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Looking Ahead: Implementing a Robotics Research Lab at a Community College to Support Undergraduate Research

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ABSTRACT

While participation in undergraduate research has many benefits for students including increased confidence and persistence in engineering, community college students do not have the same access to research as students at four-year institutions. To address this disparity, we developed a soft robotics-focused undergraduate research lab at a community college within a multi-institution collaboration. In addition to the benefits of undergraduate research, we see soft robotics research as particularly useful for creating diverse teams in engineering as a result of interdisciplinary challenges, new materials, and human-centered designs the field presents. Early assessment shows students are gaining skills in collaborating with others and building confidence in contributing to science. The success of this program shows the potential for broader impacts at other similar institutions.

Key words: Community Colleges, Undergraduate Research, Human-centered design, Soft Robotics

INTRODUCTION

Participation in undergraduate research increases awareness of opportunities in STEM and is a factor in attracting and retaining students in STEM fields (Linn et al. 2015; Balster et al. 2010).

However, students from groups underrepresented in STEM including first generation and community college students are less likely than their peers to participate in research (Grineski et al. 2018). Community colleges have made a strong case for expanding access to research opportunities (Berger and Malaney 2003; J. A. Hewlett 2018; Rosas Alquicira et al. 2022). Given that 39% of all undergraduates in the United States are enrolled in community colleges (AACC 2022), the potential impact is significant, particularly for the 20% of those students that enroll in STEM programs (Varty 2022). By performing research early in college, students can develop content knowledge, enhance science identity (Rosas Alquicira et al. 2022) and build social capital within STEM to support completion of STEM degrees (Martin et al. 2020). By building community college-based research labs, the opportunity exists to expand the benefits of research reported at four-year institutions (Seymour et al. 2004).

To explore this opportunity, we developed an apprenticeship-style (Joshi, Aikens, and Dolan 2019) soft robotics research experience. Soft robots are those devices built from compliant materials, including elastomers or textiles (Tran et al. 2023), and have a wide variety of applications in the medical field given their safety and bioinspired designs (Garcia et al. 2021). The field of soft robotics has a unique potential to create diverse teams in engineering with the broad range of specialties that contribute to robotic designs. Not only do traditional specialties aligned with robotics such as mechanical, electrical and systems engineering contribute, but also materials science, bioengineering, design, and health sciences. The highly interdisciplinary field allows students early in their careers to experience hands-on projects relevant to multiple majors and career paths. The field emerged as a result of robots being deployed in human-centered applications as bioinspired machines (Jiao et al. 2019), compliant grippers (Mosadegh et al. 2014), and wearable devices (Awad et al. 2017).

Technical challenges associated with interfacing robots and the human body have created opportunities for student innovation (Holland et al. 2018; Greer et al. 2020). Previously, we piloted an undergraduate soft robotics research program within an R1 institution aimed at giving first-generation college students, a supportive environment to gain technical skills and confidence (Radecka et al. 2021). Students left the experience more interested in graduate degrees, motivated in their majors, and research participation from this student demographic increased across the college. Given the benefits of undergraduate research and unique features of soft robotics, we expanded the mentored research program across multiple institution types, including a community college. Programs such as the Community College Undergraduate Research Initiative (CCURI) have previously created a national network of community colleges implementing undergraduate research experiences at their home institutions (McCook 2011) and collaborations with research institutions in summer and academic year programs (Halpern et al. 2018). However, to our knowledge this is the first such program that (1) focuses the research specifically on the multidisciplinary field of soft robotics, a broad field that invites contribution from a variety of majors, (2) leverages physical proximity to an R1 institution conducting the same research for in-person collaboration during the academic year, and (3) connects the community college participants with a national network of peers working on the same research. This paper discusses the initiation of a soft robotics lab at a community college site, a first at this institution, and collaboration within the multi-institution collaboration.

METHODS

Bunker Hill Community College (BHCC) is a public community college in Massachusetts offering two-year associate (A.S.) degrees in engineering. BHCC is the state's largest community college and most diverse higher education institution. The research group is led by a BHCC electrical engineering faculty member with a background in digital signal processing and sensor systems but no prior experience with soft robotics. The faculty member had experience mentoring students on several projects including NASA MINDS student design competition and advising multiple student STEM clubs. To meet the needs of BHCC, we designed a year-long research program that pairs first- and second-year engineering students in research with the goal that students will participate for two years. Throughout the experience, first-year mentees become second-year peer mentors to new students. This pipeline works with groups as small as two students but can scale to larger group sizes. When initiating the program, two students, majoring in electrical engineering and mathematics, were recruited by application to the 9-month, academic year, paid positions. On average, students work 5-7 hours per week on research. Faculty and student stipends were funded through the National Science Foundation Research Experience and Mentoring (REM) program. BHCC is exploring course-based research credit for long term sustainability.

