Work-in-Progress: From Composting to Community: Toward a Multidisciplinary Community of Practice Model for STEM Research and Leadership Self-Efficacy

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Veronica Mbaneme is a triple alumna of the Biological & Agricultural Engineering Department at North Carolina State University (NCSU), with research focusing on biological systems engineering, product development, and engineering education. Currently, she serves as a Postdoctoral Teaching Scholar for the Engineering ASCEND Program at NCSU. Veronica teaches academic and professional development courses to first-year engineering and computer science students, conducts K-12 engineering outreach activities, manages several research initiatives, and leads a multitude of programs related to recruitment, yield, retention, and graduation of undergraduate and graduate students. In addition, she executes career readiness, leadership, and mental health workshops, engages with industry, alumni, and university partners to aid in student success, and provide a brave and safe space for students to authentically be present for quality and timely advising and mentorship. Thus far, her work has been extremely rewarding, as she has helped hundreds of students gain confidence, global perspective, real-world experience, research opportunities, and happiness in their career choices.

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Chloe is a third-year Ph.D. student in Biomedical Engineering at NC State University and UNC-Chapel Hill. Her research focuses on decellularized extracellular matrix biomaterials for wound healing and tissue regeneration. Chloe is also involved in engineering education through the NC State Grand Challenges Scholars Program, where she contributes to curriculum development that supports undergraduate research and sustainability. Her interests within Engineering Education include communities of practice, undergraduate research experiences, and fostering student identity and belonging in STEM.

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Abstract
This work-in-progress (WIP) describes a multidisciplinary research and outreach program designed to cultivate leadership and professional identities among students in science, technology, engineering, and mathematics (STEM) fields. From Fall 2021 through Spring 2025, this research and outreach program has been funded by the Office of Sustainability at a Southeastern R1 university. This program has supported annual cohorts of undergraduate and graduate student researchers investigating sustainable composting solutions. As this funded period has recently concluded, this WIP paper serves as a preliminary reflection on the program's blueprint for its impact and future evolution.

Each academic year, a rigorous application and interview process selects a new cohort of multidisciplinary student researchers (typically four to eight undergraduates and one graduate research assistant). The program's central component is the establishment of a community of practice (CoP), in which students are mentored by research faculty and staff in engineering and science. This structure integrates mentored research opportunities with student-led community outreach engagements to transfer scientific knowledge to the broader campus community. This focus on research and public engagement aims to strengthen students' STEM identities by fostering self-efficacy and a sense of belonging, preparing them for future leadership roles.

This WIP presents the establishment and development of sustainable CoP infrastructure to foster a sense of belonging and professional skills related to research and leadership. It focuses on intentional strategies for creating opportunities for participants to lead, plan, and execute sustainability-focused research and outreach. The implications of this work provide a replicable framework for other institutions seeking to establish similar STEM leadership development programs with limited budgets. Specifically, this WIP includes learned practices for securing and sustaining internal funding, forming mutually beneficial faculty-student collaborations, and strategically building a CoP that promotes confidence, creativity, curiosity, and the benefits of parallel sustainability research and community outreach.

Introduction

The definition of a 'qualified engineering leader" is shifting. Beyond technical rigor, today's STEM professions demand leaders who can drive innovation and manage diverse teams. Research consistently demonstrates that in high-stakes, multidisciplinary settings, organizational success is dictated less by isolated technical knowledge and skill, and more by leadership competencies such as effective communication, adaptability, and problem-solving [1], [2], [3], [4]. Despite this recognized need, leadership development is often overlooked in traditional STEM education, leaving graduates technically skilled but less prepared to take on leadership roles [5], [6], [7].

Meanwhile, the number of STEM graduates continues to grow. From 2012 to 2022, annual STEM bachelor's degrees increased by about 29%, totaling around 4.65 million degrees awarded over the decade [8], [9]. As the STEM workforce expands, educational strategies that

purposefully combine leadership development with technical training and promote inclusive, supportive learning environments are becoming increasingly essential.

Background & Conceptual Frameworks: Self-efficacy is a person's belief in their ability to perform tasks in a specific area [10], reflecting how professional development occurs. Unlike general confidence, self-efficacy is context-specific and develops through mastery, modeling, mentorship, and feedback [11]. This study distinguishes between research self-efficacy–confidence in designing, conducting, analyzing, and communicating research–and leadership self-efficacy–confidence in guiding and influencing others. Both increase engagement, persistence, and identity in STEM [10], [11], [12], [13], [14].

