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From Barriers to Bridges: The GEES Program's Impact on Low-Income Master's Students' Success and Professional Development

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In the United States, innovation development and economic growth have been influenced by contributions made by STEM professionals to a great extent. Universities aim to offer students in STEM programs career preparedness by imparting knowledge and necessary training in specialized skills. However, it should be acknowledged that not all students have equal opportunities for the study of STEM. Students from low-income and underrepresented backgrounds often face additional challenges, which consequently limit their academic pursuits and their career progression in STEM fields [1]-[2].

In order to bridge these gaps, the U.S. National Science Foundation (NSF) Scholarships in Science, Technology, Engineering, and Mathematics Program (S-STEM) has funded programs aimed at supporting students through scholarships, mentorship, and career development. The Graduate Engineering Education Scholarship (GEES) of the University of Pittsburgh is one of the success cases of the NSF S-STEM (Track 2) initiative. The GEES program, launched 2019 by the University of Pittsburgh's Swanson School of Engineering (SSoE), is an attempt to address the financial issues that low-income students face. There are two primary objectives: (1) to increase access to Master of Science (MS) degrees through scholarship support and (2) to bridge the gap between academic preparation and professional career preparedness. And over a five-year period, GEES has awarded 60 scholarships of $10,000 each to qualified students and help them complete their MS degrees and successfully enter the workforce.

GEES is structured to support students holistically through academic coursework, career development, and practical experience. Students can choose from a variety of programs across six engineering departments, including Bioengineering (BIOE), Civil and Environmental Engineering (CEE), Chemical and Petroleum Engineering (CHPE), Electrical and Computer Engineering (ECE), Industrial Engineering (IE), and Mechanical Engineering and Materials Science (MEMS). Each program includes a three-semester MS track (30 credits) or a two-semester certificate track (15 credits), both of which are infused with career-focused learning. Within their programs, GEES scholars engage in real-world projects, industry-based internships, and networking with professionals. This structure is designed to equip them not only with technical skills but also with the ability to navigate complex workplace environments.

GEES goes beyond classroom education by integrating co-curricular activities that foster professional skills. For example, students participate in workshops on job search strategies, interview techniques, and negotiation skills, helping them navigate the professional world with confidence. Each student is also matched with an industry mentor, who serves as a guide and coach throughout the program. These mentors help scholars build networks, hone specific industry skills, and gain insights into practical engineering challenges.

Another cornerstone of the GEES program is its structured mentorship approach, which addresses challenges such as low self-confidence and career uncertainty. Each student works with a mentor to develop an Individual Development Plan (IDP) based on SMART (Strategic, Measurable, Achievable, Realistic, and Time-bound) goals, as proposed by Wosu (2016) [3].

The IDP outlines clear steps for skill development, career exploration, and professional growth, making the mentorship relationship goal-driven and supportive. Through regular mentor meetings, GEES scholars receive feedback on their progress, discuss challenges, and build professional skills that enhance their readiness for the workforce. This mentorship process is informed by past NSF programs at the University of Pittsburgh, such as the Global Engineering Preparedness Scholarship (GEPS)[1] and PITT STRIVE program (AGEP-KAT)[2], which emphasized the importance of faculty-student engagement and holistic support.

In addition, GEES scholars are not only equipped with technical knowledge but also gain exposure to interdisciplinary and industry-related experiences that position them as strong candidates in both local and global job markets. Cross-disciplinary networking, real-world project work, and opportunities to interact with industry leaders create a well-rounded experience for students. By integrating classroom learning with hands-on experience, GEES aims to produce graduates who are ready to tackle engineering challenges and thrive in diverse workplace settings

Through this comprehensive support system, the GEES program builds a bridge from academia to industry for low-income MS students in engineering, addressing both their academic needs and career aspirations. Thus, the purpose of this study is to evaluate whether the GEES program has achieved its intended objects and whether the GEES program has effectively improved these low-income MS masters students' academic and career development. Therefore, the primary question of this study is: Have GEES program activities increased students' success and professional development for the workforce?

Literature Review

Many universities in the United States have realized the importance of supporting to underrepresented and low-income students' academic success and career readiness in STEM fields. Universities design various programs to provide critical resources such as financial support, mentoring, and hands-on experiences to those students, under the NSF S-STEM initiative [4]-[5]. The GEES program specifically designed for master students in engineering also aims to achieve those objectives. By reviewing the success of other NSF S-STEM initiative awards or scholarships, we can better understand the significance of the GEES program in addressing the unique challenges faced by low-income master students.

Financial Support and Student Success

Financial support helps low-income students in STEM fields succeed in universities. For example, Cannon University's SEECS program exemplified the positive impact of financial support on student achievement. The program reported that "the availability of financial aid significantly improves student retention and allows students to focus more on their studies without having to think too much about finances" [4]. The S-STEM program at the University of Maryland, Baltimore County (UMBC) also shown that "financial scholarships combined with structured mentoring and research opportunities significantly improve student academic performance and persistence" [6]. Similarly, the "Creating Retention and

[1] The Global Engineering Preparedness Scholarship (GEPS) program at the University of Pittsburgh's Swanson School of Engineering provides S-STEM scholarships for low-income students, aiming to prepare 25 academically talented scholars with technical, global competency, and leadership skills for the global engineering workforce. The program addresses the National Academy of Engineering's call to develop globally competent engineers and includes continuous academic support and opportunities for leadership through service learning, internships, a capstone design course, or study abroad. A focus on underrepresented minority (URM) and transfer students strengthens access to engineering education and enhances diversity in the field.