Students conducted research at BHCC weekly and collaborated with peers, faculty and graduate mentors at the two collaborating sites. This occurred in-person at Harvard University in biweekly meetings with graduate mentors and virtually with University of Illinois Urbana-Champaign (UIUC) in weekly meetings with peer undergraduates. Figure 1 details the activities and interaction across institutions during the academic year program. The following sections outline the technical research experience and assessment of education methods.

Establishing Laboratory Facilities

Fabrication materials required for initial experimentation with soft robotics are low cost, keeping startup costs for the lab relatively low. The BHCC team acquired consumables such as elastomers

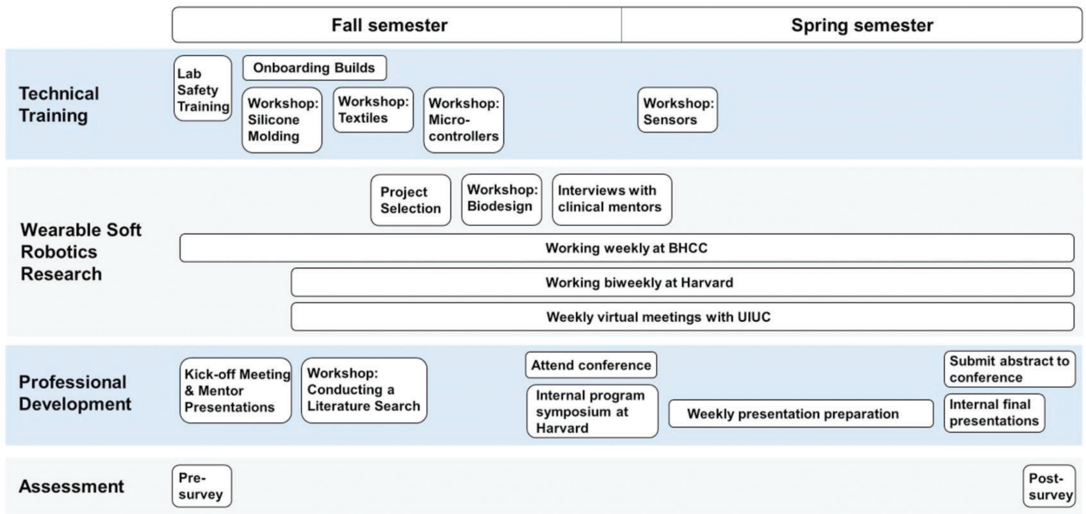

Figure 1. Timeline of BHCC involvement in undergraduate research program.

and fabrics, and reusable equipment including a vacuum chamber, air compressor, and sewing machine. The laboratory, shared with an electronics lab, contained useful equipment including power supplies, 3D printers, microcontrollers, oscilloscopes, and cutting and soldering tools. The need to train students on equipment varied depending on their completed courses. For example, at the time of joining the program, one student had not taken Introduction to Engineering, a course that introduces students to microcontrollers. As needed, the faculty mentor delivers brief workshops on topics such as soldering, 3D printing, breadboards, power supplies, or coding. Students then supplement with practice and online tutorials.

Technical Resource: Soft Robotics Toolkit

Students also routinely visited the Harvard Biodesign Lab to meet with researchers involved in the Soft Robotics Toolkit project for workshops and assistance. Orientation activities were completed by BHCC at their home institution lab using online tutorials and fabrication guides from the Soft Robotics Toolkit website. The Soft Robotics Toolkit (Holland et al. 2014) is an open access collection of design files, fabrication tutorials, and case studies related to soft robotic devices (Holland et al. 2017). Soft actuators and sensors are typically cast using 3D printed molds. The increased availability of 3D printers, including those at BHCC, allow students to use shared design documentation to develop, fabricate, and test custom components. These constructs can then be assembled in novel configurations to create new designs (Polygerinos et al. 2015; Park et al. 2014; Sardesai et al. 2018; Sikligar et al. 2022). During program onboarding, BHCC students fabricated silicone and textile-based

