Expanding and Sustaining BP-AE: Scaling Mentorship and Building Collaborative Infrastructure in Aerospace Engineering (Experience)

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The Broadening Participation in Aerospace Engineering (BP-AE) program addresses the need to expand access to research experiences and professional development in aerospace engineering. Using a train-the-trainer mentorship model, graduate mentors are equipped to train peers and lead development activities, fostering a scalable and self-sustaining network that supports student engagement and success in STEM fields.

With support from National Science Foundation (NSF) grants, BP-AE expanded to five additional institutions and provided summer research opportunities through the Transformational Technologies for Next Generation Aerospace Systems Research Experience for Undergraduates (TT-AE REU) program. Collaborations with universities and industry partners enhanced program sustainability and impact. External evaluations confirmed increased STEM engagement and retention, showcasing BP-AE's effectiveness in preparing a skilled aerospace workforce through strategic partnerships and sustainable practices.

I. Introduction

Aerospace engineering is vital in advancing industries such as commercial aviation, satellite communications, and national defense. However, the field faces a persistent challenge: a limited number of students pursuing advanced degrees and careers in aerospace engineering. For example, comparatively few institutions currently offer undergraduate degree programs in aerospace engineering, which reduces access to specialized training and research opportunities for many students.[1]

Contributing factors include limited access to aerospace-related undergraduate research experiences (UREs), key predictors of STEM retention, and the high costs of experimental facilities, which prevent many institutions from offering hands-on learning opportunities.[2] This lack of exposure to aerospace-related education and research reduces the pipeline of students entering the field and limits the development of the future aerospace workforce.[3,4,5,6]

The Broadening Participation in Aerospace Engineering (BP-AE) program incorporates best practices from three broadening participation models discussed by Walter Lee.[7] These models offer a holistic approach to engage URMs in STEM fields. **Pipeline Model**: Enhances participants' knowledge, skills, and professional socialization by addressing leaks in the educational system. Key elements include active recruitment, mentoring, peer-to-peer interactions, and project-based learning.[8] **Pathways Model**: Proactively removes systemic barriers and prepares URMs for engineering careers through mentorship, internships, and research opportunities, often engaging diverse role models.[9] **Ecosystem Model**: Develops culturally responsive environments that foster shared experiences and learning among stakeholders.[10] BP-AE integrates these elements to address systemic inequities and broaden participation in aerospace engineering.[11] To address these challenges, the following section describes the structured mentorship and professional development model implemented in the BP-AE program.

II. Methods

The BP-AE program includes four major activities to support student engagement and success in aerospace engineering:

- **Senior Capstone Design Projects**: Coordinated 30 aerospace-related projects between 2022 and 2024, sponsored by organizations like NASA, Boeing, and JPL, involving 115 students.
- **Summer Research and Internships**: Hosted more than 100 students in education and training activities. This includes 19 NASA summer internships at centers like Kennedy Space Center and Jet Propulsion Laboratory.
- **Structured Mentorship and Learning Communities**: Supported 12 Ph.D. students and 14 M.S. students. Graduate students benefited from co-advised research projects with NASA and AFRL.
- **Professional Collaborations and Employment Pathways**: Facilitated meaningful collaborations with NASA and AFRL, leading to employment opportunities for alumni. Since 2022, four BP-AE graduates have joined NASA and three have joined AFRL.

These initiatives demonstrate the BP-AE program's commitment to expanding student opportunities and strengthening the aerospace engineering workforce.

Expanded Success to a Broader Network

Building on the success of BP-AE at three core institutions, the ENBP-AE program expanded to five additional institutions (Figure 1). This expansion emphasizes sustainable growth through shared goals, collaborative partnerships, and integrated infrastructure. By leveraging these principles, ENBP-AE fosters a localized ecosystem that supports education and research in aerospace engineering. [12]

The BP-AE and ENBP-AE programs support aerospace engineering education through a structured mentorship framework, professional development activities, and collaborative partnerships. These components were designed to scale effectively as the program expanded to include additional institutions, ensuring sustainability and impact.