[2] The PITT STRIVE program at the University of Pittsburgh's Swanson School of Engineering, funded by NSF's Alliances for Graduate Education and the Professoriate-Knowledge Adoption and Translation (AGEP-KAT) initiative, aims to support the transition of URM into doctoral engineering programs and enhancing their representation and success in graduate engineering education.

Engagement for Academically Talented Engineers" program (CREATE) at a large Western land-grant university found that "students who received financial support, mentoring, and real-world experience were more likely to persist and succeed academically" [7].

In addition, the S-STEM program at Purdue University Northwest demonstrated that scholarship and comprehensive support raised the retention and graduation rates of underrepresented students. "92% degree completion rate among its participants, compared to significantly lower rates among non-participants" [5], highlighting the transformative feature of financial support in helping students achieve their academic goals. The GEES program is similar to the above programs that combine financial support with mentoring and other professional development activities to help students overcome barriers to success.

Mentorship and Professional Development

Mentorship is another essential component of student's academic and professional development. Effective mentoring provides guidance, develops necessary skills, builds professional networks, and boosts student confidence. Hund et al. emphasized that the mentorship between students and their advisor determines the quality of student's educational experience. Stress, anxiety, and depression are common challenges faced by students from disadvantaged groups, and effective and reasonable mentoring can help students overcome these challenges. Hund et al. also defined effective mentoring as three features: flexibility, communication, and trust. Establishing transparent and honest communication can build trust between the mentors and the students, and this trust can thus create an environment where the student feels supported and respected [1]. Furthermore, Wosu's work on the Relational Mentoring Model (RMM) demonstrated the need for a strong, trusting mentoring relationship, "effective mentoring relationships are rooted in mutual respect and trust, which are essential to creating an environment where mentees feel supported and motivated to achieve their" [8].

In addition, other NSF S-STEM programs have demonstrated the positive impact of mentors on student success. For example, the S-STEM program at UMBC found that "mentorship, combined with research opportunities, greatly increased students' confidence in their abilities and prepared them for future careers in STEM fields" [6]. Purdue University Northwest's S-STEM program also reported that mentors provide individualized guidance and thus improve retention and graduation rates for underrepresented students, especially first-generation college students [5]. Similarly, the GEES program's mentorship emphasizes the importance of establishing a structured, ongoing mentor-student relationship. By providing personalized mentorship, the GEES program provides low-income master's students with the skills, confidence, and professional networks needed to succeed in engineering.

Career Preparedness in Engineering Education

Career preparedness is a vital outcome of higher education, and engineering students equipped with the technical expertise, practical skills, and experiences could meet domestic and global labor market expectations. The S-STEM program at Purdue University Northwest reported that "students who received such support were more likely to secure employment in their field shortly after graduation" [5]. This indicated that the career preparedness provides an effective way for students to transform their roles from academic settings to industry. The emphasis on practical experiences to enhance preparedness for the workforce was also a focus of other S-STEM programs. Activities that were designed, such as research opportunities, professional development workshops, job shadowing, internships, community-

based design projects, and co-curricular activities, provide students with practical and real-world experiences [4], [6], [7].

On the other hand, as engineering becomes increasingly global, engineering students should acquire the necessary skills and competencies to operate effectively internationally. In order to be ready for an international career, students must possess more than just technical skills; they must also be able to engage across different cultures, know global practices, and have the capability to handle international challenges. Integrating global perspectives into the S-STEM program by utilizing case studies and exploring the social, environmental, cultural, and economic impacts ensures that students cultivate their global proficiency and become prepared to confront the world's difficulties [2].

The GEES program emphasizes the importance of preparedness in two aspects: technical proficiency and the ability to excel in diverse and global settings. This dual emphasis equips students with the necessary skills and knowledge demanded by the engineering profession, thereby positioning them as competitive candidates in both local and global labor markets.

While NSF S-STEM programs have been instrumental in supporting undergraduate students by increasing retention and graduation rates in STEM fields, there is a growing need to extend similar support to graduate students, particularly low-income master's students. These students often face unique challenges, including the necessity for advanced research skills, professional networking, and leadership development. As Wosu [8] highlights, providing targeted support at the graduate level is critical to ensuring these students succeed academically and professionally.

The GEES program addresses this need by focusing specifically on helping low-income master's students develop the skills and confidence required for a successful transition into the workforce. By doing so, the GEES program complements existing NSF S-STEM initiatives and expands the scope of support to include graduate education. This study evaluates the outcomes of the GEES program on master's students' success and professional development, thereby contributing to the broader goals of the NSF S-STEM initiative and highlighting the importance of supporting students at all levels of higher education.