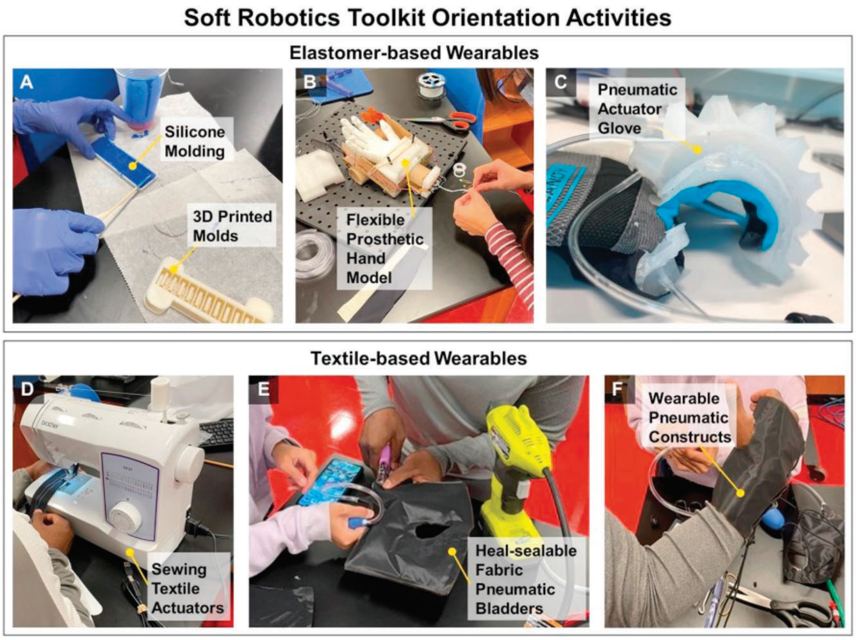

Figure 2. Students completed introductory activities to gain prototyping skills in silicone (A–C) and textile-based (D–F) designs, to lay a foundation for independent exploration in the field.

components as an orientation to the field (Figure 2). Students developed broad skills in 3D printing, polymer molding, robotics, and programming microcontrollers.

Workshops and Meetings

While most activities took place at BHCC, the project was an active collaboration among BHCC, Harvard University, and UIUC. A workshop series was organized for all students involved. Required, hour-long workshops were held at the same time weekly throughout the semester. See Figure 1 for timeline of workshops during technical training and research portions of the program. The combination of in-person and virtual events allowed for scheduling flexibility and opportunities for students to develop a national network of undergraduate peers.

Wearable Soft Robotics Research

After completing orientation builds, students in the program join ongoing Soft Robotics Toolkit projects presented by mentors. Students from BHCC work in parallel with undergraduates from UIUC and Harvard. Example projects include: (1) a physical therapy glove and (2) a low-cost prosthetic hand

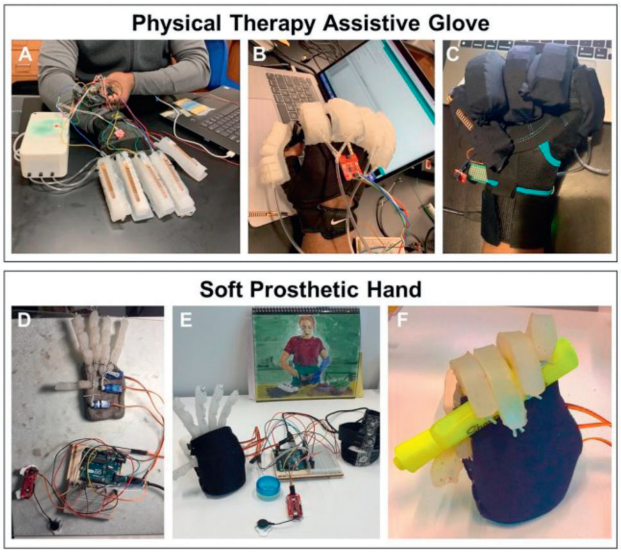

Figure 3. Students collaborated on research projects to build prototypes of a physical therapy assistive glove (A–C) and a soft prosthetic hand (D–E).

model (Figure 3). Teams from each site report weekly progress via shared slide decks and meet to discuss progress virtually. When developing designs for unmet clinical challenges, the students have access to a network of clinician and engineering mentors through on-going collaborations with medical schools at Harvard and UIUC. Project mentors helped students understand latest advances in the field through a literature review workshop. Students then contributed their own ideas to prototype development.

Technical Communication Training

Undergraduates who participate in the culture of research, publishing papers and attending conferences, are most likely to experience positive outcomes (Wrighting et al. 2021). Halfway through the academic year, participants from all sites met in-person to attend the Materials Research Society (MRS) conference in Boston, MA and share progress reports at an internal symposium held at Harvard University. Students attended presentations from soft robotics researchers at MRS, a practice shown to increase understanding of the extensive research landscape and various scientific career paths (Gopalan, Halpin, and Johnson 2018). Through technical communication focused informal workshops, students continued to develop their presentations until the research experience culminated with a virtual symposium where students presented results to internal and external attendees. Additionally, students are encouraged to present their design externally. The physical therapy glove was co-presented by BHCC and UIUC students at the next MRS annual meeting.

