

Board 361: Progress in S-STEM Program Electrical Engineering Scholars at the Benjamin Franklin Cummings Institute of Technology

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Progress in S-STEM program Electrical Engineering Scholars at the Benjamin Franklin Cummings Institute of Technology, Year 2

The goal of the Electrical Engineering (EE) Scholars Path to Boston Power (*PtoBP*) program is to enable academically qualified students--with financial need--from greater Boston Public Schools, community colleges, and those enrolled in the Benjamin Franklin Cummings Institute of Technology (BFCIT) two-year technology associate degree programs, to complete a BS in electrical engineering (EE) leading to employment or an advanced degree in EE, particularly in Electric Power Engineering. The mission of BFCIT, which is a Minority Serving Institution, is to provide technical education to under-served, economically disadvantaged communities. The community of S-STEM Scholars is supported by: a pre-matriculation overnight stay, in Maine to learn about electric energy, sustainability, and Maine's unique ecology; a project-based first-year course about power, energy, sustainability, and robotics; mentoring opportunities with local Boston middle and high school students; study group opportunities, and exposure to IEEE PES Society events and other professional activities, such as seminars and conferences. Our goal was a 90% second-year retention rate, and a 90% five-year graduation rate, with at least 50% of the Scholars going on to intern and work in the electric power industry.

The program started in October, 2021 and seven qualified EE students (Cohort 1) received the award in 2021. An eighth scholar was later added that year. Since these students had already started the fall semester, they did not do the Maine trip or the first-year seminar, but had the opportunity to attend study groups (remotely), and mentor high school students at BFCIT's annual Power Engineering Day. Students attended fewer IEEE meetings than had been intended because of the COVID pandemic. In Fall 2022, an additional eight new students (Cohort 2) received the award at the start of the semester, and three more students were added at the end of the semester. Most students in Cohort 2 had the opportunity to attend the overnight Maine trip, enroll in the first-year project-based course, and participate in the other S-STEM programming.

The retention rate of Cohort 1 Scholars after three semesters as *PtoBP* Scholars was 8/8 or 100%, i.e., all the Scholars returned in BFCIT in the Fall of 2022, although one switched to a two-year electrical engineering technology major, with the approval of the PI.

The retention rate of Cohort 2 after one semester was 6/8 or 75%. Two scholars dropped out of the program during the first semester; one switched schools to major in liberal arts and the other dropped out for unknown reasons.

So far, the overall retention rate is 14/16 or 82%, close to the 90% goal of the program.

Introduction

The overarching objectives of the NSF SSTEM's Electrical Engineering (EE) Scholars Path to Boston Power (*PtoBP*) at the Benjamin Franklin Cummings Institute of Technology (BFCIT) are to attract academically qualified students with financial need from Boston Public High Schools (BPHS) to study EE at BFCIT and to provide them with a community and support so that they would successfully graduate and obtain employment in the field or continue on to graduate school. Special emphasis was placed on electric power engineering given the collaboration between the electric power industry and the EE program, and the need of the power industry for more electric power engineers.

The goal of *PtoBP* is to improve retention to graduation in EE and entry into the STEM workforce, particularly into Electric Power, for academically qualified Boston Public High School students with limited financial means, through partnerships with a middle school program, three Boston Public high schools, one community college, and eight companies that service the electric power grid. Most students from these schools are underrepresented minority students with financial need.

The objective of *PtoBP*: to have Scholars show higher retention/persistence rates. Specifically, to have a 90% second-year retention rate, and a 90% five-year graduation rate; and to have at least half of the *PtoBP* Scholars intern in power engineering and work in power engineering.

Key Program Features

PtoBP dovetails well with BFCIT's EE program, that strives to provide support to its students who tend to be low-income students from underrepresented groups. To that end, the EE program incorporates activities and infrastructure that promote conditions for student success in STEM fields such as: math competency [1, 2, 3], self-efficacy [2, 4], met financial need [5, 6], forming an engineering identity [7, 8], faculty support [9, 10], and a sense of community [11, 12].