Methods

Our study used a convergent mixed methods design [9] to explore the impact of the GEES program on low-income master students. This design involved collecting both quantitative (pre- and post-survey) and qualitative (semi-structure interview) data in parallel, analyzing separately and then integrating findings to gain a comprehensive understanding of students' professional development outcomes in GEES program.

Pre and Post Survey

We used during pre- and post-surveys with a panel of Likert scale items to collect quantitative data from GEES scholarship students. The students rated six aspects of their abilities and preparedness on a scale from 1 (poor/strongly disagree) to 5 (excellent/strongly agree), including perceived abilities, interest levels, self-confidence, engineering workforce preparedness, skills preparedness, and importance of mentorship. 29 students responded to the pre-survey and 27 students responded to the post-survey. After data cleaning with removing incomplete responses, there were 27 pre-survey respondents and 23 post-survey respondents.

Semi-structured Interview

To gain a comprehensive understanding of the GEES program's impact on low-income master's students, we also utilized a qualitative method. 23 students who had been part of the GEES program did the semi-structure interviews focused on academic and professional development. The interview was designed to explore three main themes: academic development, mentorship experience, and career readiness. GEES program students' academic development, centered on students' overall experiences during their first year of graduate school. The second theme addressed mentorship experiences, where interviewees discussed their involvement with mentorship supports offered through the masters and GEES programs. Questions covered the frequency and accessibility of mentor interactions, specific contributions of mentorship to their academic success and faced challenges. Interviewees were encouraged to provide specific examples and describe the most valuable qualities in their mentorship. The last theme focused on how the GEES program contributed to students' career readiness. Interviewees were asked to reflect on specific courses or programs that the greatest impact on their career preparedness and to discuss other career guidance they received during their studies.

Results and Findings

Survey Results

Demographics

This study included 27 GEES program students who completed the pre-survey and 23 who completed the post-survey. Regarding gender distribution, the pre-survey included 12 females (44.4%) and 14 males (51.9%), while the post-survey comprised 9 females (39.1%) and 13 males (56.5%). For race groups, most participants (81.5%, n=22) were White, with 11.1% (n=3) Black or African American and 7.4% (n=2) Asian in the pre-survey. The race group components of post-survey were same with the pre-survey: White (87.0%, n=20), Black or African American (8.7%, n=2) and Asian (4.3%, n=1).

The participants represented a range of intended master's degree majors within engineering fields. The majority were pursuing degrees in Bioengineering (BIOE) with 29 participants (58%), followed by Mechanical Engineering and Materials Science (MEMS) with 10 participants (20%). Smaller representations were noted in Chemical and Petroleum Engineering (CHPE) with 4 participants (8%), a joint degree in BIOE & MBA with 1 participant (2%), Master of Science (unspecified discipline) with 1 participant (2%), and Master of Science in Public Administration (MS-MPA) with 1 participant (2%).

Participants also reported their academic year to help us gain the insights of students' varying levels of experience with GEES program. The majority (74.07%, n=20) started in the 2020–2021 academic year. Smaller groups began in the 2019–2020 academic year with 2 participants (7.41%) and in the 2021–2022 academic year with 5 participants (18.52%).

Enhancements in Technical Skills

Participants reported significant enhancements in their perceived engineering or technical abilities during the GEES program. The average rating increased from 3.48 in the pre-survey to 4.00 in the post-survey, a significant mean difference of 0.52, $t(48) = 2.28$, $p < .05$. This suggests that the GEES program was related to an increase in students' confidence in their technical competencies, a critical aspect of their engineering education.

Table 1. Students' Perceived Abilities in Pre and Post Survey

Perceived Abilities	Post-Survey		Pre-Survey		Mean-diff	t
	observations	mean	observations	mean		
writing	23	4.35	27	4.00	0.35	1.94
oral communications	23	3.87	27	3.67	0.20	0.76
leadership (influencing desired changes in others)	23	4.09	27	3.59	0.49	2.00
leadership (influencing desired changes in oneself)	23	4.17	27	3.81	0.36	1.81
engineering or technical skills	23	4.00	27	3.48	0.52*	2.28

Note: ** indicates $p < .01$, and * indicates $p < .05$.

Increased Confidence in Coursework and Work Performance

There were also significant gains in participants' self-confidence regarding their ability to perform well in engineering coursework and job tasks during the GEES program. The average rating for confidence in coursework performance improved from 3.74 before the program to 4.39 after, a significant mean difference of 0.65, $t(48) = 3.49$, $p < .05$. Similarly, confidence in work performance increased from 3.48 to 4.22, a significant mean difference of 0.74, $t(48) = 3.36$, $p < .05$. These results indicate that participation in the GEES program was associated with increased confidence in academic and professional abilities in the engineering field.