Community-based learning environments provide structured contexts for development [6], [7], [15], [16]. Wenger's Community of Practice (CoP) framework includes three dimensions: (1) shared domain, (2) mutual engagement, and (3) shared practice [17], [18]. In structured CoPs, experienced members model norms and leadership, while novices perform disciplinary tasks. Students gain mastery and research self-efficacy through activities such as writing abstracts, conducting experiments, and creating research papers, which serve as inquiry-based learning (IBL) within authentic sustainability contexts [19]. As they practice, students take ownership, initiate investigations, challenge experts, and lead outreach, developing leadership self-efficacy. This pathway from novice to expert supports the next generation of practitioners in the STEM community [14], [17], [20].

Unlike a general "community," a CoP focuses on active participation in shared practice. Through continuous engagement with mentors and peers, students develop a sense of belonging, which is essential for professional identity growth, confidence, and leadership development [14], [20], [21], [22], [23]. Within a structured CoP, research, leadership, and belonging develop as interconnected, mutually reinforcing domains rather than as siloed areas of growth. This WIP explores how leadership self-efficacy, research self-efficacy, and belonging develop in an intentionally designed, multidisciplinary CoP focused on sustainability, providing authentic research, leadership, and collaboration opportunities. It presents preliminary evidence of growth to develop a transferable CoP model for future STEM leaders.

Program Design

Program Overview and Context: Established at a Southeastern R1 public university via a university-wide funding initiative, this program supports sustainability research across campus. The *(name redacted)* initiative, administered by the *(name redacted)* Office of Sustainability, provided resources for development, including multidisciplinary research and outreach. The proposal aimed to develop undergraduate and graduate STEM researchers in sustainability inquiry and community outreach. The program PIs facilitated a CoP focused on sustainable composting.

Participant Recruitment and Selection: The application was open to all students at the university. Appendix A summarizes the demographics of the 2024–2025 cohort, which included eight female undergraduates. This all-female cohort, selected through merit, differs from previous mixed-gender groups and is a contextual characteristic that may influence this work. By opening the application university-wide, a multidisciplinary student network was formed,

becoming part of the CoP. After selection, students chose from faculty-led research projects in ecology, engineering, and biology, reflecting the program's multidisciplinary approach.

Program Commitments and Expectations for Students: Participants committed 5–10 hours weekly over two semesters in 2024–2025, learning lab skills and supporting research self-efficacy (see ***Appendix B***), with funding from the Office of Sustainability providing a $15/hour stipend. Weekly tasks varied by project. Students attended biweekly workshops, engaged with mentors, and submitted research abstracts, posters, and presentations internally and at a university symposium. They designed sustainability outreach initiatives, met research standards like experimentation and data collection, and demonstrated professional conduct through attendance, communication, and progress updates. These efforts aimed to build research skills, leadership, and accountability within the CoP. Figures in ***Appendix B***, including ***Figure B1*** and ***B2***, show the research and leadership models linked to workshop topics, program opportunities, and required student activities.

Mentorship: The cohort also included one master's-level female graduate student assistant who supported administrative coordination and mentoring. Because the graduate role and program expectations differed substantially from those of the undergraduate participants, the present analysis focuses exclusively on the eight undergraduate students. However, the inclusion of a graduate-level mentor added an additional tier to the CoP, serving as an intermediary between undergraduate participants and faculty mentors.

Faculty researchers were selected and invited by programmatic PIs based on their research areas related to sustainable composting and their passion for developing STEM students. As described in prior work, research mentors received training to foster a productive and welcoming environment before engaging with the 2024–2025 cohort [24]. Program facilitators outlined the structure and expectations of the CoP, including the students' required participation in laboratory training, experimentation, scholarly communication, time commitments, and presentation of research findings at the university's internal research symposium. Mentors and mentees reviewed these expectations together and formally agreed upon them prior to the start of research activities.

Designing the CoP – Domain, Community, and Practice: Aligned with Wenger's three-pillar CoP framework—domain, community, and practice—the program aimed to foster sustainability research and leadership [17], [18]. The shared domain centered on composting as applied sustainability and STEM problem-solving, emphasizing authentic environmental challenges, scientific inquiry, and disciplines. The community comprised multidisciplinary undergraduates supported by program PIs, mentors, a lab network, outreach partners, and a graduate assistant, built through interactions, biweekly meetings on entering research [25], troubleshooting, peer learning, and shared milestones, fostering mutual engagement. Shared practice involved research, leadership, and professional behaviors through structured activities like informal updates, experimental design, data troubleshooting, abstracting, presenting, leading outreach, initiating projects, and maintaining mentorship and research norms. The program used the TIDieR framework to structure implementation and outcomes [26].

