Four-year Summative Evaluation of REU Site Research Program in Smart Engineering and funded by NSF REU Program

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Abstract

This Research Experience for Undergraduate (REU) program was conducted over four years, including a no-cost extension (NCE) fourth year. The program trained 34 Community College (CC) students in Smart Engineering across four strands: Artificial Intelligence/Machine Learning, Smart Health, Smart Materials, and Smart Infrastructure. Operating as a 10-week non-residential summer program for local CC students from the greater Boston area, participants engaged in high-quality research at Northeastern University, working directly with faculty in the College of Engineering while receiving mentorship from graduate students and guidance on transferring to four-year institutions. This paper presents a summative evaluation examining cohort demographics, research projects, formative evaluations, student reflections, impact metrics, and the integration of Generative AI in the final year.

Introduction

Community college students represent a vital yet often underutilized talent pool in STEM education. The REU-PATHWAYS program, funded by the National Science Foundation (NSF #2150417), aimed to provide authentic research experiences to community college students in the Boston area, with particular focus on students from underrepresented groups. Over four summers (2022-2025), the program engaged 34 students from eight community colleges in cutting-edge research while developing their technical skills, professional competencies, and pathways to continued STEM education.

Program Structure and Evolution

The REU-PATHWAYS program operated consistently across all four years with several key components:

Core Research Experience: Students were paired with faculty mentors and placed in research laboratories for approximately 20-40 hours per week, engaging in projects spanning computer architecture, materials science, bioengineering, environmental systems, machine learning, and robotics.

Arduino/SparkFun Workshops: These hands-on sessions introduced students to circuits, programming, sensors, and prototype fabrication using the commercially-available SparkFun Inventor's Kit. A significant programmatic adjustment occurred after Year 1 feedback: the workshop duration was shortened from 10 weeks to 3 weeks, and students were given well-defined projects (building autonomous robots) rather than open-ended assignments. This change reduced student stress and improved outcomes.

Professional Development: Students attended faculty research presentations (7-9 per summer), skill-building workshops on presentation skills, resume/LinkedIn development, and poster creation. Daily homeroom sessions provided peer support and structured opportunities for weekly status report presentations.

Field Trips and Social Activities: Students visited industry sites (Amgen), research facilities (Marine Science Center in Nahant), and cultural venues (Museum of Fine Arts, Institute of Contemporary Art), while participating in team-building activities including engineering design challenges and campus scavenger hunts.

Cohort Demographics and Recruitment

Across four years, the program recruited 34 students from eight community colleges: Bunker Hill CC (8), MassBay CC (11), Middlesex CC (5), Northern Essex CC (2), North Shore CC (5), Roxbury CC (1), Cape Cod CC (1), and Framingham State University (1).

Gender Distribution showed evolution toward greater female participation:

- 2022: 4 male (57%), 2 female (29%), 1 nonbinary (14%)
- 2023: 4 male (44%), 4 female (44%), 1 nonbinary (11%)
- 2024: 5 male (38.5%), 8 female (61.5%)
- 2025: 1 male (20%), 3 female (60%), 1 nonbinary (20%)

Academic Quality remained consistently high, with average GPAs of accepted students: 2023 (3.41), 2024 (3.83), and 2025 (3.74).

Recruitment Challenges: The NSF ETAPS platform proved ineffective for reaching community college students, with only 5.7% of Year 3 applicants meeting eligibility criteria. The program pivoted to SurveyMonkey applications with significantly better results (92.9% eligible applicants in 2025).

Research Projects and Faculty Participation

Nineteen faculty members from across Northeastern colleges participated over four years:

- College of Engineering: Civil & Environmental (2), Chemical (3), Electrical & Computer (5), Mechanical & Industrial (5), Bioengineering (1)
- College of Science: Chemistry (1), Biology (1), Physics (2)
- Bouvé College of Health Sciences: Physical Therapy (1)

Research topics spanned diverse areas including graph neural networks, single atom catalysts, causal coupling inference, carbon nanotube networks, ferromagnetic materials, analog computing for biomedical devices, complex fluid flows, neuronal signals and terahertz radiation, natural language processing, urban environmental systems, human-robot interaction, microfluidic devices, opioid treatment analytics, osteoporosis in mouse models, hydrogen peroxide monitoring, anomalous activity detection using deep neural networks, and wearable soft sensors.