Table 2. Students' Self-confidence in Pre and Post Survey

Self-confidence	Post-Survey		Pre-Survey		Mean-diff	t
	observations	mean	observations	mean		
engineering coursework performance	23	4.39	27	3.74	0.65**	3.49
engineering work/job performance	23	4.22	27	3.48	0.74**	3.36

Note: ** indicates $p < .01$, and * indicates $p < .05$.

Engineering Workforce Preparedness

Participants demonstrated significant enhancements in their preparedness for the engineering workforce, related to their involvement in the GEES program. The average rating for understanding societal issues increased from 3.48 to 4.13, a significant improvement of 0.65, $t(48) = 2.67$, $p < .05$. Understanding of cultural issues improved from 3.30 to 3.83, a

significant mean difference of 0.53, t(48) = 2.19, p < .05. The most profound improvement was in overall preparedness for the global engineering workforce, where the average rating rose from 2.56 to 3.78, a highly significant increase of 1.23, t(48) = 4.82, p < .05. These results highlight that the GEES program was associated with significant improvements in participants' preparedness for the complexities of globalized engineering environments.

Table 3. Students' Engineering Workforce Preparedness in Pre and Post Survey

Workforce Preparedness	Post-Survey		Pre-Survey		Mean-diff	t
	observations	mean	observations	mean		
global issues (i.e., the world around you)	23	3.87	27	3.44	0.43	1.51
societal issues (i.e., the people and societies in the world around you)	23	4.13	27	3.48	0.65*	2.67
cultural issues (i.e., the ways people typically do things in the world around you)	23	3.83	27	3.30	0.53*	2.19
global engineering workforce preparedness	23	3.78	27	2.56	1.23**	4.82

Note: ** indicates p < .01, and * indicates p < .05.

Enhancements in Practical Skills

Participants showed widespread improvements in their practical skills during the GEES program. The ability to break down complex concepts into simple, understandable ideas increased significantly, with the average rating rising from 3.96 to 4.43—a mean difference of 0.47, $t(48) = 2.54$, $p < .05$. Participants also reported gains in their ability to interface with industry, with the average rating increasing from 3.11 to 4.09—a mean difference of 0.98, $t(48) = 3.24$, $p < .05$. Additionally, their ability to manage multiple projects improved from 3.67 to 4.26, a mean difference of 0.59, $t(48) = 2.40$, $p < .05$. These results indicate that participation in the GEES program was related to significant improvements in practical skills, which are crucial for future success in the engineering profession.

Table 4. Students' Skills Preparedness in Pre and Post Survey

Skills Preparedness	Post-Survey		Pre-Survey		Mean-diff	t
	observations	mean	observations	mean		
solve problems	23	4.39	27	4.04	0.35	1.91
meet deadlines	23	4.43	27	4.33	0.10	0.40
be able to adapt and learn new technologies	23	4.48	27	4.07	0.40	1.88
communicate orally	23	4.22	27	3.78	0.44	1.54
work in teams	23	4.35	27	3.93	0.42	1.69
process strong analytical ability	23	4.30	27	4.07	0.23	1.13
communicate in writing	23	4.39	27	4.15	0.24	1.19
break down complex concepts into simple, understandable ideas	23	4.43	27	3.96	0.47*	2.54
approach problems systematically	23	4.35	27	4.11	0.24	1.30
tailor communication to your audience	23	4.09	27	3.67	0.42	1.88
interface with industry	23	4.09	27	3.11	0.98**	3.42
give presentations	23	4.00	27	3.59	0.41	1.46
use multiple tools to solve complex problems	23	4.30	27	3.96	0.34	1.78
manage multiple projects	23	4.26	27	3.67	0.59*	2.40
write technical reports	23	4.09	27	3.63	0.46	1.68
work across disciplines	23	4.22	27	3.78	0.44	1.94

Note: ** indicates $p < .01$, and * indicates $p < .05$.

Stable Interest Levels and Views on Mentorship

There were no statistically significant changes in participants' interest levels or their views on the importance of mentorship associated with the GEES program. While participants' interest

ratings remained high for both an engineering career and graduate school, there were minor reductions that were not statistically significant. The average rating for an engineering career slightly decreased from 4.74 to 4.57, and for graduate school from 4.44 to 4.09. This consistency suggests that students were already strongly motivated toward engineering and advanced studies before entering the GEES program.

Table 5. Students' Interest Levels in Pre and Post Survey

Interest Level	Post-Survey		Pre-Survey		Mean-diff	t
	observations	mean	observations	mean		
an engineering career	23	4.57	27	4.74	-0.18	-1.04
graduate school	23	4.09	27	4.44	-0.36	-1.41
an international engineering career	23	3.30	27	3.04	0.27	0.78
global, societal, or cultural contexts or issues within engineering	23	3.52	27	3.33	0.19	0.68

Note: ** indicates $p < .01$, and * indicates $p < .05$.