Math Competency: BFCIT's EE program closely monitor students' progress in their course through bimonthly meetings of the EE faculty, where courses with their students are discussed. BFCIT's Academic Success Center monitors students through Dropout Detective, which is a tool inside Canvas™ that helps identify "at risk" students. During the mid-winter and summer breaks, the EE program offers remedial courses for students who did not achieve the required C in a prerequisite course. This enables students to improve their grade in the course and allows them to continue to the next EE course and stay on track to graduate with their cohort. The EE program also administers its own exam assessing pre-Calculus concepts at the beginning of the spring semester freshman year, and again at the beginning of the spring semester sophomore year. The results of the assessment exams are used formatively to advise students to improve their math skills by getting tutoring help and alerting EE instructors about which students may need extra math help.

Self-efficacy through project-based hands-on learning: Studies [2, 13, 14] have found that project-based, hands-on learning, when done correctly, increases self-efficacy. All but one BFCIT EE class has a laboratory component where students perform, either individually or as a team, hands-on exercises and projects that engage students in understanding the theoretical concepts learned in their lectures. As much as possible, "real-world" applications are used so that students get a sense that what they are learning is important and relevant.

Financial need: BFCIT is a Minority Serving Institution (MSI) and has the lowest tuition of any private institution in Massachusetts with tuition and fees for the EE program set at \$17,600 in years 1-2 and \$18,800 in years 3-4. With Federal Pell Grants, state MassGrants, the remaining tuition is about \$10,000.

Forming an engineering identity: The BFCIT EE program promotes forming an engineering identity through STEM mentoring activities; networking, educational, and internship professional opportunities; and with role models.

STEM Mentoring Opportunities: BFCIT EE students have the opportunity to mentor BPS students in visits to BPS schools, in our annual Power Engineering Day, and in volunteering at the Latino-STEM Alliance Robotics and Science Fair.

Visits to partner schools: BFCIT EE students visit BPS high schools to do experiments that teach about EE and BFCIT. At these visits, they also share their college experiences and answer questions. Some BFCIT EE students attended these Boston Public Schools, giving the visits special meaning to both the EE students and the high school students for whom the Scholars serve as role models.

Power Engineering Day¹: Each year, the EE program hosts Power Engineering Day in which groups of Boston Public high school students, led by EE students, visit each demonstration to listen to power engineers describe their work and instruct the students with hands-on activities.⁴ This event started as part of a prior NSF SSTEM award of principal investigator at Suffolk University [15]. Several of the engineers who staff the demo booths are former Scholars from the Suffolk program and BPS graduates, who are ideal role models for both BFCIT EE students and Boston high school students. EE students also have tables where they demonstrate their senior design projects and other projects. EE students also spend time with the BPS students, discuss college life and being an engineering student.

The Latino-Stem Alliance (LSA) Robotics and Science Fair Competition²: LSA holds an annual robotics competition and family science fair in June in an inner-city neighborhood in Boston for students in grades 4-8 and their families, to promote engineering to students from underrepresented groups. BFCIT EE students regularly participate in this event by being judges and by demoing their projects.

Networking, Educational, and Internship Professional Opportunities: BFCIT EE students are encouraged to attend biweekly IEEE PES student chapter meetings with pizza, the chapter's annual dinner, and the IEEE northeast regional student conference where they can participate in a micro-mouse competition. In addition, students are encouraged to apply for the IEEE PES Scholarship Plus initiative which gives students modest scholarships and provides information about internship opportunities. In their junior year, EE students are encouraged to apply for summer internships hosted by BFCIT industry partners and other companies.

Role models: Although the EE faculty is not racially diverse, one of the three full-time EE faculty is a woman (the PI). At some of the IEEE PES student chapter meetings, electrical engineers from underrepresented groups talk to the students about their careers and career paths.

Faculty support: EE students consistently list faculty support as one of the chief best qualities of the program. Faculty regularly attend the IEEE PES student chapter meetings and are engaged in all the professional and mentoring activities that the EE program offers.

Sense of community: Because of the EE program's small size, and because EE majors take most of the same classes, BFCIT's EE program does well with Cohort building and fostering a sense of community.

