Engineers' (SWE) SWENext program and the National Academy of Engineering's EngineerGirl program have made strides in promoting engineering among young women. These programs primarily focus on large-scale, digital outreach through mentorship and creative competitions. In contrast, the initiative described in this paper adopts a localized, hybrid model that combines direct mentorship with hands-on, inquiry-based learning tailored to underserved communities.

Research supports the efficacy of such approaches. Programs that integrate mentorship with real-world problem-solving have been shown to significantly enhance participants' interest in engineering [6][7]. Consistent with these findings, the present initiative emphasizes sustained

engagement and visibility of female role models, particularly for students with limited prior exposure to engineering professionals.

II. Program Structure

The initiative comprises three interconnected components: (1) an academic-year program featuring weekly sessions, (2) summer residential camps, and (3) virtual engineering challenges. These programs were offered to different cohorts, with some students participating in multiple components. A total of 120 students engaged in the program, completing a variety of mini-projects across engineering disciplines rather than focusing on a single task. Activities included bridge building, electronic circuit design, wind turbine construction, and biomedical device prototyping. This diversified approach promoted broad exposure to core engineering principles and enabled assessment of student engagement across multiple domains.

The weekly sessions were held during the fall and spring semesters and consisted of eight one-hour, hands-on workshops. These inquiry-based activities allowed students to explore engineering concepts through guided experimentation. The final session culminated in a capstone project, where students applied their skills to address a real-world problem. The summer residential camps provided participants with immersive exposure to university life. Students visited engineering laboratories, observed demonstrations of advanced technologies, and participated in mentorship panels featuring female engineers who shared their professional journeys. Team-based projects further encouraged collaboration and problem-solving in a supportive environment.

A distinctive aspect of the program was its digital extension, which included virtual engineering challenges. Students received kits by mail and completed projects remotely, ensuring that those in rural or underserved communities could fully participate. This hybrid model effectively broadened access to hands-on learning, regardless of geographic constraints.

III. Assessment and Evaluation

The assessment of the program was conducted through pre- and post-program surveys, participant journals, project-based assessments, and structured interviews. The pre- and post-surveys were designed to measure shifts in student attitudes toward engineering careers, confidence in STEM subjects, and perceptions of engineering's societal impact.

A. Pre- and Post-Program Surveys

The pre- and post-program surveys were designed to evaluate changes in student attitudes toward engineering careers, confidence in STEM subjects, and perceptions of engineering's societal impact. The pre-program survey assessed students' baseline knowledge, confidence, and interest in engineering before they participated in the program. It included questions such as their familiarity with different engineering disciplines, their confidence in solving STEM-related problems, their likelihood of pursuing a career in engineering, and their level of engagement in STEM-related activities outside of school.

The post-program survey aimed to measure shifts in these attitudes and engagement levels after program completion. It asked students whether their confidence in solving STEM problems had increased, which engineering activities they found most engaging and why, whether they were more likely to consider a career in engineering after completing the program, and if they felt the program provided sufficient mentorship and exposure to

engineering professionals. The surveys incorporated a mix of Likert-scale and open-ended questions, enabling both quantitative and qualitative analysis.

A comparative analysis of pre- and post-survey responses was conducted to quantify changes in student confidence, interest, and engagement in STEM activities. The results indicated substantial positive shifts in these areas, suggesting that the program effectively influenced students' perceptions of engineering and their willingness to consider it as a viable career path. The surveys included both Likert-scale and open-ended questions to capture both quantitative and qualitative data. The pre-program survey aimed to assess students' baseline knowledge, confidence, and interest in engineering. Sample pre-program questions included:

- "How familiar are you with different engineering disciplines?"
- "How confident do you feel in solving STEM-related problems?"
- "Do you see yourself pursuing a career in engineering? Why or why not?"
- "How often do you engage in STEM-related activities outside of school?"

The post-program survey was designed to evaluate changes in perceptions and engagement levels. Sample post-program questions included:

- "Has your confidence in tackling STEM problems increased after participating in this program? If so, how?"
- "Which engineering activities did you find most engaging and why?"
- "Are you more likely to consider a career in engineering after completing this program?"
- "Do you feel that the program provided sufficient mentorship and exposure to engineering professionals?"

The surveys were analyzed to quantify changes in student confidence, interest, and engagement in STEM-related activities. A comparative analysis of pre- and post-survey responses helped determine the program's effectiveness in fostering long-term interest in engineering.

B. Participant Journals

Students maintained journals throughout the program, documenting their experiences, challenges, and key takeaways from each session. These journals were reviewed to identify recurring themes such as increased confidence, curiosity in biomedical applications, and problem-solving skills. The qualitative data from the journals provided insights into how students engaged with the activities and the extent to which the program influenced their perception of engineering.

C. Project-Based Assessments

Each student participated in hands-on projects designed to reinforce engineering principles and enhance problem-solving skills. These projects required students to engage in critical thinking, creativity, and teamwork while applying engineering concepts to real-world challenges. The assessment criteria included problem-solving ability, creativity and innovation in project designs, collaboration in teams, and a demonstrated understanding of engineering concepts. Each project was evaluated using a structured rubric that assessed technical execution, the uniqueness of design solutions, and the ability of students to articulate how their project addressed real-world problems. The rubric also measured students' ability to iterate on their designs, demonstrating adaptability and learning through

experimentation. By integrating a structured assessment framework, the program ensured that students not only completed projects successfully but also gained a deeper appreciation of engineering as a field that requires both technical knowledge and creative problem-solving.