Similarly, students' views on mentorship remained consistently positive throughout the GEES program, even though no statistically significant changes observed. Ratings for mentorship aspects like serving as a role model increased slightly from 4.33 in the pre-survey to 4.43 in the post-survey, and the importance of sharing personal experiences rose from 4.59 to 4.65. Additionally, the value placed on mentors providing a safe space to discuss anxieties saw a minor increase from 4.26 to 4.35. Conversely, ratings for mentors as a consistent source of advice showed a small decrease from 4.67 to 4.65, though this change was not significant. These stable ratings suggest that students entered the program with a strong appreciation for mentorship, which the GEES program successfully reinforced by offering supportive and responsive mentoring relationships aligned with students' academic and professional goals.

Table 6. The Importance of Mentorship in Pre and Post Survey

Mentorship	Post-Survey		Pre-Survey		Mean-diff	t
	observations	mean	observations	mean		
serve as a role model	23	4.43	27	4.33	0.10	0.40
share history of her/his career with you	23	4.48	27	4.33	0.14	0.80
share personal experiences as	23	4.65	27	4.59	0.06	0.33

examples from which you can learn						
respect you as an individual	23	4.78	27	4.78	0.00	0.03
serve as a consistent source for advice and support	23	4.65	27	4.67	-0.01	-0.09
provide opportunities for you to ask questions w/o fear of affecting your grades or career options	23	4.65	27	4.70	-0.05	-0.33
encourage you to talk openly about anxiety and fears that detract from your academic work	23	4.35	27	4.26	0.09	0.38
understand how your background (gender/race/ethnicity) may affect your experiences as a student in your field of study	23	3.78	27	3.96	-0.18	-0.63
convey interest in hearing about your ideas	23	4.48	27	4.59	-0.11	-0.65
help you explore a range of possibilities when you face decision points	23	4.74	27	4.70	0.04	0.25
encourage you to prepare for the next steps in your academic program or career	23	4.74	27	4.70	0.04	0.25
explore career options with you	23	4.52	27	4.63	-0.11	-0.59
help you overcome insecurities about your abilities as a scientist or engineer	23	4.35	27	4.22	0.13	0.53

Note: ** indicates $p < .01$, and * indicates $p < .05$.

Survey Findings

The GEES program is associated with positive changes in the technical skills, confidence, and workforce readiness of low-income master's students in engineering. These findings are consistent with research on similar STEM support programs, suggesting that integrated support systems—financial, mentorship, and professional development—contribute to student success.

Enhanced Technical Skills and Academic Performance
Students reported significant increases in their perceived technical abilities during the GEES program. The average rating rose from 3.48 in the pre-survey to 4.00 in the post-survey, reflecting improved confidence in technical competencies—a critical aspect of engineering education. This aligns with findings from Purdue University Northwest's S-STEM program, where financial and academic support systems were correlated with higher retention and academic success among underrepresented students [5].

Increased Self-Confidence in Coursework and Work Performance
There were also notable gains in students' self-confidence regarding academic coursework and job-related tasks during the GEES program. The average rating for coursework confidence increased from 3.74 to 4.39, and for work performance from 3.48 to 4.22. These results suggest that the program was associated with enhanced confidence in students' abilities to handle engineering challenges. This mirrors findings from UMBC's S-STEM initiative, which showed that financial support and mentorship contributed to students' self-assurance and persistence in STEM [6].

Workforce Preparedness for Engineering
Participants demonstrated improvements in their preparedness for the engineering workforce, including an understanding of societal and cultural issues. The average rating for societal awareness rose from 3.48 to 4.13, with the most significant gain in overall preparedness for the global workforce, which increased from 2.56 to 3.78. These improvements align with the goals of the Global Engineering Preparedness Scholarship (GEPS) program, which emphasizes the importance of global preparedness and cultural competence in engineering [2]. These findings suggest that students felt better equipped for local and global engineering roles, likely due to GEES's integration of real-world projects and industry networking.

Practical Skill Development and Industry Engagement
Students reported positive changes in practical skills, particularly in simplifying complex concepts, engaging with industry, and managing projects. For instance, industry interfacing skills saw a notable increase from an average rating of 3.11 to 4.09. This outcome is consistent with the S-STEM program at Appalachian State University, which found that real-world experience and industry connections contributed to skill development [10]. GEES's emphasis on practical application appears to have supported students in developing the skills necessary for engineering professions.

Stable Interest Levels and Established Appreciation for Mentorship
There were no statistically significant changes in students' interest levels in engineering careers or their views on mentorship, though ratings remained high. This suggests that students entered the program with a strong motivation toward engineering and a well-established appreciation for mentorship. The consistency in these areas aligns with findings from programs such as the Relational Mentoring Model (RMM), which underscores the importance of pre-existing mentor relationships in fostering sustained student engagement [8].

Overall, students reported significant positive changes during the GEES program in areas essential for professional and academic success, including technical skills, self-confidence, and practical abilities. These results add to a growing body of evidence from NSF-supported programs, suggesting that comprehensive support systems can play a substantial role in promoting the development of underrepresented students in STEM. The GEES program's

approach to workforce readiness—particularly in fostering career preparedness and practical skills—demonstrates its alignment with best practices for empowering diverse students to succeed in engineering.

Interview Findings

The interview with 23 GEES program students revealed three significant themes: academic and skill development, mentorship and support, and career preparedness. Those three themes illustrate how the GEES program influenced low-income masters students' educational journeys and supported their career development.