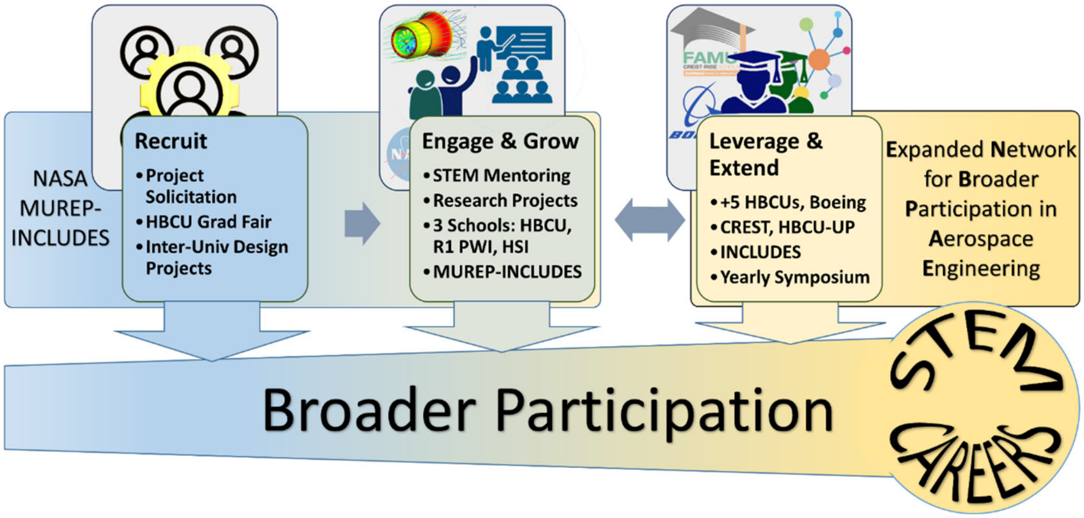

Figure 1: Program flow for ENBP-AE.

Mentorship Program Structure

BP-AE employs a triangulated mentorship model that establishes connections between faculty, graduate students, and undergraduates (Figure 2). This model ensures that each mentee benefits from multiple layers of guidance, fostering both academic and professional growth. Recognizing the challenges posed by program growth, the initiative transitioned from a single mentoring director approach to a train-the-trainer model. In this new framework, experienced graduate mentors are trained to lead mentor training sessions, enabling them to mentor undergraduates while also equipping additional graduate students with mentoring skills.

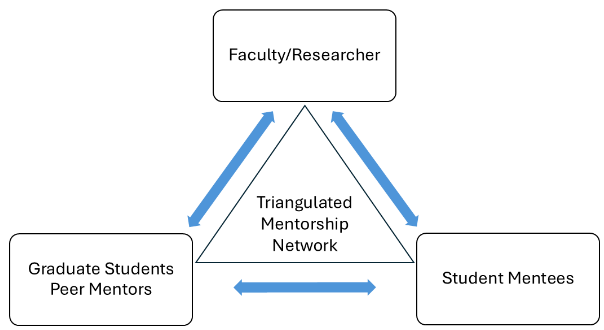

Figure 2: BP-AE's form of mentorship

This scalable approach has expanded mentoring capacity across three partnering institutions, where six additional graduate mentors have been trained to support local mentee cohorts. Graduate mentors trained with the CIMER "Entering Mentoring" curriculum [13], developing leadership skills while using tools like IDPs and mentorship compacts to guide relationships.[14,15,16] Reverse mentorship practices ensured continuous reflection and improvement.[17]

Professional Development Activities

The programs provide extensive professional development opportunities to complement mentorship. Students participate in technical seminars, workshops on project management, technical communication, and Responsible Conduct of Research (RCR) training (Figure 3). They also lead activities, such as panel discussions on transitioning from academia to the workforce, building leadership and organizational skills.

Collaborative Partnerships

The program's success relied on establishing and leveraging strategic partnerships with government agencies and industry leaders. Collaborators such as NASA centers, Air Force Research Laboratory (AFRL), JPL, and Boeing provided critical resources, mentorship, and access to high-impact projects. These partnerships enabled students to engage in meaningful internships at NASA, AFRL, JPL, and Boeing (Figure 4). Additionally, these collaborations facilitated career opportunities, with three participants securing positions at NASA and one at Boeing over the past three years.

