A Summer Biotechnology Boot Camp to Increase STEM Interest Among Minority High School Students

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There is a disparity in the number of adults from minority populations employed in STEM careers. In order to increase the interest of at-risk high school students in the STEM field in Queens, NY, an immersive summer biotechnology boot camp was developed. Fifty-five predominantly minority and female students completed the summer boot camp over a three-year period. Students learned about molecular biology, conducted modern biotechnology techniques, detected genetically modified foods sourced from their own homes, created a presentation, and were rewarded with Barnes and Noble gift cards. They then took a survey to reveal their thoughts on the program and their likelihood of pursuing a degree in the STEM field before and after the workshop. Participants became more confident in their science and math skills and indicated they were more likely to complete a STEM degree. Overall, high school students enjoyed the hands-on self-discovery aspect of the project. Many indicated that they became more interested in STEM, which could help increase the number of college entry-level minority students interested in STEM fields.

The demographics of the United States are changing. In the past seven years, the percentage of white children (ages 5–17) in the population decreased by 10%, yet education beyond a high school (HS) diploma is still a struggle for those coming from underrepresented groups. Last measured in 2014 by the National Center for Education Statistics, 57% of students enrolled in colleges are White, while the percentages of Black (14%) and Hispanic (18%) students are much lower. Furthermore, fewer non-White students graduate with associate/bachelor's degrees: White (61/68%), Black (14/11%), and Hispanic (17/11%). Disparities are even greater when analyzing the statistics for higher education degrees in STEM by race (Asian: 31%, Two or More Races: 18%, White: 17%, Pacific Islander: 15%, American Indian/Alaskan Native: 14%, Hispanic: 14%, and Black: 11%) or gender (women: 35%) (Musu-Gillette et al., 2016).

Queens County, one of the five boroughs of New York City, is ranked as one of the top five most racially diverse (Narula, 2014) in the nation. The population includes White/non-Latino (27.6%), Asian American (22.8%), Latino (27.5%), African American (17.7%), Native American (0.3%), and other (4%) (U.S. Census Bureau, 2017). Queensborough Community College is one of the 24 schools in the City University of New York (CUNY) system, the country's largest urban public university, and its student population reflects the diverse demographics of its county. During the fall semester of 2016, enrollment at QCC was Latino (33%), Asian or Pacific Islander (28%), Black (26%), and White (15%); 88% of the students enrolled were from NYC (Queensborough Community College Fact Book, 2016).

Research shows that early interactive exposure to STEM concepts can help to increase STEM interest and confidence in minority populations (Finkel, 2017; Fowler & Schreiber, 2017; Hazari et al., 2010; Kelly, 2016; Shin et al., 2016). Queensborough Community College's Minority Science and Engineering Improvement Program (MSEIP), funded by the U.S. Department of Education, began in 2014. The goal of this grant was to help engage students from minority and underprivileged populations in STEM fields. One aspect of the program was an intensive summer immersion experience for high school (HS) students. The two-week summer boot camp was geared toward high-needs students, all of whom were at risk of educational failure because of poverty, English language barriers, poor grades, homelessness or foster care, pregnancy or parenting status, and/or who had family or other situations that placed them at risk of not graduating from HS.

All MSEIP summer immersion participants were selected from among QCC–Project PRIZE students. Project PRIZE is a Liberty Partnerships Program (LPP) funded by the New York State Education Department. Students in Project PRIZE are referred to LPP for a variety of reasons (e.g., high risk of educational failure, poor academic performance, low attendance in school, family issues, negative peer pressure), and they receive a minimum of six hours per week of additional guidance and instruction to help make their middle and high school years more productive. These students enroll and participate in a number of on-campus activities throughout the summer. We hypothesized that addressing a modern-day science topic and exposing these students to state-of-the-art research techniques and equipment as part of the MSEIP Biotechnology Summer Boot Camp would help increase interest in STEM among this urban, minority HS student population, as well as aid these students in becoming more confident with their math and science skills.