Academic Development

The transition to graduate studies under the GEES program exposed participants to deeper, more specialized academic content that many found transformative. A common sentiment was that graduate school allowed them to move from theoretical knowledge to practical applications. One participant noted, *"In undergrad, it was all about passing exams. Now, I feel like I'm creating something real. It's not just knowledge; it's hands-on skills."* For those involved in internships or applied research, these experiences were especially impactful. One participant engaged in neural engineering research shared, *"It's a surreal feeling, knowing the work I'm doing could actually help patients in the future. Before, engineering felt like numbers and theories. Now, it's connected to real people."* Another participant working in space engineering emphasized the hands-on aspect, stating, *"The project work was eye-opening. I'd never thought about the logistics of real-world engineering before, like budgets and timelines. Now, I see how my skills fit into a larger picture."*

Participants also highlighted the development of specific skills, such as technical writing, project management, and collaborative problem-solving. One participant explained, "*Writing research papers was a challenge initially, but now I feel like I can present my ideas clearly. That's something I never really got to practice in undergrad."* Another mentioned learning to manage project timelines and resources, saying, *"In my research, there were so many moving parts. Learning to manage those pieces was probably the most valuable skill I gained."*

However, not all aspects of academic development were universally praised. Some participants desired greater depth in technical coursework. One participant reflected, *"We touched on so many topics, but I wanted to go deeper in a few areas. Sometimes I felt like we were just skimming the surface."* Another participant transitioning from industry to academia admitted, "*It was difficult to go back to school mode and set my own pace. In industry, I had strict deadlines. Here, I had to learn to manage my own time, and that was hard."*

Mentorship and Support

Mentorship was a cornerstone of the GEES program, though experiences varied widely among participants. For many, mentors provided essential support, both academically and personally. One participant who was also a parent noted, *"Grad school is hard enough, but with a family, it's a whole other level. My mentor was there not just for academic advice but personal encouragement, reminding me that it's okay to take breaks."*

Participants shared that their mentors played a crucial role in connecting them with professional networks and research opportunities. One participant described their mentor's proactive approach, saying, *"She introduced me to contacts in my field and even suggested conferences I should attend. That exposure changed everything for me."* Another participant, whose mentor facilitated an internship placement, emphasized, *"Without that internship, I*

don't think I'd have the confidence I do now. My mentor was instrumental in bridging the gap between academics and the real world."

However, some participants reported challenges with mentorship. One participant expressed frustration with the informal mentorship matching process, stating, *"It felt random. Some people got amazing mentors, and some of us didn't click as well. A formal matching system might make it more fair."* Another participant shared that they often had to take the initiative to maintain communication with their mentor, explaining, *"My mentor was great, but they were also very busy. Sometimes, I felt like I was chasing them just to get feedback."*

In some cases, participants wished for more structured mentorship activities, such as regular meetings or specific mentorship goals. One participant noted, *"I would have appreciated more structure. Having set expectations or checkpoints with my mentor would have made it easier to gauge my progress."* Despite these challenges, most participants viewed mentorship as one of the program's most valuable components, emphasizing its role in building confidence, professional connections, and resilience.

Career Preparedness

Another significant theme across interviews was the GEES program's role in preparing participants for their careers. Many participants felt that the program bridged the gap between academic learning and industry demands, often through hands-on experiences and targeted coursework. One participant explained, *"In grad school, I felt like I was actually preparing for my career, not just getting through classes. I knew the skills I was building would directly transfer to my job."*

Internships and industry-focused projects were often highlighted as transformative experiences that clarified participants' career goals. One participant who interned with a medical device company described it as *"the first time I truly saw myself as an engineer in a professional setting,"* adding that it helped solidify their commitment to the field. Another participant shared that a course on medical product development introduced them to various aspects of the field, saying, *"I learned not just about design, but the whole product lifecycle—regulations, funding, market strategy. That was incredibly valuable."*

Some participants, however, noted areas where the program could improve career preparation, particularly in niche or emerging fields. One participant aiming for a career in bioengineering shared, *"It's challenging because bioengineering isn't always a clear path. Job titles don't align perfectly with what we study, and that can be confusing when applying for jobs."* Another participant suggested that more resources on industry-specific career paths would be helpful, stating, *"I knew the technical side, but navigating the job market was a different story. Some guidance on how to approach specific industries would have made a big difference."*

Overall, participants valued the program's focus on career readiness, with most feeling equipped to transition into their chosen fields. As one participant summed up, *"This program wasn't just about academics; it was about learning to be a professional. I'm leaving with skills and experiences that I know will make me competitive in the job market."*

Conclusion

The GEES program was associated with significant positive changes in the technical skills, confidence, and workforce readiness of low-income master's students in engineering. Survey

results indicated that participants experienced notable enhancements in their perceived engineering abilities, self-confidence in coursework and job performance, and preparedness for the engineering workforce. These quantitative findings were reinforced by qualitative insights from participant interviews, which highlighted three key themes: academic development, mentorship and support, and career preparedness.