Figure 3: BP-AE summer workshop

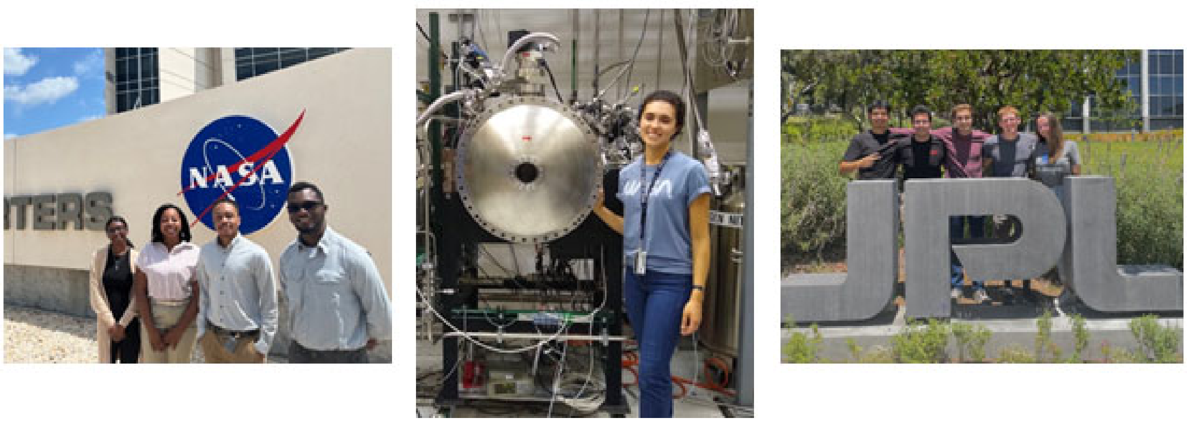

Figure 4: BP-AE summer interns at NASA Centers and JPL.

By working alongside professionals on aerospace innovations, students gained valuable experience that bridged the gap between academic training and industry demands. Through these collaborations, we are preparing students for leadership roles in aerospace engineering while demonstrating the scalability and sustainability of its approach.

Program Expansion and Scaling

The success of the initial BP-AE program at Universities A, B, and C demonstrated the effectiveness of its mentorship and professional development strategies. Building on this foundation, the Expanded Network for BP-AE (ENBP-AE) program was established to extend these efforts and scale the impact to a broader network of institutions and students.

The ENBP-AE program strategically added five institutions selected based on the desire to increase pathways into aerospace careers and existing faculty connections. Since the program's expansion, one of the added institutions has established an undergraduate program in aerospace engineering, and a core institution has launched a graduate program in Aerospace Engineering, further enhancing the capacity for aerospace education within the network.

The train-the-trainer mentorship model was pivotal for integrating these institutions, as graduate mentors from the original BP-AE institutions conducted training at three of the new partners. This approach ensures consistent implementation while enabling scalability of the mentorship framework. The next section presents the program outcomes, including mentorship effectiveness, student research participation, and career placements.

III. Results

The ENBP-AE program created a collaborative infrastructure emphasizing shared goals, communication, and resource sharing. Regular meetings, symposiums, and workshops supported coordination among institutions, enabling collective problem-solving and the exchange of best practices.

Key initiatives included a virtual graduate fair, supported by partner faculty, and in-person visits to strengthen recruitment efforts. The Florida Center for Advanced Aero-Propulsion (FCAAP) served as a central hub, providing state-of-the-art research facilities. Students from four of the partner institutions gained hands-on experience through summer internships at FCAAP, enriching their academic journeys and reinforcing faculty collaboration across institutions.

Securing Resources for Expansion

Significant external funding, including the NSF TT-AE REU grant, supported the program's growth. In 2024, the program funded summer research experiences for 20 students, 13 from outside the home institution and four from ENBP-AE partner institutions. These opportunities offered cutting-edge aerospace research projects paired with mentorship and professional training. Collaborations with North Carolina A&T State University and the University of South Florida expanded research engagement and institutional capacity, supporting future partnerships and program scalability.

Figure 5: BP-AE summer interns at University Lakefront Park and Retreat Ctr.