Methods

Project PRIZE advertised and recruited boot camp attendees from local high schools during the spring semester each year. The lead PI developed the recruitment protocol in consultation with Project PRIZE staff. Applications and brochures were developed for parents and school counselors to aid in recruitment. These protocols and applications were then approved by the City University of New York Institutional Review Board. We reached out to HS staff in February and March to help with recruitment efforts. A member of the QCC faculty led the boot camp activities by designing the lesson plans and recruiting two QCC student mentors who were trained previously in biotechnology laboratory techniques. These student mentors helped in daily lab activities and in the construction of group PowerPoint presentations. Each year, the five-day workshop (Table 1) was conducted at the beginning of July using materials from an Edvotek® "Identification of Foodstuffs from Genetically Modified Organisms (GMOs)" kit.

Table 1. *Outline of Five-Day Workshop Events*

Dates	Topics	Hands-On Activities
Day 1	Student Introductions Background on Molecular Biology What Are GMOs?	How to Pipette Work on PowerPoint
Day 2	What is a Centrifuge? What is a PCR?	DNA Extraction of Food Work on PowerPoint
Day 3	What is Gel Electrophoresis?	Conduct a PCR Work on PowerPoint
Day 4	How to Make/Deliver an Effective PowerPoint	Run Gel Electrophoresis DNA/Gel Imager Finalize PowerPoint
Day 5	Certificate/Gift Certificate Ceremony	Students Deliver Final Presentations Final Survey

Final presentations were conducted on the last day of the boot camp. Family, friends, faculty and staff were invited to see the work that was conducted. Before the conclusion, a computerized MSEIP Summer Biotechnology Boot Camp survey was administered by QCC personnel, and all participants were awarded a $200 Barnes and Noble gift card. The survey was designed to obtain participant demographics and assess the effectiveness of the boot camp. Since one of the goals of MSEIP was to address the STEM skills gap of high-need HS students, a series of questions were posed to determine students' STEM interest and science self-concept; students were asked to rate each statement before and after the boot camp

using a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). Concurrent with our analysis, the survey raw data was also sent to our external evaluator at Kansas State University.

Results

Fifty-five students participated over the first three years of the program, and the vast majority self-identified as being part of an underrepresented minority population (Table 2): (year one) African American/Black (n = 8, 40.0%), Hispanic (n = 6, 30.0%) and American Indian/Alaskan Native (n = 1, 5%); (year two) African American/Black (n = 13, 61.9%), Hispanic (n = 6, 28.6%), and American Indian/Alaskan Native (n = 1, 4.76%); and (year three) African American/Black (n = 11, 78.6%), Hispanic (n = 3, 21.4%). Of the participants, 52.8% were HS seniors, 43.6% were juniors, and 3.6% were sophomores (Table 2).

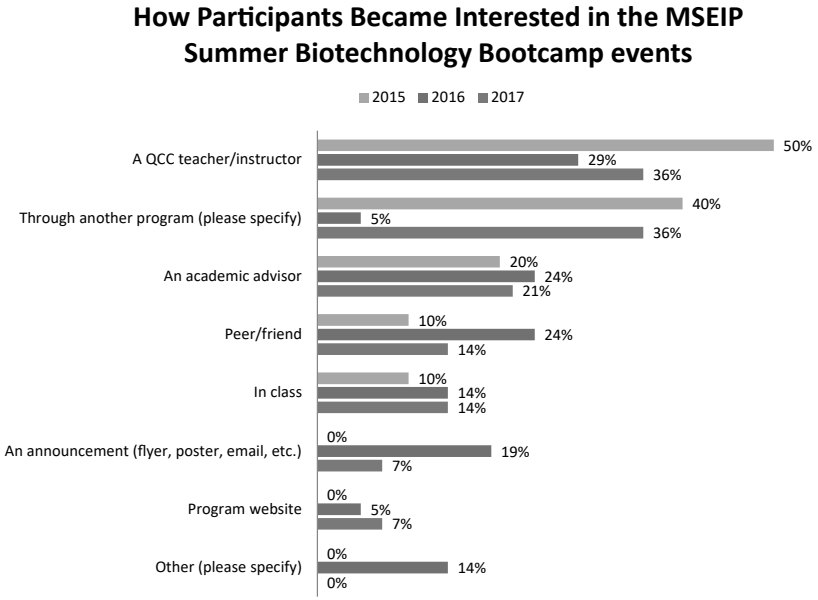
Table 2. *Demographics of Boot Camp Students by Year*