Assessment, Results & Analysis

Data Collection – Survey Methods: Feedback from the 2024–2025 cohort was collected via an online post-program survey administered as part of routine program evaluation (the full survey is available in ***Appendix C***). The survey builds on a previously published instrument assessing research self-efficacy in an engineering research program [27], which was adapted from established measures of undergraduate research preparedness and engineering self-efficacy [28], [29]. Additional items were informed by validated literature on sense of belonging [30] and science/professional identity development [12]. Although modified to align with the CoP framework and not re-validated as a scale, the instrument remains conceptually grounded in established self-efficacy, belonging, and identity constructs.

The survey included five sections: demographics, background/experience, skill development and growth, community and belonging, and final reflections. Skill development items used a 0 to 5 Likert-type scale (with 5 being "strongly agree"), perceived growth in research and leadership/professional competencies (***Appendix C, section 3***), while community items examined belonging and network development; open-ended responses captured insights related to research, leadership, and community impact. As a non-validated tool, these questions were designed to be relatable and easy for program participants to understand; therefore, they did not use traditional Likert-type question phrasing. Questions were also asked to understand the students' perception of community and their sense of belonging after program participation (***Appendix C, section 4***). Qualitative responses were reviewed in full, and recurring keywords were grouped into preliminary categories that were consolidated into broader themes aligned with program outcomes. Representative quotations are presented to illustrate each theme. Given the small single-cohort sample (n = 8) and use of an exploratory instrument, no inferential testing was conducted. Results are presented descriptively to identify within-cohort trends across research self-efficacy, leadership self-efficacy, and sense of belonging/emerging professional identity.

Outcomes of Research Self-Efficacy: Descriptive trends indicated perceived growth in research skills across the cohort. Students reported increased confidence in literature review, research design, data analysis, and communication of findings, with high agreement ratings on items related to generating methods, analyzing data, and presenting results. Qualitative responses reinforced these trends, highlighting increased independence, clearer understanding of the research process, and greater confidence in conducting inquiry from question development through dissemination.

The program's cross-campus collaboration among undergraduate researchers, graduate assistants, staff mentors, and faculty established a shared intellectual focus on applied sustainability research. Across the 2024–2025 cohort (n = 8), 100% of participants agreed or strongly agreed that participation strengthened their research identity through increased self-efficacy and confidence. Students frequently linked gains in identifying research topics and mentors, implementing methodologies, analyzing data, and articulating findings to a stronger sense of identity as researchers. One participant described their growth:

> *"This opportunity helped me grow in many ways… I worked independently, coordinating with the composting center, designing my methods, conducting weekly fieldwork, and working through lab protocols...While I'm a naturally organized self-starter, this project pushed me in new ways... I became more comfortable solving problems and learning*

through feedback. My mentors were supportive and encouraged independence, which helped build my confidence and taught me that I can figure things out on my own... While there's still much to learn, I now feel confident in my foundational lab skills. Compared to the structured environment of [a class], this experience gave me a deeper, hands-on understanding of lab work...Getting to see the entire process, from designing the compost pile and sampling it, to isolating DNA and analyzing data in R Studio, gave me a much richer understanding of [research]. It also helped me identify which parts of the process I find most engaging…I discovered a real interest in leading field work. I'm also excited by the idea of working in sustainability at the government level. This opportunity… solidified that interest..." (Quote 1; Student 3).

Outcomes of Improved Leadership Self-Efficacy: Although participation in outreach was required, leadership was not mandated. Several students voluntarily assumed leadership roles, coordinating events, facilitating communication, and presenting to community and industry audiences. Descriptive survey trends indicated increased confidence in initiative-taking, project management, and leadership capacity. Qualitative responses framed leadership as practice-based and enacted through responsibility rather than positional authority. Students described taking ownership of tasks, initiating side projects, and stepping forward to lead outreach efforts beyond expectations, demonstrating emerging leadership self-efficacy through action.

Across the 2024–2025 cohort (n = 8), all participants agreed or strongly agreed that their research and leadership capabilities improved. Regardless of prior leadership experience, students reported growth in communicating with diverse audiences, leading with confidence and integrity, active listening, navigating team dynamics, and fostering collaborative partnerships. Participants also described improved ability to plan strategic collaborations, acquire and analyze data, generate proposals, and manage projects. These outcomes are illustrated in the student reflections below, highlighting themes of communication, leadership, and collaboration:

"My written and verbal communication skills also improved throughout my involvement with [this program]. Designing a research poster was a new but exciting challenge. I worked with [a professor] on the structure and used campus resources to refine my writing. I presented my poster twice, at a [national and university-level conference]... These experiences taught me how to effectively communicate complex ideas to audiences with varying levels of scientific background. It also helped with writing clear, concise content, which is especially helpful when working within the limited space of a poster" (Quote 2; Student 3).

'This opportunity to gain leadership skills has benefited my short-term goals of getting better at team communication, time management, and creative thinking in my research and solution brainstorming" (Quote 3; Student 2).