By integrating summer activities across BP-AE, ENBP-AE, TT-AE, and other research programs, the initiative brought together about 25 students, promoting collaborative learning and enriching extracurricular engagement (Figure 5). This consolidation optimized resource use and enhanced the impact of individual initiatives. These efforts exemplify a scalable model for future STEM education and research programs. In the following, we provide just-in-time assessment results of the 2024 summer REU program while expanding the evaluation process to comprehensively assess the overall BP-AE efforts.

Framework for Evaluation

The evaluation used Lent's Social Cognitive Career Theory (SCCT) [18,19] and Deci and Ryan's Self-Determination Theory (SDT)[20]. SCCT highlights the role of self-efficacy and success expectations in shaping career choices, while SDT emphasizes the importance of autonomy, self-efficacy, and supportive relationships in fostering motivation.

Mentor and Mentee Participants

- **Mentors:** A total of 24 graduate student mentors; 11 (45%) completed evaluation surveys. Most respondents were male (82%). Mentorship experience varied, with 64% mentoring for the first time.
- **Mentees:** A total of 17 (71%) of 24 mentees responded to evaluation surveys.

Mentor Training

Mentor training included options. Six (54%) of respondents were trained through the Research Experiences for Undergraduates (REU) program, three (27%) received training through the University Research Opportunity Program (UROP), and two reported they received "other" training. Most mentors found their training somewhat effective (54%), particularly regarding communication skills and setting mentee expectations. Respondents' open-ended suggestions for improvement included receiving more information regarding mentoring strategies and help with developing mentoring plans.

Mentors' Support and Competence

- **Types of Mentor Support:** Mentors reported providing mentees with technical and motivational support. See details in Figure 6 in the Appendix.
- **Mentors' Competence:** Using Fleming et al's Mentoring Competence Assessment[21], mentors rated their competence moderately to highly, particularly in research guidance and project management (Figure 7 in Appendix).

Mentee Outcomes

- **Research Experience Promoted Confidence and Research Self-Efficacy:** Mentees reported that, because of their summer research experience, they gained confidence and self-efficacy for doing research, particularly regarding knowing about the responsible conduct of research, collecting data and analyzing data (Figures 8 and 9 in Appendix).
- **Skills for Future Success:** Mentees indicated that, because of their summer research experience, they obtained skills for graduate school and/or careers in industry (Figures 10 and 11 in Appendix).
- **Engineering Goal:** Mentees indicated they felt positive about their goal to get an engineering degree (Figure 12 in Appendix).
- **Belonging in Engineering:** Mentees indicated that they experienced belongingness within the field of engineering (Table 1 in Appendix).
- **Positive Expectations for Future Engineering Coursework:** Mentees indicated they experienced positive self-efficacy for engineering coursework and expected positive course outcomes (Table 1 in Appendix).
- **Motivation for Engineering:** Mentees indicated they experienced positive motivation/enjoyment for conducting engineering tasks (Table 1 Appendix).
- **Preparation for the Future:** Mentees indicated that their participation in the summer program helped them feel prepared for the future (Table 1 Appendix).

These findings highlight the program's impact, which is further discussed in the concluding section, including sustainability strategies and future directions.

IV. Conclusion

Through open-ended survey items, Mentees wrote that they valued mentorship, networking, and hands-on research experiences. These aspects informed their decisions about graduate school, clarified career goals, and strengthened their readiness for future challenges.

Program Sustainability Strategies

The BP-AE and ENBP-AE programs aim to establish a sustainable coalition to strengthen aerospace engineering education and research, leveraging advanced infrastructure and institutional support. Three strategic directions guide these efforts:

1. **Partnership Expansion:** Building on the success of BP-AE, we secured funding through NSF grants to expand best practices to five additional institutions and enhance mentorship structures. Plans include applying for additional NSF funding to develop innovative strategies and expand collaborations. Ultimately, the goal is to establish a regional consortium to promote sustainable and transformative efforts.

2. **Sustained Engagement:** We pursued additional funding to ensure lasting impact. Successful proposals include the University of South Florida's Hy-POWERED program, focused on hydrogen-based research, and North Carolina A&T State University's SOARE initiative, strengthening aerospace research and workforce development. Complementary programs, such as NSF REU and DOE projects, support partner institutions and participants.
3. **New Degree Program:** Starting in Fall 2025, our program will launch M.S. and Ph.D. degrees in aerospace engineering, making it the first institution within the network to offer such programs. This milestone aligns with institutional investments in hypersonic systems and underscores the program's commitment to advancing aerospace graduate education.