HS Student MSEIP Boot Camp	Female/ Male	Underrepresented Minority (URM) [a]	Sophomore/Junior/ Senior	Total
		2015		
Number participating	18/2	15	0/12/8	20
		2016		
Number participating	18/3	20	2/8/11	21
		2017		
Number participating	7/7	14	0/4/10	14

[a] NSF Definition of URM: Black or African American, Hispanic (may include Guyanese), Alaskan Natives, Native Americans, Native Hawaiians, and other Pacific Islanders.

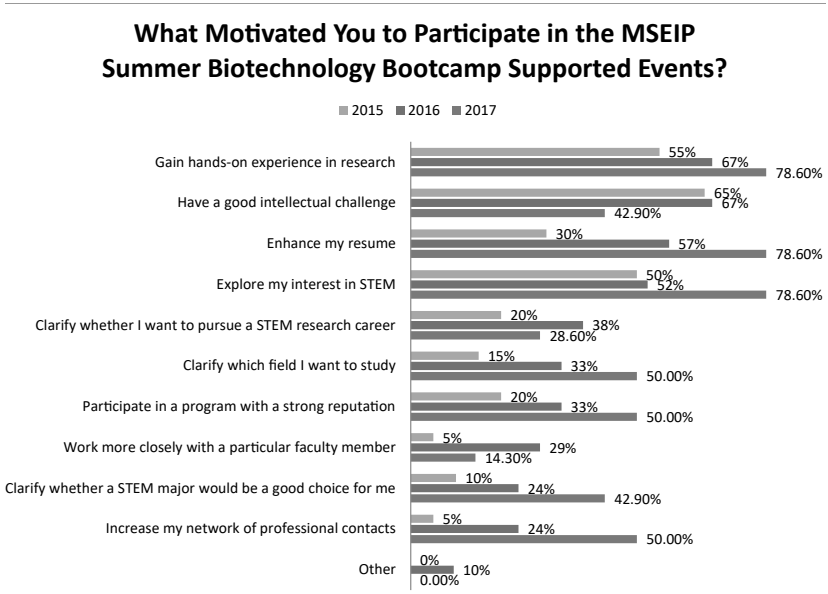
The boot camp was promoted in a variety of ways in order to encourage student participation (Figure 1). In the first year (2015), most participants indicated that another Project PRIZE program (40%) or teachers (50%) were the primary sources of their knowledge about the program. In 2016, students still primarily learned of the program through their teachers (29%), but also through friends (24%), HS academic advisors (24%), and flyers (19%); 2017 saw a similarly diverse means of awareness.

Figure 1. Ways student participants gained knowledge of the program. (Respondents could choose more than one option.)



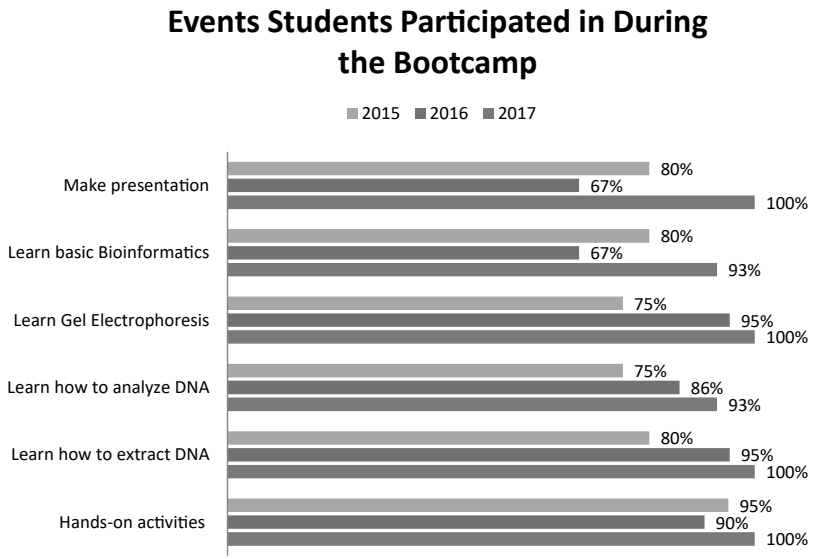
Students participating in the program registered for a number of reasons. The most common reason students identified was to "gain hands on experience in research," followed by "explore my interest in STEM," and have a "good intellectual challenge" (Figure 2). As the program continued, it grew in popularity: 50% of those enrolled in the second year indicated that it was a program with a strong reputation. The motivation to participate also increased over time as evidenced by the fact that the number of reasons that students selected as to why they registered for the program increased.