D. Structured Interviews and Focus Groups

To gain deeper insights into student experiences, structured interviews and focus groups were conducted with participants, parents, and instructors. Questions in these sessions focused on identifying which program components had the greatest impact, whether mentorship played a role in career aspirations, and how students perceived their engineering potential after completing the program.

The combination of surveys, journals, project assessments, and interviews provided a comprehensive evaluation of the program's effectiveness in inspiring young women to pursue careers in engineering. To measure program effectiveness, both qualitative and quantitative assessments were conducted. The study utilized a mixed-methods approach incorporating pre- and post-program surveys, participant journals, project-based assessments, and structured interviews. The pre- and post-surveys measured students' attitudes toward engineering careers, confidence in STEM subjects, and perceptions of engineering's societal impact.

Participant journals provided qualitative insights into their experiences, challenges, and learning outcomes. These journals were analyzed using a thematic coding approach, identifying recurring themes such as increased confidence, interest in biomedical applications, and enjoyment of problem-solving. Project-based assessments were used to evaluate students' problem-solving abilities and creativity, ensuring that they could apply learned concepts effectively.

Structured interviews and focus groups were conducted with students, parents, and instructors to gain deeper insights into the program's effectiveness. The survey included Likert-scale and open-ended questions to assess key indicators of success. Sample questions included: "I see myself as an engineer," "Engineering is important to solving real-world problems," and "I am considering studying engineering in college."

Additionally, data was collected to assess whether specific mini-projects had a greater impact on participants' interest in engineering. Comparisons were made between students who engaged in biomedical engineering projects versus those who engaged in structural or energy-related projects. Early analysis suggests that projects with a direct societal impact, such as biomedical sensors and renewable energy applications, led to a higher percentage of students expressing interest in pursuing engineering careers. However, further longitudinal study is required to determine whether these initial interests translate into long-term engagement in STEM fields.

IV. Results and Effectiveness

A comprehensive evaluation of the outreach initiative was conducted using a mixed-methods approach that incorporated surveys, project-based rubrics, participant journals, and interviews. The findings summarized below highlight the program's impact through both quantitative and qualitative measures.

A. Survey Results

The table below presents key metrics derived from the pre- and post-program surveys, illustrating the measurable impact of the initiative on participants' interest in engineering, confidence in STEM subjects, and overall engagement. Quantitative analysis revealed statistically significant improvements across all categories, suggesting that the program effectively influenced students' perceptions and attitudes toward engineering.

Metric	Pre-Program (%)	Post-Program (%)	Change (%)
Interest in Engineering Careers	45%	80%	+35%
Confidence in STEM Subjects	50%	70%	+20%
Likelihood of Majoring in Engineering	40%	65%	+25%
Engagement in STEM Discussions at Home	30%	60%	+30%

Responses to open-ended survey questions provided additional context. For instance, 58% of students identified biomedical projects, especially those involving wearable sensors and health diagnostics, as the most engaging, due to their clear relevance to real-world societal issues. In contrast, 43% found structural engineering activities such as bridge building enjoyable but less meaningful in terms of real-life application.

B. Project-Based Assessments

Students completed final design projects that were evaluated using a structured rubric covering four domains: (1) conceptual understanding, (2) technical execution, (3) creativity, and (4) teamwork. Key findings from 96 evaluated projects include:

- 85% of students achieved "Proficient" or "Advanced" ratings in problem-solving and innovation.
- Projects in biomedical and renewable energy domains received the highest scores for creativity and real-world relevance.
- 72% of students showed improvement in design iteration and documentation between initial and final projects.

C. Participant Journals and Reflections

Thematic analysis of over 300 journal entries revealed consistent growth in student engagement and self-efficacy:

- 63% of students reported increased belief in their potential to pursue engineering (e.g., "I now believe I can be an engineer").
- Many students emphasized enjoyment in hands-on experimentation, especially when linked to societal impact.
- 78% explicitly cited the influence of female mentors and guest speakers as inspirational.

D. Parental Feedback

Structured interviews with 42 parents indicated broader impacts beyond the classroom:

- 71% observed an increase in STEM-related conversations at home.
- 68% noted their child expressed a stronger interest in engineering as a potential career.
- Several parents also reported improved confidence in school STEM subjects and heightened enthusiasm for extracurricular STEM activities.

Overall, the program yielded positive outcomes across all assessment categories. Among the cohort of 120 students, a substantial majority reported increased interest in engineering, enhanced confidence in STEM, and stronger intent to pursue engineering-related pathways. Mentorship and real-world problem-solving emerged as the most consistently valued elements.

These findings demonstrate that early, targeted outreach programs can foster meaningful engagement in engineering among young women. However, future longitudinal research will be essential to assess whether these early shifts translate into sustained interest and actual enrollment in engineering disciplines at the postsecondary level.

V. Conclusion

The results of this study demonstrate that well-structured, targeted outreach initiatives can meaningfully enhance students' interest and confidence in engineering, particularly among underrepresented female populations. The combination of mentorship, hands-on project work, and exposure to socially relevant engineering problems proved especially effective in fostering student engagement. Assessment data showed marked improvements across key metrics, including a 35% increase in interest in engineering careers and a 30% increase in STEM-related discussions at home.

Although these short-term outcomes are promising, this study does not claim to solve the gender gap in engineering. Rather, it provides a foundation for ongoing research and programmatic development. Future longitudinal studies will be needed to evaluate whether early gains in interest and confidence translate into sustained engagement and enrollment in engineering fields. Nonetheless, the results suggest that localized, mentorship-driven, and contextually meaningful interventions can be a vital part of the broader effort to make engineering more inclusive and representative.

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