The BP-AE and ENBP-AE programs demonstrate the power of well-coordinated strategies to support aerospace engineering education and research. Through mentorship, professional development, and industry partnerships, they create a scalable framework that enhances student success and workforce readiness. Establishing new graduate programs in aerospace engineering marks a significant milestone, while strategic partnerships and institutional investments ensure lasting impact, laying the foundation for a regional consortium. These programs prepare the next generation of aerospace engineers and set a precedent for impactful education and research in STEM.

V. Acknowledgments

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VII. Appendix

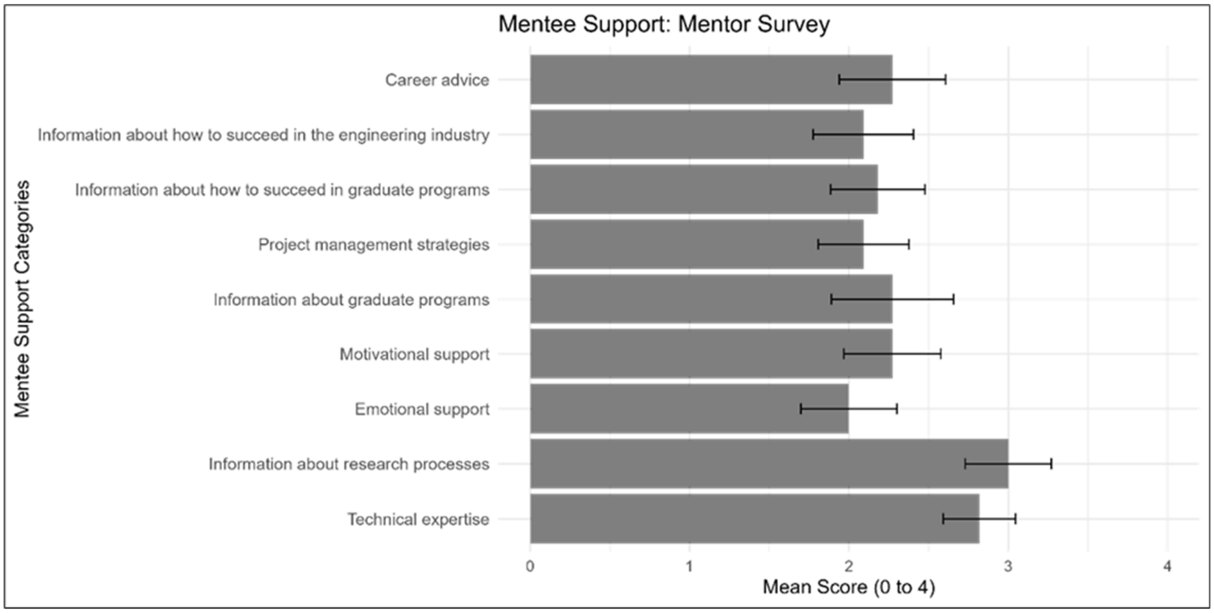
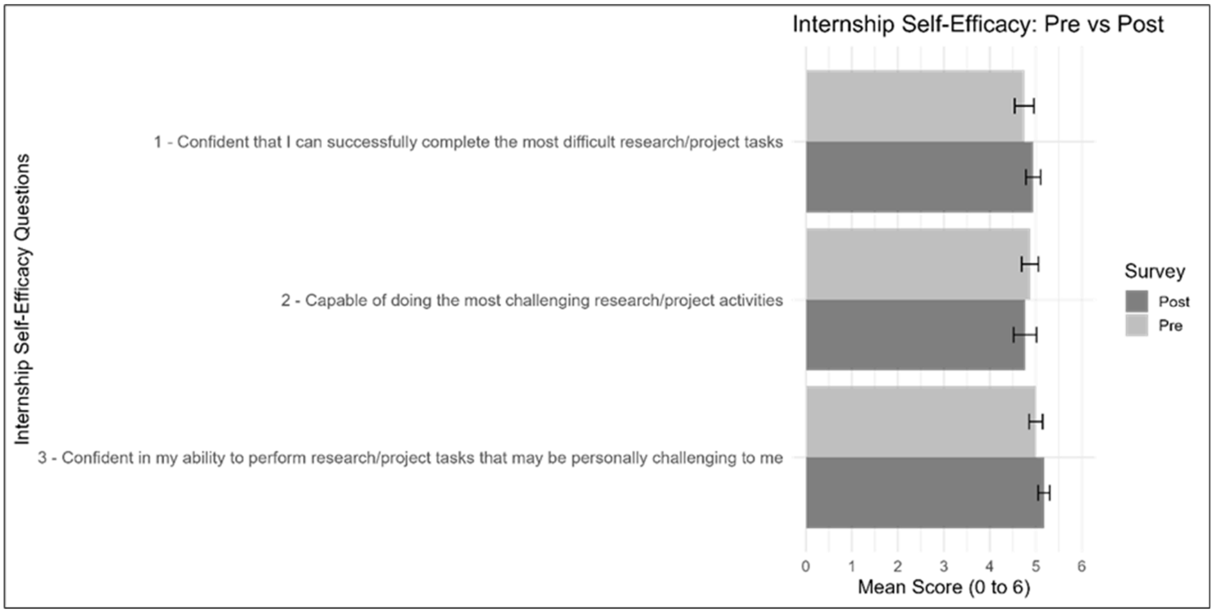