PtoBP Programming

¹ Suspended during the COVID-19 pandemic but resumed in May 2022.

² Suspended during the COVID-19 pandemic but will resume in June 2023.

The previous section described the existing features of BFCIT's EE program. The following describes features that were added for *PtoBP*:

NSF Scholarship: Most existing BFCIT EE students meet the financial need criteria for NSF's SSTEM program and the students who have been admitted into the program receive the full \$10,000 per year that the program allows, which enables Scholars to pay little or no tuition.

A four-day trip to Maine: To enhance the sense of community and self-efficacy, a pre-matriculation trip to northern Maine's Center for Ecological Teaching and Learning is part of *PtoBP* which also had been a part of the PI's previous SSTEM program at Suffolk University [16]. The Center for Ecological Teaching and Learning, which was formerly known as the Suffolk University Friedman Field Station, offers food and lodging to enable the study of the unique ecology of the intertidal zone of Cobs Cooke Bay. The trip is guided by Dr. Carl Merrill, who was formerly the director of the Friedman Field Station and is an expert on Maine ecology. The PI and another BFCIT faculty member also guide the trip and provide experiments for students to learn about energy and sustainability.

The Maine activities include a whale watch, a tour of Eastport, Maine including a model of FDR's plan to generate electricity from tidal power and the 100+ years old Raye's Mustard Factory, and a hike to learn about the ecology of Shackford State Park. Additional activities included measuring current velocities in Cobscook Bay and wind velocities in order to understand the energy content of the running that could be harnessed to generate electricity; experiments on photovoltaics, and performing solar thermal experiments involving light and dark cups as well as liquids of different heat capacities. Students may also hike in West Quoddy Head State Park Bog and the spruce-moose/forest rocky coast of Maine. Upon their return home, students complete surveys and write essays detailing their experiences.

Project-Based Freshman course

BFCIT has their largest attrition rate after the first semester and a first semester project-based course may help to address that. Research [17] has shown that highly impactful educational practices include first year experiences that involve teams in research and service learning. Therefore, in their first semester, freshman Scholars, as well as BFCIT EE freshmen, meet for six hours per week in three two-hour sessions, each led by a full-time EE faculty member, to work in teams on projects that teach about electrical engineering; projects include those involving wind and solar energy, electric motors, robotics, and general electrical engineering laboratory tools such as oscilloscopes, signal generators, and multimeters. Software such as LabVIEW™ and Mathematica™ as well as Arduino™ technology is introduced. Students also design experiments, and robots. They present their projects at: (a) partner BPS high schools, (b) The LSA Robotics Competition and Science Fair, and (c) Power Engineering Day.

Study group participation

BFCIT has not had prior experience with a formal study group program. With funding from the grant, the PI intended to work with BFCIT's Director of Student Success Shawn Ayala to set up a study group system which includes training leaders on effective techniques, monthly meetings led by an experienced study group leader, and pairing new study group leaders with more experienced ones.

Program Execution

Year 1

PtoBP started on October 1st 2021. At that point, there were seven EE majors who met all the criteria for the award as determined by their FAFSA form and their GPA, and these students were given the award. Out of these seven Scholars, four were freshman, one was a sophomore, and two were juniors. In the spring semester, an additional sophomore was added. Of those eight, five transferred from local community colleges or other four-year colleges, two were recent graduates of Boston Public Schools, and one came from a BFCIT technology program. Demographically, three of the eight Scholars are female and five are male. Six are African-American, one is Latin-American, and one is Asian.