"One key takeaway from this opportunity is that I thrive in team settings. I also realized that leadership is important to me. I enjoy collaboration and communication, and I value the energy that comes from working with others toward a shared goal" (Quote 4; Student 3).

Program participants developed improved leadership skills by being exposed to a range of resources/personnel to assist in their academic, professional, and mental development, as well as to internships and funding opportunities for alternative research and study-abroad experiences. Students received support and sponsorship in pursuing the aforementioned opportunities. For example, four of the nine 2024-2025 participants planned a subsidiary research coalition, also mentored by the program leaders, and applied for a sustainability fellowship, drawing on prior knowledge. The four students also received financial awards twice and conducted a secondary student-led research project on composting in collaboration with the local government during the spring and summer of 2025. The leadership development opportunities facilitated by the CoP helped participants build self-efficacy, effective communication skills, and collaborative networks. The aforementioned outcomes have also been observed in other studies that highlight the benefits of community-based leadership training for self-efficacy and skill development [31], [32], [33].

***Outcomes of Sense of Belonging and Emerging Professional Identity*:**
Sustained institutional investment and continued student interest provide additional evidence of program impact. Since 2021, the CoP has maintained four consecutive years of funding, supported by cross-college collaboration, structured sustainability programming, and integration with research development resources. Required participation in monthly campus-wide sustainability workshops and optional research competency sessions through the Office of Undergraduate Research reinforced multidisciplinary engagement and applied research skill development.

The program has been informally improved since its initiation. By aligning program objectives with evolving sustainability challenges and expanding collaborative partnerships, the CoP has consistently delivered value to both students and the institution. Ongoing student demand and institutional support suggest the model is perceived as impactful and relevant. Students cited mentorship, multidisciplinary collaboration, and applied sustainability focus as motivating factors for participation. As one student noted:

> *"I applied… because I wanted hands-on experience and was excited by the opportunity to explore sustainability through one of 30 unique positions. I was especially drawn to [this program] for its cohort-oriented approach and the opportunity to find out whether I enjoy lab work–an important consideration for Biological Sciences majors like myself"* (Quote 5; Student 3).

Results show students, confident and empowered through community, knowledge, and skills, maintained their curiosity and motivation to seek opportunities for growth as researchers, leaders, and professionals in STEM. Participants demonstrated continued engagement beyond program requirements: three presented at multiple conferences, five pursued additional research projects, and two secured internships. One senior obtained a local government internship directly attributed to research involvement and demonstrated leadership and communication skills. All undergraduate researchers articulated future STEM leadership aspirations, linking these goals to the confidence they gained through the CoP. The reflections below illustrate individualized impacts related to belonging, identity development, confidence, and career direction:

> "*This experience has been incredibly meaningful to me on many levels. I felt lost coming into NC State with no direction until [a faculty member]gave me a tour of the*

biotechnology labs. I fell in love with the lab and… I knew I wanted to get into scientific research…This opportunity has also taught me… that research doesn't need to be picture-perfect and complete… to communicate results. I've gained confidence in my ability to learn and embrace humility when everything around me is unfamiliar. This experience has carefully crafted motivation to continue chasing new opportunities to lead and develop, but at a much healthier pace. This year has helped me…reflect [on my values]… to figure out who I am and how I can [continue developing] in the most sustainable way" (Quote 6; Student 1).

"This experience has benefited my goals of determining what my academic interests…. I was inspired by the research I conducted and changed my degree concentration. It also opened up my eyes to the research and industry combinations available for someone [interested in] sustainability and engineering" (Quote 7; Student 2).

"*I'm deeply grateful for my experience… and for the mentorship. This was the first time I truly felt like a scientist, applying what [I've] learned in my coursework to a real-world project. I now have a clearer sense of what matters to me in a career, and I feel confident [drawing] from this experience as I step into the professional world"* (Quote 8; Student 3)."

As program expectations increased, students' professional networks expanded beyond the three core CoP environments to include additional internal and external partners, such as government professionals, multidisciplinary faculty, and the university's Composting Center. Participants actively leveraged these connections to advance both research and leadership deliverables, as well as broaden their support networks. Research presentations, outreach initiatives, including a Zero Waste Football Game, Women in Science Book Club, and Agroecology Farm Day, and reciprocal knowledge-sharing opportunities positioned students as content experts while strengthening communication and collaboration skills.

Notably, the 2024–2025 cohort, which consists entirely of women, showed recurring themes of empathy, empowerment, and authenticity in anecdotal data. Program leaders observed increased peer engagement and open discussions about professional identity and imposter syndrome, strengthening a sense of connection within the cohort. Consistent with previous community-focused programs [23], [24], [34], [35], [36], students reported feeling accepted, valued, supported, and understood. Through intentional networking, shared research experiences, and structured community-building, students reinforced a sense of belonging as a core mechanism that supports research self-efficacy, leadership development, and professional identity formation. Student reflections below further highlight these themes.