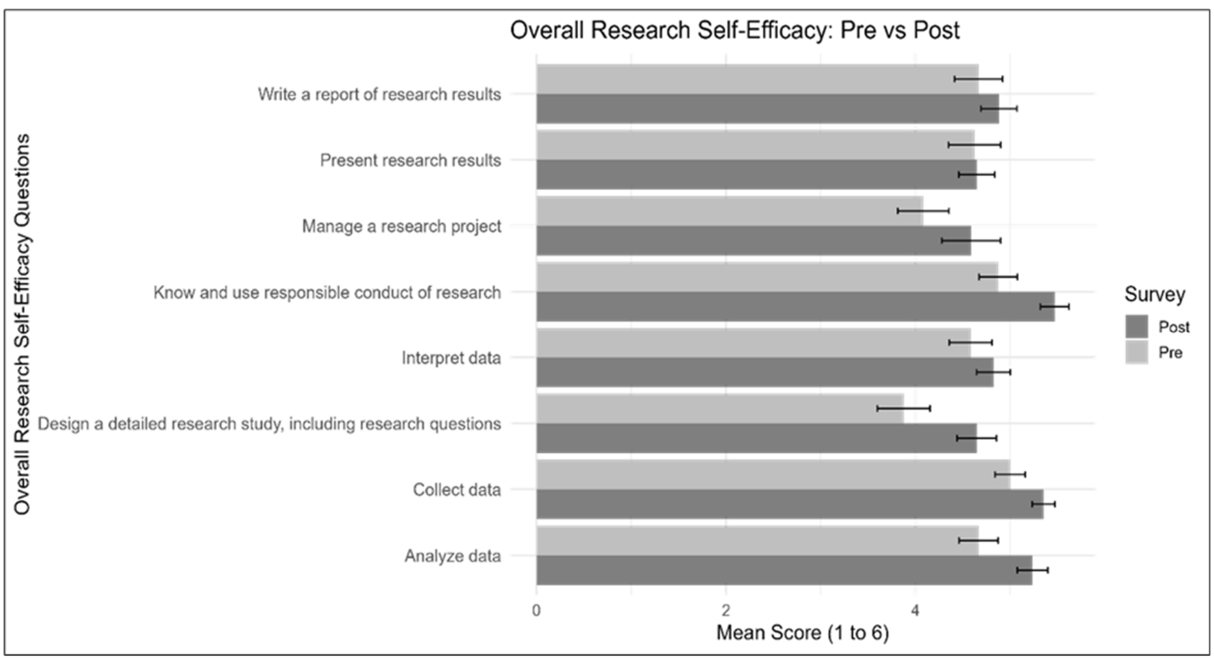
Figure 6: Types of Mentor-Provided Support

Figure 7: Mentors' Self-Ratings of Mentoring Skills



Note: 1= Not at all → 6= Absolutely

Figure 8: Mentees' Pre-survey and Post-survey Ratings on Internship Self-Efficacy