Academic Development and Skills
Participants reported that the transition to graduate studies within the GEES program allowed them to delve deeper into specialized academic content and engage in practical applications of their knowledge. The program was associated with improvements in specific skills such as technical writing, project management, and collaborative problem-solving. Students emphasized the value of hands-on experiences and real-world projects, which bridged the gap between theoretical learning and practical application.

Mentorship and Support
Mentorship emerged as a cornerstone of the GEES program, providing essential academic and personal support. While experiences varied, many participants found that mentors played a crucial role in connecting them with professional networks, research opportunities, and industry contacts. However, some participants noted challenges related to the informal mentorship matching process and expressed a desire for more structured mentorship activities. These insights suggest that while mentorship was beneficial, there is room for enhancing its effectiveness through more formalized processes.

Career Preparedness
The program was associated with increased career preparedness among participants. Through internships, industry-focused projects, and targeted coursework, students felt better equipped to transition into their chosen engineering fields. They reported gaining valuable insights into industry demands, project management, and the practical applications of their studies. Some participants suggested that additional resources focused on niche or emerging fields would further enhance career preparation.

Stable Interest Levels and Appreciation for Mentorship
Despite significant gains in other areas, there were no statistically significant changes in participants' interest levels in engineering careers or their views on the importance of mentorship. This stability suggests that participants entered the program with strong motivations toward engineering and well-established appreciation for mentorship, which remained consistent throughout their involvement in GEES.

Implications and Future Directions
The findings from this study contribute to the growing body of evidence that comprehensive support systems—encompassing financial assistance, mentorship, and professional development—are vital in promoting the success of underrepresented students in STEM fields. The GEES program's multifaceted approach appears to be associated with enhanced student outcomes and lead them success, aligning with best practices identified in similar NSF-supported initiatives.

However, the study also highlights areas for improvement. Formalizing the mentorship matching process and providing more structured mentorship activities could enhance the effectiveness of mentor-mentee relationships. Additionally, offering tailored career

preparation resources for students interested in niche or emerging engineering fields may further support their professional development.

Overall, the GEES program was associated with meaningful enhancements in participants' technical skills, confidence, and preparedness for the engineering workforce. By addressing both academic and professional development needs, the program demonstrates a successful model for supporting low-income master's students in engineering. Implementing the suggested improvements could further amplify its impact, contributing to the advancement of underrepresented groups within the STEM fields.

Limitations

While the study provides valuable insights, it is important to acknowledge its limitations. First, the study cannot establish causation between the GEES program and the reported improvements in skills, confidence, and workforce readiness. Many factors, including prior experiences, concurrent academic and professional opportunities, and personal growth outside the program, may have influenced these outcomes. Thus, we interpret the findings as correlational, reflecting associations rather than direct effects of the program.

Second, the survey data were collected from different respondents for the pre- and post-surveys, meaning that we were unable to perform paired matching. As a result, we could not directly measure individual-level changes over time, which limits the precision of the reported changes. Future studies could benefit from a longitudinal design where the same participants complete both surveys to enable paired comparisons.

Third, the sample size for the survey was relatively small (n=50), which limits the generalizability of the results to other populations. As participants were all from a single institution and program, the findings may not fully represent the experiences of low-income or underrepresented students in other settings or fields of engineering.

Finally, potential response biases should be considered. Students who were particularly engaged with or benefited from the program may have been more inclined to participate in the surveys, possibly skewing the results toward more favorable outcomes. Furthermore, self-reported data is inherently subject to biases, as students may overestimate or underestimate their skills and confidence due to personal perceptions.

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Appendix

Table 7. Pre-survey Descriptive Statistics

	Obs	Mean	SD	Min	Median	Max

writing	27	4.00	0.620	3	4	5
oral communications	27	3.67	1.074	1	4	5
leadership (influencing desired changes in others)	27	3.59	0.888	2	4	5
leadership (influencing desired changes in oneself)	27	3.81	0.622	3	4	5
engineering or technical skills	27	3.48	0.802	2	4	5
an engineering career	27	4.74	0.594	3	5	5
graduate school	27	4.44	0.892	2	5	5
an international engineering career	27	3.04	1.285	1	3	5
global, societal, or cultural contexts or issues within engineering	27	3.33	1.074	1	3	5
engineering coursework performance	27	3.74	0.712	2	4	5
engineering work/job performance	27	3.48	0.753	2	3	5
global issues (i.e., the world around you)	27	3.44	0.974	1	3	5
societal issues (i.e., the people and societies in the world around you)	27	3.48	0.849	2	4	5
cultural issues (i.e., the ways people typically do things in the world around you)	27	3.30	0.869	1	3	5
global engineering workforce preparedness	27	2.56	0.801	1	3	4
solve problems	27	4.04	0.759	2	4	5
meet deadlines	27	4.33	0.877	2	5	5
be able to adapt and learn new technologies	27	4.07	0.829	2	4	5
communicate orally	27	3.78	1.155	1	4	5
work in teams	27	3.93	0.997	1	4	5
process strong analytical ability	27	4.07	0.781	2	4	5
communicate in writing	27	4.15	0.770	2	4	5
break down complex concepts into simple, understandable ideas	27	3.96	0.649	3	4	5
approach problems systematically	27	4.11	0.506	3	4	5
tailor communication to your audience	27	3.67	0.734	3	4	5
interface with industry	27	3.11	0.974	1	3	5
give presentations	27	3.59	1.047	1	4	5
use multiple tools to solve complex problems	27	3.96	0.706	2	4	5