Figure 2. Percent of students indicating specific reasons for workshop registration. (Respondents could choose more than one option.)



Two important goals of the workshop were that all students participate to their fullest capacity and that they become empowered by the experience. At least two-thirds of the participants indicated that they contributed to or participated in each of the six aspects of the project (Figure 3), and the majority of the respondents strongly agreed with statements regarding their interest and desire to stay in STEM. When asked if they felt satisfied with the way the boot camp was conducted, students rated the experience 4.56 out of 5 over the three years analyzed (see Table 3). Most of the statements received at least a 4.0; however, three fell slightly below. Not surprisingly, because of their age and level of experience, participants expressed the least confidence in having "clarified which STEM field I would like to study" (3.74) through their participation in the boot camp.

Figure 3. Percentage of students active in the six aspects of the workshop.



All three years also demonstrated an increase in STEM interest at the end of the boot camp. The mean STEM interest composite scores increased from 3.0, 4.2, and 3.3 before the boot camp to 3.28, 4.45, and 3.67 after the boot camp for 2015, 2016, and 2017, respectively (Table 4). Students also felt more comfortable with STEM; the mean Science Self-Concept scores increased from 3.22, 3.94, and 3.28 to 3.41, 4.15, and 3.67 for 2015, 2016, and 2017, respectively (see Table 4).

Discussion

In order for our country to have a diverse community of STEM employees, students need to be exposed to science at an early age. Over the course of three summers, the MSEIP Biotechnology Summer Boot Camp was successful in recruiting 55 students, predominantly from minority populations, and exposing them to an interactive experience dealing with a modern-day biotechnology issue that impacts their daily lives. Our biggest struggle was getting students to register and commit to the project. We recommend working with a program already established on campus similar to Project Prize to help with the recruitment. Given the at-risk student population, the major issues we faced in continued student participation in the program were instances where students were required to attend summer school due to failed classes, or were financially mandated to find work or needed to babysit younger siblings or help with elderly

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Table 3. *Results of Participant Satisfaction Survey After the Boot Camp.*

Statement	2015		2016		2017		
	No. of Responses	Mean (SD)	No. of Responses	Mean (SD)	No. of Responses	Mean (SD)	Overall Mean
I feel satisfied with the way in which the MSEIP Summer Biotechnology Boot Camp events were conducted.	20	4.7 (0.6)	21	4.3 (0.6)	14	4.7 (0.5)	4.6
The MSEIP Summer Biotechnology Boot Camp event(s) met my expectations.	20	4.2 (1.1)	21	4.3 (0.6)	14	4.6 (0.6)	4.3
I found the MSEIP Summer Biotechnology Boot Camp event(s) to be worth my time and effort.	20	4.5 (1.0)	20	4.2 (0.9)	14	4.6 (0.6)	4.4
The MSEIP Summer Biotechnology Boot Camp event(s) encouraged me to meet with staff, faculty, or others about my STEM interest and education.	20	3.9 (1.2)	21	4.2 (0.9)	14	4.4 (0.8)	4.1
The MSEIP Summer Biotechnology Boot Camp event(s) encouraged me to get involved with activities and organizations related to my STEM interest.	20	4.1 (1.3)	21	4.3 (0.9)	14	4.4 (1.1)	4.2
The MSEIP Summer Biotechnology Boot Camp event(s) faculty and staff provided me with feedback about my academic work.	20	NA	21	4.1 (0.7)	14	4.4 (0.6)	4.2
The MSEIP Summer Biotechnology Boot Camp event(s) faculty and staff believed in my potential to succeed as a scientist.	20	NA	21	4.1 (0.8)	14	4.2 (0.8)	4.2
The MSEIP Summer Biotechnology Boot Camp event(s) faculty and staff recognized my achievements in STEM education.	20	4.0 (1.0)	21	4.1 (0.8)	14	4.2 (0.7)	4.1