Note: 1= Not at all → 6= Absolutely

Figure 9: Mentees' Pre-survey and Post-survey Ratings on Research Self-Efficacy

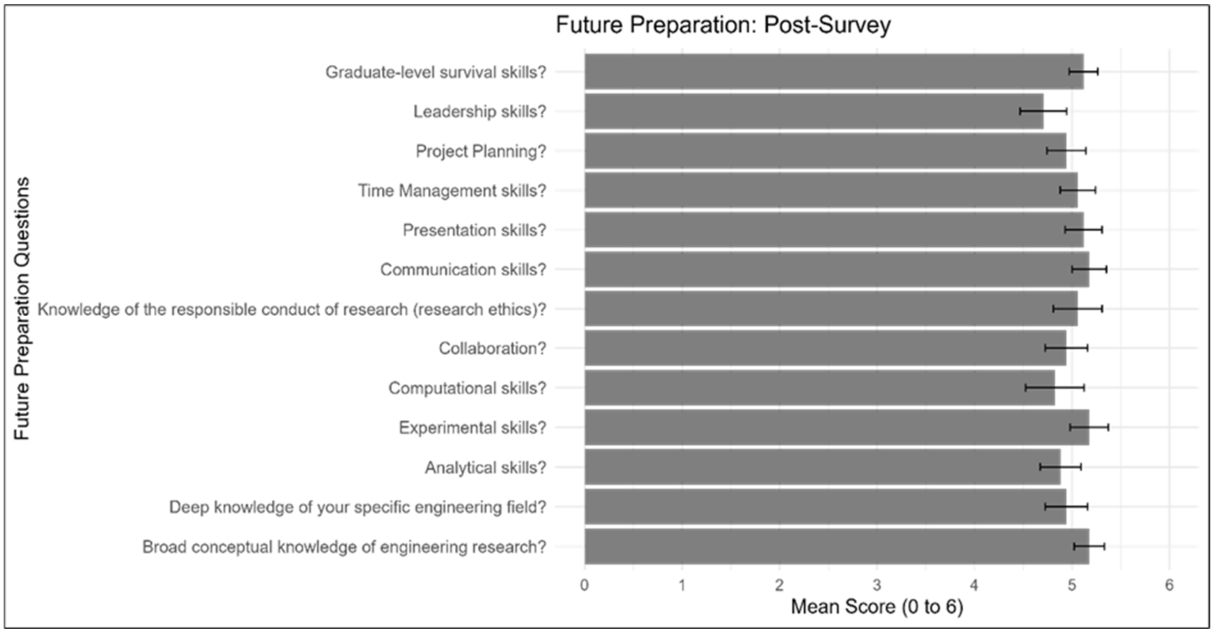


Figure 10: Summer Research Experience Helped Mentees Obtain Skills for Graduate School and/or Careers in Industry