manage multiple projects	27	3.67	0.877	2	4	5
write technical reports	27	3.63	1.043	2	4	5
work across disciplines	27	3.78	0.801	2	4	5
serve as a role model	27	4.33	0.961	1	5	5
share history of her/his career with you	27	4.33	0.734	2	4	5
share personal experiences as examples from which you can learn	27	4.59	0.747	2	5	5
respect you as an individual	27	4.78	0.577	3	5	5
serve as a consistent source for advice and support	27	4.67	0.555	3	5	5
provide opportunities for you to ask questions w/o fear of affecting your grades or career options	27	4.70	0.465	4	5	5
encourage you to talk openly about anxiety and fears that detract from your academic work	27	4.26	0.859	2	4	5
understand how your background (gender/race/ethnicity) may affect your experiences as a student in your field of study	27	3.96	1.055	1	4	5
convey interest in hearing about your ideas	27	4.59	0.636	3	5	5
help you explore a range of possibilities when you face decision points	27	4.70	0.542	3	5	5
encourage you to prepare for the next steps in your academic program or career	27	4.70	0.542	3	5	5
explore career options with you	27	4.63	0.565	3	5	5
help you overcome insecurities about your abilities as a scientist or engineer	27	4.22	0.847	3	4	5

Table 8. Post-survey Descriptive Statistics

	Obs	Mean	SD	Min	Median	Max
writing	23	4.35	0.647	3	4	5
oral communications	23	3.87	0.757	2	4	5

leadership (influencing desired changes in others)	23	4.09	0.848	2	4	5
leadership (influencing desired changes in oneself)	23	4.17	0.778	3	4	5
engineering or technical skills	23	4.00	0.798	2	4	5
an engineering career	23	4.57	0.590	3	5	5
graduate school	23	4.09	0.900	2	4	5
an international engineering career	23	3.30	1.105	2	3	5
global, societal, or cultural contexts or issues within engineering	23	3.52	0.846	2	3	5
engineering coursework performance	23	4.39	0.583	3	4	5
engineering work/job performance	23	4.22	0.795	2	4	5
global issues (i.e., the world around you)	23	3.87	1.014	2	4	5
societal issues (i.e., the people and societies in the world around you)	23	4.13	0.869	2	4	5
cultural issues (i.e., the ways people typically do things in the world around you)	23	3.83	0.834	2	4	5
global engineering workforce preparedness	23	3.78	0.998	1	4	5
solve problems	23	4.39	0.499	4	4	5
meet deadlines	23	4.43	0.896	2	5	5
be able to adapt and learn new technologies	23	4.48	0.665	3	5	5
communicate orally	23	4.22	0.795	2	4	5
work in teams	23	4.35	0.714	2	4	5
process strong analytical ability	23	4.30	0.635	3	4	5
communicate in writing	23	4.39	0.656	3	4	5
break down complex concepts into simple, understandable ideas	23	4.43	0.662	3	5	5
approach problems systematically	23	4.35	0.775	2	4	5
tailor communication to your audience	23	4.09	0.848	2	4	5
interface with industry	23	4.09	1.041	1	4	5
give presentations	23	4.00	0.905	2	4	5
use multiple tools to solve complex problems	23	4.30	0.635	3	4	5
manage multiple projects	23	4.26	0.864	2	4	5
write technical reports	23	4.09	0.848	3	4	5

work across disciplines	23	4.22	0.795	2	4	5
serve as a role model	23	4.43	0.788	2	5	5
share history of her/his career with you	23	4.48	0.511	4	4	5
share personal experiences as examples from which you can learn	23	4.65	0.487	4	5	5
respect you as an individual	23	4.78	0.518	3	5	5
serve as a consistent source for advice and support	23	4.65	0.573	3	5	5
provide opportunities for you to ask questions w/o fear of affecting your grades or career options	23	4.65	0.647	3	5	5
encourage you to talk openly about anxiety and fears that detract from your academic work	23	4.35	0.775	3	5	5
understand how your background (gender/race/ethnicity) may affect your experiences as a student in your field of study	23	3.78	0.951	1	4	5
convey interest in hearing about your ideas	23	4.48	0.593	3	5	5
help you explore a range of possibilities when you face decision points	23	4.74	0.449	4	5	5
encourage you to prepare for the next steps in your academic program or career	23	4.74	0.449	4	5	5
explore career options with you	23	4.52	0.730	2	5	5
help you overcome insecurities about your abilities as a scientist or engineer	23	4.35	0.832	3	5	5