PRELIMINARY RESULTS

Assessment

Over the timeline of the project we have collected data from students at all participating sites. Students were invited to participate in Institutional Review Board approved pre- and post-program surveys. The Undergraduate Research Self-Assessment Survey (URSSA) is composed of 5-point Likert scale questions assessing gains from the research experience (Weston and Laursen 2015) where zero is "no gain" and five is "great gain". Due to the small numbers of community colleges students, we report aggregate survey results at all sites. Of the n=16 responses across all sites, preliminary data shows greatest gains were reported in the Personal Gains factor (*m=mean ± standard deviation, m=4.77±0.08*). This factor includes questions such as "Comfort in working collaboratively with others" (*m=4.9±0.25*), "Confidence in my ability to contribute to science" (*m=4.8±0.40*), and "Develop patience with the slow pace of research" (*m=4.8±0.3*). Other factors showed good (4) gains in Thinking and Working Like a Scientist (*m=4.48±0.3*), and Attitudes and Behaviors (*m=4.38±0.6*). Participants reported positive outcomes from collaborating in person with co-located institutions. Free responses help to support these results. One student wrote:

> *"It wasn't just a research project; it was a buildup of our professional careers and approach to teamwork."*

Pilot results show that our goals of providing content knowledge, professional development, and research skills are reflected in student responses. We asked students, "What technical disciplines contribute to soft robotics?" Data in Figure 4 shows that students entering the program had an appreciation for the broad range of fields that contribute. After completing the program, responses narrowed. The most frequent responses correspond to the degrees held by the faculty mentors at each site. This may have been influenced by the mentoring triads and dyads of the apprentice model (Joshi, Aikens, and Dolan 2019) but requires further exploration to draw conclusions. Additionally, "medical professional" responses increased, potentially influenced by interactions with clinical mentors during the project design phase.

We are also tracking career related outcomes for BHCC students involved in the program. At the end of the first year, one BHCC student graduated with an A.S. degree in mathematics. Because of increased interest in healthcare technologies, they transferred to a four-year pre-med program in health sciences. The second student went on to serve as a peer mentor in the second year of the program alongside a new BHCC student majoring in engineering. This student completed an NSF

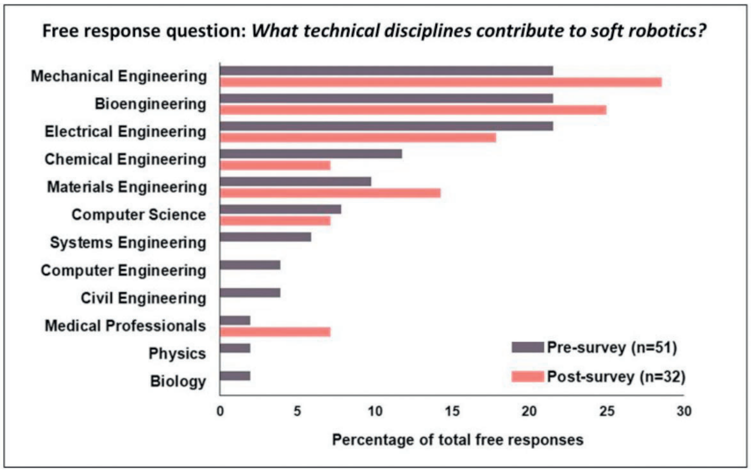

Figure 4. Visualization of data from an example free response question.

funded REU program in engineering at a local university during the summer and is expected to graduate with an A.S. in electrical engineering and transfer to a four-year program.

Reflections

The multi-institution collaboration created many unique opportunities as well as presented unique challenges. Initiating the virtual collaboration across institutions was made easier by students' familiarity with video conferencing platforms. However, mentors noted a significant increase in virtual collaboration after the students met in-person during the mid-program symposium at Harvard. At BHCC, an engineering lab manager played a significant role in making space available for the program, even getting involved with mentoring the students. These resources, in addition to faculty time, may be limited at some colleges seeking to implement the program. BHCC is exploring course-based research to engage more students and to provide research for credit opportunities.

NEXT STEPS

The implementation was successful as measured by URSSA pilot assessments and feedback surveys. Moving forward, our goal is to add institution pairs (R1 and community college) in the same location, to collaborate with the larger national network of institutions. Triads and diads (Joshi, Aikens, and Dolan 2019) refer to the intended mentorship model. Triads are composed of a faculty member, graduate student, and undergraduate student. Diads are composed of a faculty member and undergraduate student. Triads and diads are used based on institution size. BHCC and Harvard form a triad of a BHCC faculty member, Harvard graduate student mentor, and BHCC student. There are also diads of BHCC faculty and undergraduate students working together. Moving forward, the BHCC lab will serve as a model for collaboration with a midwest-based community college and others. Our next collaborating school is in regional proximity to UIUC. We will also track how students engage with training resources and assess student gains after participation. These data will inform our efforts to scale the program to include more co-located institutions nationwide. The BHCC lab startup has been a first step toward leveraging multidisciplinary, soft robotics to enhance community college student research engagement to support diversifying engineering.

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