Study groups: Since these Scholars started mid-semester, they did not participate in the Maine Trip or project-based freshman course. While there were no study groups for upper classmen due to low enrollment exacerbated by the COVID-19 pandemic, five Scholars, however, did participate in a student group for their Circuit Theory I course (DC circuits). One of the Scholars who was excelling in the course agreed to be its study group leader. Attempts were made to recruit a study group leader from among the upper classmen who already took the course, but they were unsuccessful, mainly because most BFCIT students hold outside jobs, and so have little time for other endeavors. The scholar who became the study group leader also maintains outside employment, but since he needed to study for the course anyway, he was able to find the time. Five Scholars, including the study group leader participated in the study groups, and three of the five achieved the required C to continue on to the next course in the EE sequence. However, for the Scholars who did not achieve a C, the PI ran a mini-course after the semester ended, to raise their skill levels to C level. Out of the two, one was able to continue to the next course, while it was recommended to the other, that he change his major to a two-year electrical technology major, which he eventually did. It should be noted that the student who did not achieve the skills needed to continue in the major, also scored very poorly on our department's math pre-Calculus assessment tests, even though he scored at least a C in Pre-Calculus, Calculus I and Calculus II, which indicates that grades do not always reflect student's skills.

IEEE meetings: BFCIT's IEEE student chapter is also a Power and Energy Society chapter, and meetings resumed with the abating of COVID-19 cases. Meetings are held with pizza, and topics such as employment opportunities or preparing for the IEEE micro-mouse competition are discussed. Outside speakers such as an EE alumnus were also brought in to speak to the students. Students reported that they benefitted from the alumnus' talk about his career path and experience in industry, and also appreciated the updates that the three full-time EE faculty, who also attended these meetings, gave about upcoming EE events. One of the Scholars ended up interviewing with the alumni for an internship, and thought that the experience improved her interviewing skills.

Power Engineering Day: Three of the eight Scholars from Cohort 1 participated in Power Engineering Day as well as other BFCIT's EE majors, over 150 Boston Public High School students, and several community college students. Among the latter two groups were six students who later became Cohort 2 Scholars. Industry partners came from National Grid, Eversource, Nexamp, ElectroSwitch, Black & Veatch, Phoenix Electric, and Qualus. Scholars from both Cohorts 1 and 2 reported that they found the day worthwhile and appreciated seeing BFCIT students demo their final projects. Cohort 1 Scholars liked the chance to interact with engineers from companies, enquire about internships, and learn how electrical engineers benefit society; they also liked that they were both mentoring high school students, and being mentored by the visiting engineers, many of whom were alumni of the EE program when it existed at Suffolk University-- some of the alumni were even former SSTEM Scholars of the PI. They also reported that they were particularly gratified to inspire the future Scholars of Cohort 2 to join them in the program. Scholars from Cohort 2 reported that not only did Power Engineering Day teach them much about how electric power and renewable energy but also encouraged them to study the major by seeing the passion

of the industry presenters. Moreover, Scholars reported that interacting with the EE faculty allayed their fears about studying such a rigorous major and encouraged them to apply to the program. The Cohort 1 Scholars who did not attend, wished that they could have attended but that their work schedule did not permit it.

Year 2

Seven new Scholars were added before the start of the fall semester of year 2: six freshmen, one sophomore, and one junior. Demographically, all were male, three were African-American, three Latin-American, and one White. After the first few weeks of the semester, an additional Latin-American male freshman was added, when it was discovered after contacting his high school for more information about his transcripts, that he met the academic criteria. Four of the five freshmen were recent high school graduates, with four from Greater Boston high schools, and one from a local community college. The sophomore came from BFCIT's automotive program, and the junior had been a BFCIT EE student two years prior to re-enrolling but had withdrawn because he needed to work full-time. This junior student, who was a graduate of a Boston Public High School, only returned to BFCIT because of the Scholarship award, which allowed him to work part-time. At the beginning of the following spring semester, three additional Scholars (a freshman, sophomore, and senior) who were already EE students at BFCIT were added. Demographically, two were African American males and one a White female. All three went to high school in the Greater Boston Area.

Maine Trip: Four new Scholars participated in the Maine trip. Of the three who didn't go, one became sick the morning of the trip, one had an appointment that couldn't be cancelled, and the other said that he'd be away. All four Scholars who participated were satisfied with the experience and viewed it as beneficial to their start in the electrical engineering program. They reported that they appreciated learning about the environment and energy, developing connections with other Scholars, spending time in the rustic Maine countryside, and learning how electrical engineering can be applied to solve environmental problems. They also appreciated getting to know their professors outside a classroom setting. The Scholars also reported that the trip boosted their confidence to study electrical engineering. One Scholar stated, "*I have been camping, traveling, visiting places and having fun, but the trip to Maine was exceptional, it was not only camping or getting to know Maine, but it was also about learning by doing some great experiences that will help in our study. It's something that every student, specially STEM ones, should do. This trip made feel ready to start my new adventure as an electrical engineer.*" Students suggested that the trip might be enhanced by having upperclassmen attend who can serve as mentors to the new students.