"This opportunity gave me a better sense of belonging at NC State because it provided me with a structure to meet new people and also explore my interests" (Quote 9; Student 2).

"This program has cultivated a sense of home and comfort. Coming together as a team of researchers (and, might I add, women) made it an intimate and meaningful space. I felt so happy engaging in discussion with my peers AND my mentors. Outside activities, like

the Agroecology Farm, helped me get closer to my peers as well. Pulling weeds out of cilantro beds next to [a program peer] is a cherished memory" (Quote 10; Student 1).

"I really enjoyed the book club we had in the fall. It was really interesting to hear about everyone's experience in sustainability and their educational path(s). I made close friends through this program, and I am excited to continue to work with [other participants]" (Quote 11; Student 3).

"My mentors were absolutely amazing. The care and support from all of my mentors [have] meant the world to me. Their kind words and gentleness in response to my experiences [have] touched me deeply. To know that they too experience[d] what I shared has made me feel less alone" (Quote 12; Student 1).

Logistical Improvements: All students in the 2024–2025 CoP cohort benefited from the implemented structure of resources, personnel, and developmental opportunities. In addition, when students reflected on their experience navigating program logistics, 100% of participants reported few to no complications. The cohesiveness and fluidity directly resulted from the annual programmatic improvements implemented in response to informal student and partner feedback since its initiation in 2021. Nonetheless, the iterative improvements for the 2024–2025 programmatic cycle included strengthening the CoP's bonds among students and mentors and expanding the established network. The team improved the opportunities for bonding by increasing in-person and virtual meetings with students and mentors, participating in additional outreach activities conducted internally and externally to the university, and engaging in multidisciplinary work across campus with other researchers, including participants in the Grand Challenges Scholar Program.

Discussion & Conclusion

Participants applied concepts to real-world problems within the socially structured CoP, developing transferable skills, strengthening self-efficacy, fostering a sense of belonging, and deepening commitment to sustainable environmental goals [13], [16], [36], [37]. These experiences contributed to emerging STEM research and leadership identities [20], [38], consistent with the theorized metrics of a transactionally designed CoP [23], [39]. Through inclusive mentorship, knowledge exchange, and collaborative problem-solving, students developed skills valued in STEM leadership roles [1], [5], reflecting characteristics of traditional transactional models [39]. Future evaluations should consider integrating complementary frameworks, including transformational approaches that emphasize creativity, motivation, and emotional connection to community [31], particularly given observed themes of collaboration, authenticity, and empathy within this cohort [14], [40].

Intentional CoP Structure Supported Student Development: Findings from the 2024-2025 cohort indicate that the program's intentional CoP design fostered interconnected growth in research, leadership, and belonging. Regular participation in applied sustainability research built technical mastery and research self-efficacy. Inquiry-based activities such as designing methods, troubleshooting, analyzing data, and communicating findings helped students progress from novices to more independent researchers. Peer and mentor modeling sped up this growth. Leadership was practiced rather than assigned; students took responsibility through outreach,

initiative, and collaboration. These experiences boosted confidence and helped develop leadership identities.

CoP as a Pathway to Belonging and Identity, and Sustained Engagement: Belonging was central in the CoP, where interaction, shared challenges, and knowledge transfer fostered support and valued students. This social reinforcement boosted research and leadership skills, aiding identity development as emerging STEM professionals. The cyclical structure, with engagement, feedback, mastery, reflection, and renewed engagement, strengthened student growth. As competence grew, students took on more responsibility, which further enhanced efficacy and belonging. Moving from novice to practitioner exemplifies a CoP's core function and suggests that combining research, leadership, and community can speed up STEM identity development. Continued student interest and four consecutive years of institutional funding provide indirect evidence of sustained engagement and institutional validation. By integrating inquiry-based research, mentoring, leadership practice, and multidisciplinary collaboration, the CoP offers a multidimensional alternative to more siloed undergraduate research models. Preliminary findings suggest that this structure may support persistence and long-term leadership aspirations in STEM.

Limitations & Future Works: This WIP is limited by a small, single-cohort sample (n = 8) from one institution and disciplinary context. The survey was exploratory and not validated. Findings rely on descriptive trends and self-reports (surveys), with no longitudinal or comparison groups included (i.e., traditional research experience or program(s)). Results are preliminary and not yet generalizable.