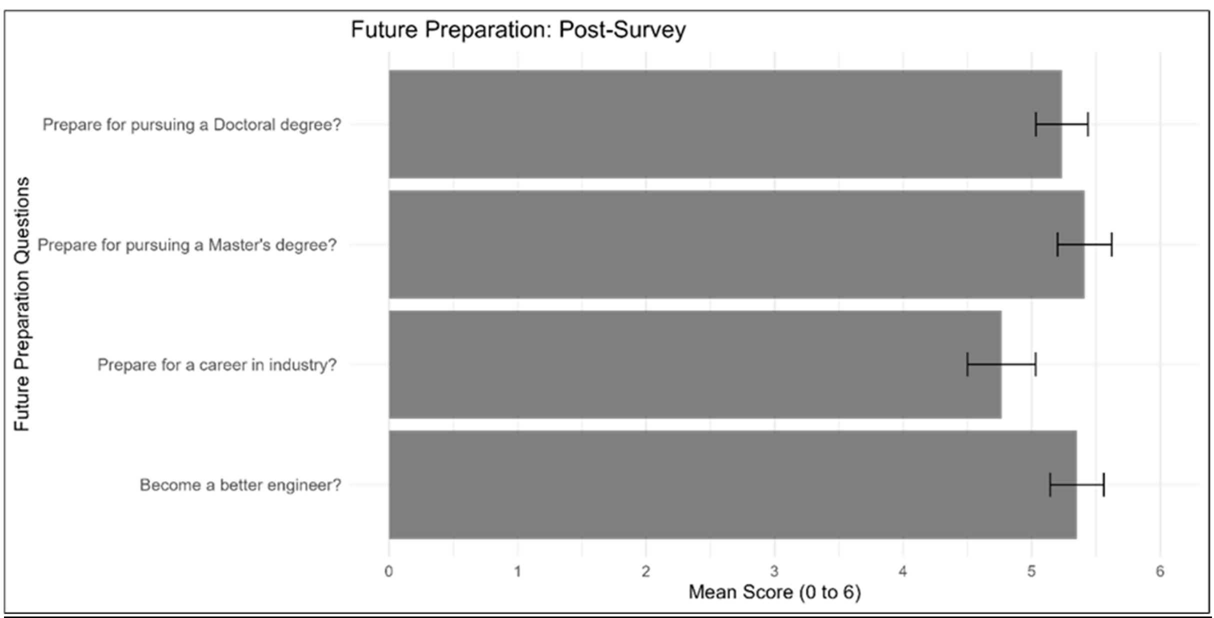


Figure 11: Summer Research Experience Helped Mentees Prepare for Future Advanced Education and Careers in Industry

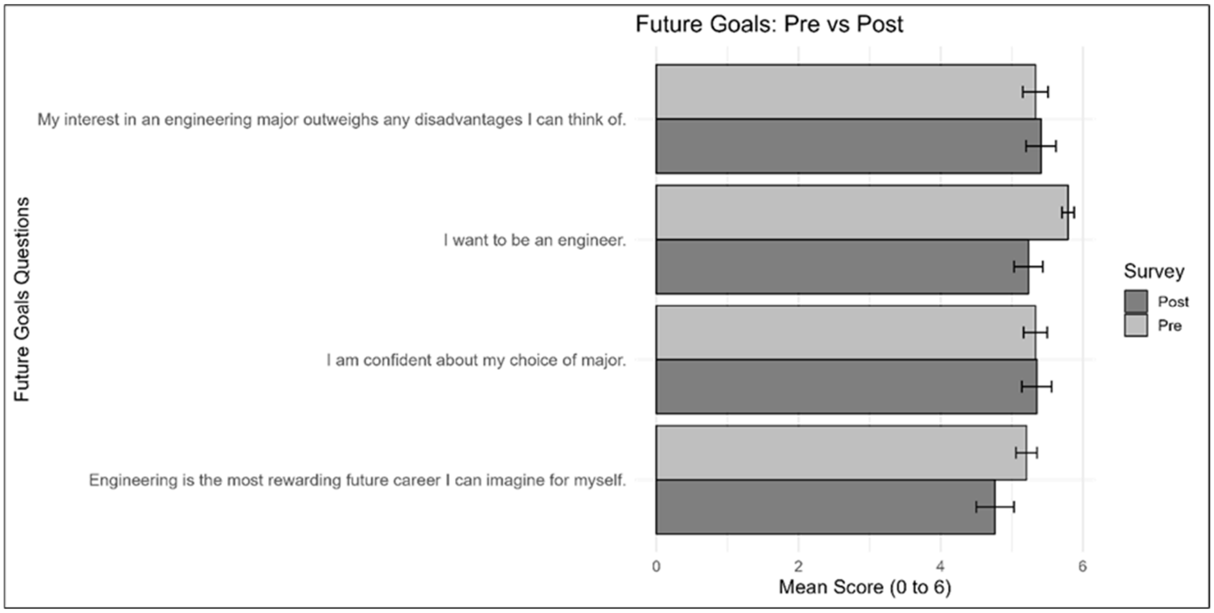


Figure 12: Pre-survey and Post-survey on Mentees' Engineering Goals

Table 1

Mentees' Ratings for Outcomes

Outcomes	Range	Mean	Standard Deviation
Engineering Goal	4.00 - 6.00	5.18	.69
Belongingness	3.25 - 6.00	4.73	.71
Course Self-efficacy	4.00 - 6.00	5.20	.62
Engineering Motivation	4.00 - 6.00	5.00	.71
Prepared for the Future	3.82 - 6.00	5.05	.57