Project-Based Freshman course: This was the first semester that the course in this format was offered³. Of the thirteen students who enrolled in the class, seven were Scholars. At the end of the semester, one student who had not been eligible academically for *PtoBP* performed well in the class and in his other classes to be able to join *PtoBP*. The students who responded to the end of semester evaluation surveys (5/13 students) either agreed or strongly agreed with the following statements:

1. The course motivated me to learn the material and apply concepts to my personal and professional life.
2. As a result of taking this class I have a deeper insight into electrical engineering.
3. The course material helped me to understand electrical engineering.
4. The course encouraged me to conduct additional research when completing assignments.

³ Previously, the PI had not been involved in the course which had mainly focused on robotics.

All respondents found the projects and their write-ups, to be very useful to learning the skills necessary for a job in EE, and students disagreed or strongly disagreed that the course content was boring and uninteresting.

Student grades in the course were mainly either above their HS GPA's or slightly below their HS GPA's as can be seen in Figure 1. The faculty view this as an indication that most students were engaged in the course and student performance either exceeded or was close to average HS performance. Scholars indicated that they appreciated learning about sustainable energy sources such as solar and wind.

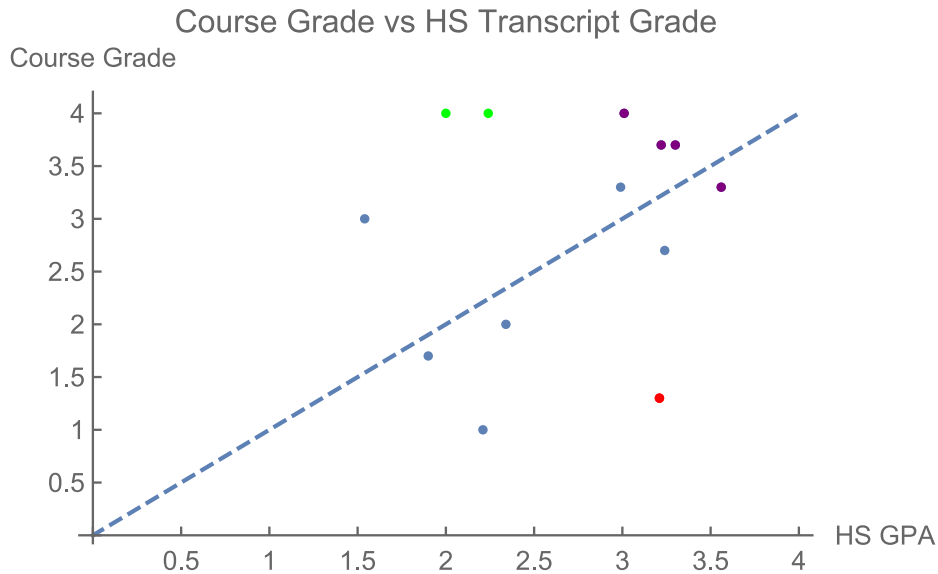


Figure 1 Project-based freshman course grade vs HS GPA is shown. The purple points represent the grades of Scholars who took the course. The red point also represents a scholar, but he did not attend the course during the last month of the semester, which hurt his grade. The two green points represent older students who did not enter the program directly from high school. For the students that attended the course through the end, all but one earned a grade either close to their HS GPA's or above it.

A trip to visit the MIT Nuclear Reactor was a requirement for this course and optional for other students in the program. Nine Scholars attended the tour, six who were taking the class and three who weren't. Scholars appreciated learning about nuclear energy, a topic that they did not have much knowledge of, and seeing a nuclear reactor facility, viewing it as a once in a lifetime experience.