Future efforts will focus on instrument refinement and validation, including psychometric testing of constructs related to research self-efficacy, leadership development, belonging, and identity. Comparative studies examining CoP-based models alongside traditional Research Experiences for Undergraduates (REUs) will clarify the structural differences and their impacts. Longitudinal studies are needed to examine leadership trajectories, STEM persistence, and sustained professional identity development. Expanding cohorts to larger, more diverse populations will strengthen evaluation of scalability and inclusivity. Additional investigation into mentor variability and disciplinary contexts will elucidate transferability. We believe this CoP structure is transferable because its core components, intentional domain alignment, sustained community interaction, inquiry-based practice, and mentoring, are adaptable across institutional settings. Future research will explore the potential for replication and the implications for programs seeking to integrate research, leadership, and community to cultivate STEM practitioners and leaders.

Recommendations for expanding STEM research and leadership CoP Model: Creating this type of program, especially on a limited budget, can be difficult. Informed by this experience, best practices include: (1) securing internal sustainable funding with targeted metrics; (2) using a centralized application process; (3) setting clear expectations for partners and participants; (4) fostering authenticity and collaboration; and (5) employing creative developmental techniques. Successful practices involve securing ongoing internal funding, simplifying fund transfers and resource procurement, and using existing application structures to boost collaboration and appeal to funders and students. Designing a CoP that builds confidence and encourages exploration

supports professional identity development. Clarifying engagement expectations, training PIs and students, and fostering mentor-mentee collaborations enhance effective advising and reduce mental health challenges associated with limited time.

Appendix A: Detailed demographic characteristic composition of undergraduate participants in the 2024–2025 program cohort, including undergraduate academic level (***A1***), Gender Identity (***A2***), and Academic Interests/Major (***A3***) in the study cohort.

Figure A1–Distributions of undergraduates (n=8) by Academic Level.

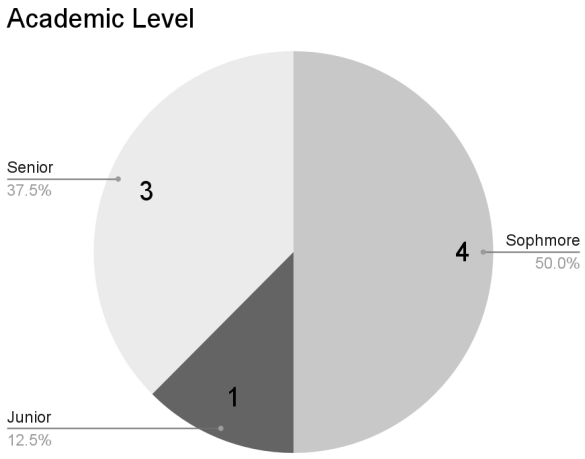


Figure A2–Distributions of undergraduates (n=8) by Academic Level.

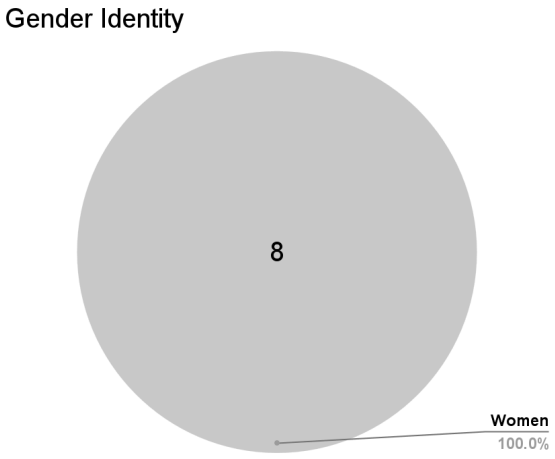
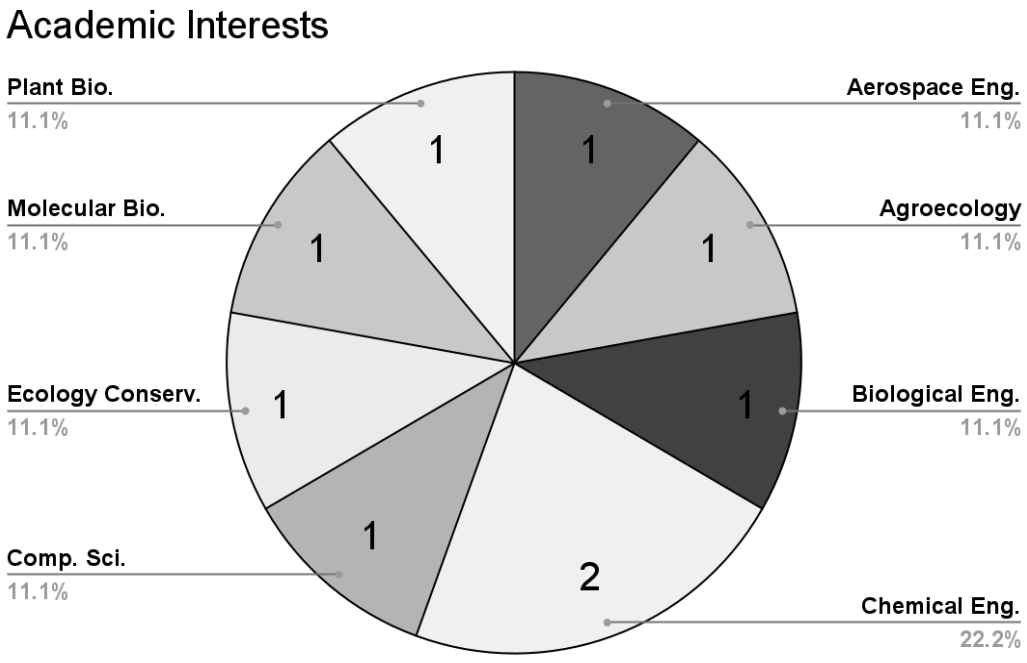