Evaluation Results: Measuring Impact

External evaluation by Davis Square Research Associates consistently demonstrated significant gains across four target constructs using retrospective pre-post surveys:

Year-over-Year Gains (percentage improvements from pre to post):

- **Importance of Engineering**: 2022 (17.1%), 2023 (18.3%), 2024 (24.7%)
- **Confidence in Engineering**: 2022 (48.5%), 2023 (22.2%), 2024 (57.0%)
- **Likelihood to Continue**: 2022 (39.4%), 2023 (15.2%), 2024 (31.4%)
- **Understanding of Engineering**: 2022 (49.6%), 2023 (33.8%), 2024 (56.0%)

The 2024 cohort showed the strongest gains across all measures, with effect sizes ranging from moderate to large (0.66-2.32). Importantly, gains in confidence, understanding, and likelihood to continue showed strong intercorrelations ($r=0.45$-0.75, $p<.05$), indicating that research experience built both competence and commitment simultaneously.

2025 Detailed Impact: Using the CISE REU Toolkit, the final cohort demonstrated substantial improvements in research skills (ranging from +8.7% to +121.9%), with the largest gains in data collection (+36.1%), data analysis (+80.1%), research proposal writing (+100%), and career options knowledge (+100%). Communication skills improved by 4.3% to 27.8%, while personal identity as scientists/engineers increased by 13.3% to 33.3%.

Student Voices: Qualitative Insights

Student reflections revealed three interconnected themes across all years:

Self-Discovery: Students consistently reported unexpected insights about their capabilities and interests. Representative quotes include: "The biggest surprise was realizing how fast I could adapt and grow in a challenging research setting" (2024); "I just realized coding is super important for engineering" (2024); "The most important thing I gained was an in depth understanding of what it takes to carry out a research project from start to finish" (2025).

Research Realities: Students gained authentic understanding of engineering research careers. One 2024 student noted: "I've realized that I think I want to be educated in science, but I want to be an entrepreneur, not necessarily a scientist or engineer." This demonstrates the program's success in providing genuine career exploration rather than simple recruitment.

Community and Belonging: The cohort structure proved vital. As one 2024 student wrote: "Despite the fact that we all came from such diverse backgrounds, all the students were united in their commitment, maturity, and sincerity. I had a fantastic time."

Program Refinements and Lessons Learned

Several key adjustments improved program effectiveness:

1. **Arduino Workshop Restructuring**: Shortening from 10 to 3 weeks and providing structured projects rather than open-ended challenges reduced stress while maintaining learning outcomes. Student ratings remained strong (4.5/5.0 in 2025).
2. **Homeroom Implementation**: Daily morning sessions in 2024-2025 provided crucial peer connection and structured presentation practice, though students sometimes felt conflicted between program activities and dedicated research time.
3. **Mentor Training**: Despite offering pre-program mentor training through CIMER (Center for the Improvement of Mentored Experiences in Research), attendance remained low, particularly among faculty. Post-program mentor surveys revealed desires for more ongoing support and peer mentoring forums.
4. **Research Time Balance**: Students and mentors consistently requested more uninterrupted research time, suggesting that while enrichment activities were valued, the core research experience remained paramount.

Generative AI Integration: A Fourth-Year Innovation

The 2025 cohort experienced a novel integration of Generative AI into the Arduino workshops. We created a custom AI chatbot specifically designed to help students learn Arduino, troubleshoot circuits, and guide challenge projects outside workshop hours.