High School Visits

Students in the project-based freshmen course interacted with three Boston High Schools; students from Jeremiah Burke School visited the course at BFCIT, and BFCIT students in the course performed experiments with students at Charlestown High and the O'Bryant School. Of the seven out of thirteen students who visited the high schools, five were or became Scholars. Scholars report positive experiences in demoing their projects to the high school students and informing them about using solar energy and wind energy to power the motors. They were also pleased that some of the high school students indicated that they'd like to be part of BFCIT's EE program, when they graduate.

IEEE Meetings and Banquet Attendance

Finding a time for IEEE student chapter meetings that would accommodate all Scholars proved difficult, so Cohort 2 Scholars mainly attended the meetings that were held every two or three weeks, but only

three Cohort 1 students⁴ regularly attended those meetings because they tended not to be on campus those days. Nonetheless, students in Cohort 2 appreciated meeting upper class EE students. These meetings kept the same format as was described in Year 1. Scholars in both Cohorts appreciated the meetings and felt that the outside speakers served as role models and better prepared them for their careers. They suggested that they would benefit from hearing from more speakers.

Six Scholars, two from Cohort 1 and four from Cohort 2 attended the Annual IEEE PES Boston Chapter Dinner. Scholars reported that the banquet was eye-opening. Students had the opportunity to interact with electrical engineers who were currently working, and who also had their own businesses which they found informative. They appreciated this opportunity to network, and enjoyed learning about some of the engineering involved in solar energy, energy storage, and the aspects involved in making the electric grid have net-zero carbon emissions. After the dinner, Scholars thought they were more likely to become electric power engineers.

Study Group Attendance

Study groups are not offered during the first semester freshman year so only Cohort 2 had study groups made available to them. However, because of study group leaders' outside work commitments, only a few sessions of study groups were available for Circuit Theory II in which five Scholars were enrolled, with one scholar leading the group. Although an online tutoring service is available to students, Scholars preferred tutors that they knew and wanted tutors or study groups for all their engineering courses. As a result of this feedback, the PI is looking into finding EE students at Boston schools such as MIT, Northeastern, BU, and Wentworth who can serve as study group leaders or tutors.

Figure 2 summarizes the number of activities in which scholars participated, with three scholars participating in two activities, five scholars in three, etc. As had been mentioned, Scholars indicated that work schedule often prevented them from participating in more activities.

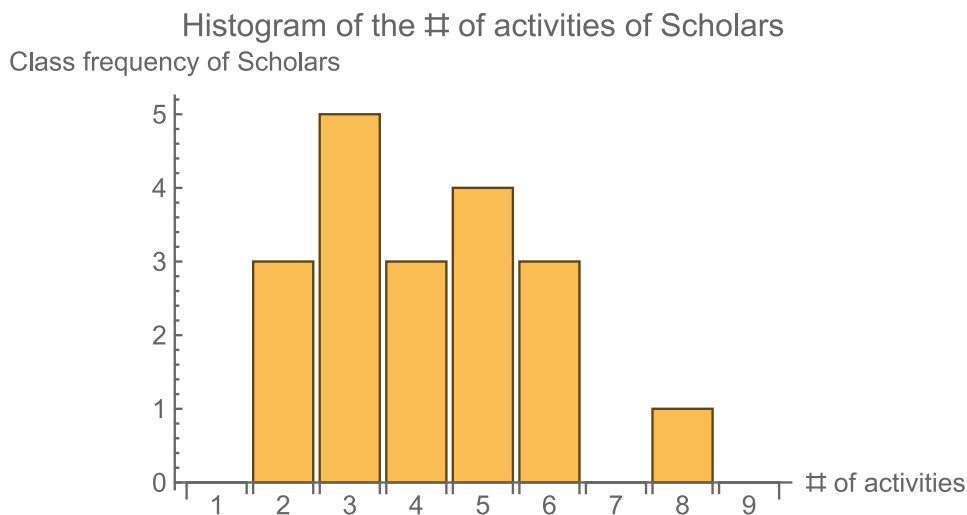


Figure 2 Histogram for the number of activities in which Scholars participated. Scholars indicated that work schedule often prevented them from participating in more activities.