Figure A3–Distributions of Academic Interests/Majors in the cohort (n=8 undergraduates, n=1 graduate student assistant).



Appendix B: Figures B1 and ***B2*** are presented together to illustrate the parallel and complementary developmental pathways through which the program cultivated both research and leadership self-efficacy. This includes participation in program activities, workshop themes, and student requirements. ***Figure B1*** presents the development framework, demonstrating how structured research participation within a PI-led Community of Practice (CoP) fosters research self-efficacy among undergraduate STEM students. Similarly, ***Figure B2*** outlines the structures for developing leadership self-efficacy**.**

Fig. B1

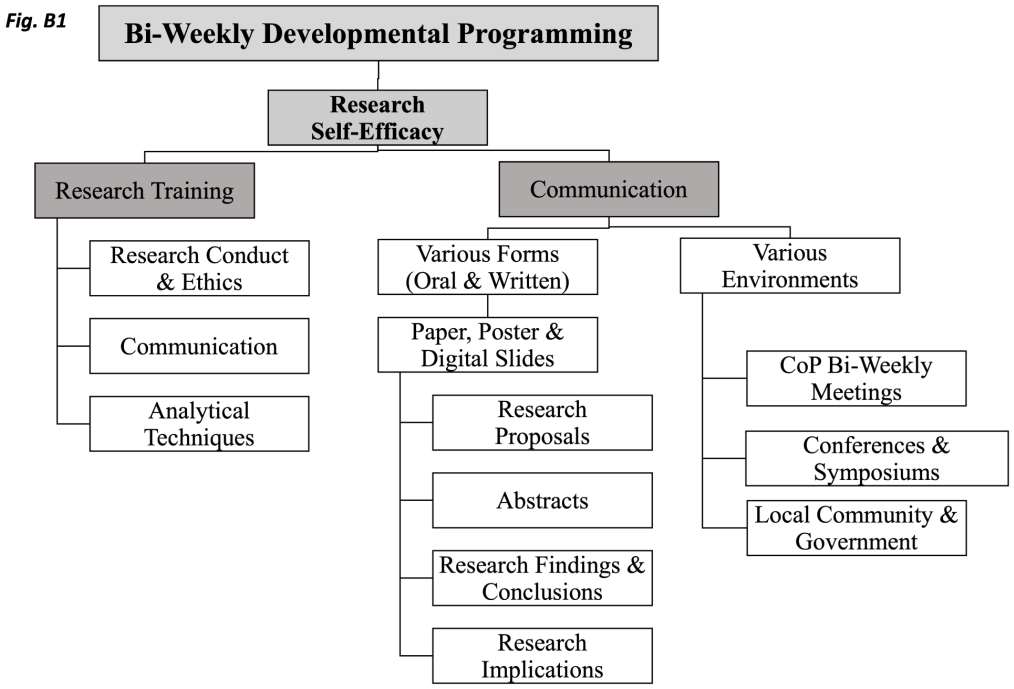
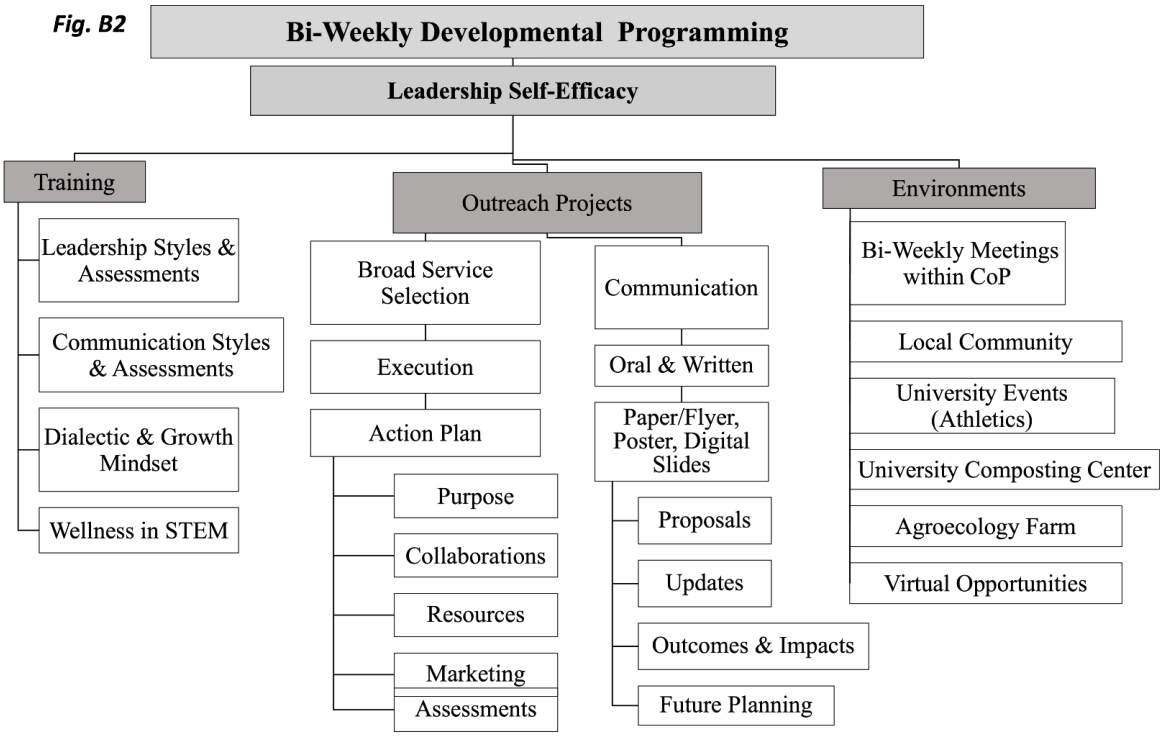