Student Reception: All five students used the AI assistant and found it helpful, though two noted it could provide excessive assistance: "The chatbot was very helpful...but it will do the entire project for you without strict supervision." Another reflected: "ChatGPT was incredibly helpful in translating my ideas—expressed in plain language—into functional code...despite my limited background in programming."

Pedagogical Balance: Students recommended modifications to prevent AI from immediately providing corrected code, instead suggesting it should "only guide students in the right direction or point them to resources where they can read/critically think through the solution themselves." This insight highlights an emerging challenge in STEM education: leveraging AI as a learning scaffold rather than a solution generator.

Broader Implications: One student's experience demonstrated AI's potential for accessibility: "As someone without formal training in coding, ChatGPT...allowed me to bridge the gap between concept and implementation." However, another cautioned: "It does make mistakes from time to time so asking intentional questions and understanding what the code is doing is important."

Impact Metrics and Persistence

Publication Record: The program generated multiple peer-reviewed publications showcasing student work, including presentations at ASEE conferences and submissions to international symposia. Students presented 34 research posters and presentations across four years.

Educational Pathways: While complete longitudinal data is pending, informal tracking suggests strong transfer rates to four-year institutions. Students from 2022-2024 cohorts have transferred to institutions including Northeastern University and other regional universities. The external evaluator recommended formal longitudinal studies using semi-structured interviews to track long-term outcomes.

Workforce Readiness: For students choosing immediate workforce entry, the program provided substantive research experience, technical skills development, and professional networking—all valued by employers in STEM fields.

Challenges and Recommendations

Recruitment: The NSF ETAPS platform proved ineffective for community college recruitment. Programs should utilize direct outreach to community college advisors and alternative application platforms.

Mentor Preparation: Making mentor training mandatory and implementing bi-weekly check-ins with mentors could improve the mentoring ecosystem. Creating forums for mentors to share experiences would build mentoring capacity.

Student Preparedness: Some mentors reported students lacked fundamental skills for high-level research. This suggests either more careful selection criteria or front-loaded skill-building in the first weeks of the program.

Program Duration: Ten weeks consistently felt short to both students and mentors. Students working 30-40 hours weekly (rather than the expected 20) achieved more meaningful results, suggesting either longer programs or clearer expectations about research commitment.

Activity Balance: While enrichment activities (presentations, workshops, field trips) were valued, they sometimes conflicted with research progress. Future programs might front-load more activities or make some optional beyond the first weeks.

Conclusions

The REU-PATHWAYS program successfully achieved its primary goals of engaging community college students in authentic research experiences, building their confidence and competence in engineering, and providing pathways to continued STEM education. The consistency of positive outcomes across four distinct cohorts, coupled with the external evaluator's conclusion that the 2024 cohort showed "the most positive effects of participation among the three cohorts," demonstrates the program's increasing effectiveness over time.

Key success factors included: (1) genuine research experiences with meaningful faculty and graduate student mentorship; (2) cohort-based structure providing peer support; (3) hands-on engineering design experiences through Arduino projects; (4) responsive program adjustments based on formative feedback; and (5) comprehensive support services addressing both academic and professional development needs.

The integration of Generative AI in the final year opened new questions about pedagogical approaches in an AI-enabled era. Students' thoughtful reflections on AI's benefits and limitations suggest that digital natives can engage critically with these tools when provided proper framing and guidance.

For the broader REU community, this program demonstrates that community college students, when provided appropriate support and authentic research opportunities, can thrive in research environments and make meaningful contributions to scientific knowledge. The high satisfaction rates among both students and mentors, combined with measurable skill gains and continued STEM persistence, validate the investment in this often-overlooked population of talented students.

Future iterations should prioritize longer program duration, mandatory mentor training with ongoing support, careful balance between enrichment activities and research time, and continued exploration of AI tools as learning scaffolds. Most importantly, programs should maintain the core commitment to authentic research experiences paired with comprehensive support systems that recognize and address the unique needs and strengths of community college students.

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