Student Performance and Retention

⁴ There were though, other EE students outside the SSTEM program, at these meetings.

Cohort 1

All eight Scholars in Cohort 1 are still in the program, although one switched to a two-year electrical engineering-related technology program with the encouragement of the PI. Seven Scholars are in good-standing at the current time, the third semester of *PBtoPB*, and one is on academic warning. Students reported that a major factor impeding their academic performance was long hours at an outside job. Some Scholars reported that when they were working long hours (30+) their academics suffered. Other Scholars reported that they cut back on their working hours after poor performances in the courses, and that the scholarships enabled them to cut back on their work hours. From math assessment tests, it was found that Scholars' math skills need improvement, likely because long hours at an outside job impeded their ability to focus on their math courses. Other issues are family commitments-some Scholars are the children of non-English speaking immigrants and need to help their parents with day-to-day issues that require the knowledge of English; others are parents themselves and have childcare responsibilities. Most Scholars have said that they would not have lasted this long in the program had it not been for the Scholarship. It should be noted that Scholars' outside commitments often prevented them from participating in the program's retention-encouraging activities and they expressed regret about not being able to participate more fully in the program.

Cohort 2

Of the eight students who started at or close to the beginning of the fall 2022, six remain and all are in good standing. The two students who left the program were both freshmen, Latino-American, male, and graduates of high schools in the Greater Boston area. Both participated, to some extent, in *PtoBP's* programming, with one attending the Maine trip, and the other attending the IEEE PES Society banquet. In the project-based freshman course, one had good attendance, project participation and assignment submission, but left the school in mid-October; the other had good attendance, preferred to work alone, rarely submitted assignments (although excelled in the hands-on project work), and stopped coming to class in mid-November, although remained enrolled. The former indicated to other students that he transferred to a liberal arts college, preferring not to study a STEM major, and the latter registered for spring classes but then never came. Attempts made to contact these students by the PI were unsuccessful. Of the six remaining students, all participated in *PtoBP's* programming to some extent, with five highly active (participated in four or more activities), and one somewhat active (participated in two or three activities). As had been mentioned, three students were admitted to the program at the end of the fall semester. Reasons for admission to the program include improvement in academic performance, and a need for the students to work fewer hours, in order for them to succeed academically. One of these three was highly active in the programming that was available to non-Scholars, and the other two participated less, due to the demands of an outside job. A scholar reported that the potential for the Scholarship motivated him to study harder.

Conclusion

The Electrical Engineering (EE) Scholars Path to Boston Power (*PtoBP*) program is into its second year at the Benjamin Franklin Cummings Institute of Technology. Currently the program is serving sixteen students. Two students dropped out of the program (and BFCIT)-one because he decided that he preferred liberal arts to STEM and the other for unclear reasons. Another student remains at BFCIT but switched to a two-year electrical engineering-related technology program, which seems to be a better fit for the student. While all Scholars participate in the program activities to some extent, few participate to a large extent, mainly because of outside work commitments and also because of family responsibilities. Power Engineering Day was a successful event, which not only benefitted existing Scholars but potential

Scholars as well. Students also expressed satisfaction with the Maine trip, and, although one dropped out, the other three highly participate in the *PtoBP* activities. Scholars appreciated the other professional activities provided by the program and suggested adding more of them such as job-shadowing and a learn and earn course. Some Scholars also expressed that the various activities changed their perspective on electrical engineering and that they are more heavily considering electric power, as a career path, due to the professional activities to which they had been exposed. One program that needs improvement is the study group program, because most potential study group leaders at BFCIT have outside jobs and aren't available to lead study groups. While BFCIT has contracted with an online company that provides tutoring, students felt that it would be better if they had a consistent tutor that they knew. Therefore, the PI is looking into recruiting study group leaders from local colleges in Boston such as MIT, Northeastern, BU, and Wentworth. It is noteworthy that most Scholars state that without the Scholarship, they likely would not be able to continue to study electrical engineering and would have either dropped or failed out.

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