Fig. B2



Appendix C. Full 2024-2025 Post-Program Survey. This survey was used to assess the program and comprised five sections covering demographics, research, leadership, community, and growth among participating students. The survey builds on a previously published instrument assessing research self-efficacy in an engineering research program [27], which was adapted from established tools of undergraduate research preparedness and engineering self-efficacy [28], [29]. Other items were informed by similar sources for sense of belonging [30] and science/professional identity development [12].

Section 1: Demographics

1. Initial questions gathered demographic data, including name, major, anticipated graduation year, GPA, gender identity, and ethnic background.

Section 2: Experience Background

2. Was this experience your first time conducting research? If not, please provide a brief description of past research experience.
3. Was this experience your first time engaging in a leadership role? If not, please provide a brief description of past leadership experience.

Section 3: Skill Development & Growth

The following questions used a Likert scale from 0 (no experience or not applicable) to 5 (strongly agree).

Research Skills

4. Did the experience help you learn to select research topics and mentors?
5. Did the experience help you develop skills to review literature?
6. Did you learn how to generate a research abstract?
7. Did you learn how to generate research methods?
8. Did you learn how to analyze research data/results?
9. Did you learn how to make conclusions and implications regarding findings?
10. Did you learn various ways to communicate findings (visuals/presentations)?
11. Did you learn about various funding options to support research?

Leadership & Professionalism

12. Did the experience help you learn about various leadership styles?
13. Did you learn the importance of understanding team dynamics?
14. Did you gain skills related to project management?
15. Did opportunities exist for you to take the initiative or lead?
16. Did opportunities exist for you to creatively problem-solve?
17. Did you develop/gain confidence as a researcher?
18. Did you develop/gain confidence as a leader?
19. Did you develop/gain confidence as a STEM student?
20. Did the experience help you learn to manage stress?
21. Did the experience help you learn to manage time and work-life balance?

Section 4: Community & Belonging

22. Did your engagement help you gain a sense of belonging?
23. Did the experience help you network with individuals with similar interests (a Community of Practice)?

24. Did opportunities exist to mutually develop with your cohort?
25. Did you strengthen your network of supporters, sponsors, or peers?

Section 5: Final Reflections

34. Please provide one word to describe your experience.
35. At this point in your academic career, how has gaining research skills benefited your short and/or long-term goals?
36. How has gaining leadership skills benefited your short and/or long-term goals?
37. How has this opportunity helped you establish a sense of community?
38. Is there anything else you want us to know about your experience?

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