The MSEIP Summer Biotechnology Boot Camp event(s) clarified which STEM field I want to study.	20	3.4 (1.4)	21	4.2 (0.8)	14	3.6 (1.0)	3.7
The MSEIP Summer Biotechnology Boot Camp event(s) clarified whether a STEM major is a good choice for me.	20	3.6 (1.2)	21	4.4 (0.7)	14	4.2 (0.9)	4.1
The MSEIP Summer Biotechnology Boot Camp event(s) clarified whether I want to pursue a science research career.	20	3.6 (1.4)	21	4.2 (0.9)	14	4.0 (1.1)	3.9
The MSEIP Summer Biotechnology Boot Camp event(s) increased my network of professional STEM contacts.	20	3.7 (1.4)	21	3.9 (1.0)	14	4.1 (0.9)	3.9
The MSEIP Summer Biotechnology Boot Camp event(s) empowered me to learn more.	20	NA	21	4.5 (0.6)	14	4.7 (0.6)	4.6
The MSEIP Summer Biotechnology Boot Camp event(s) encouraged me to get involved with other groups and activities.	20	NA	20	4.1 (1.0)	14	4.5 (1.0)	4.2
The MSEIP Summer Biotechnology Boot Camp faculty and staff showed concern about my interest.	20	NA	21	4.3 (0.8)	13	4.5 (0.8)	4.4
Composite Average		3.6		4.2		4.34	

Note. Students Responded to Each Statement on a 1- (Strongly Disagree) to 5- (Strongly Agree) Point Scale.

Table 4. *STEM Interest and Science Self-Concept Scores Before and After the Boot Camp Experience*

	2015				2016				2017			
	Before the events		After the events		Before the events		After the events		Before the events		After the events	
STEM Interest Statements	Number of Responses	Mean (SD)	Number of Responses	Mean (SD)	Number of Responses	Mean (SD)	Number of Responses	Mean (SD)	Number of Responses	Mean (SD)	Number of Responses	Mean (SD)
I enjoy talking about science and/or math with others.	19	3.4 (1.3)	20	3.5 (1.3)	21	4.5 (0.7)	19	4.6 (0.5)	14	3.6 (0.7)	13	3.7 (0.9)
I am interested in pursuing a career in science, technology, engineering, or math (STEM).	19	3.1 (1.5)	19	3.0 (1.6)	21	4.3 (0.9)	19	4.5 (0.7)	14	3.1 (1.3)	13	4.1 (0.9)
I am interested in the way science and engineering help people.	19	3.0 (1.5)	20	3.5 (1.6)	21	4.2 (0.6)	19	4.5 (0.6)	14	3.6 (1.0)	13	4.0 (0.9)
I am interested in helping others use science.	19	3.2 (1.5)	20	3.4 (1.5)	21	4.1 (0.7)	19	4.4 (0.7)	14	3.1 (1.0)	13	3.8 (1.0)
I am interested in reading websites, articles, magazines or books about scientific issues.	19	2.9 (1.2)	20	3.4 (1.5)	21	4.1 (0.9)	19	4.3 (0.8)	14	3.1 (0.7)	13	3.2 (1.0)
STEM Interest Composite Score	**19**	**3.0**	**20**	**3.3**	**21**	**4.2**	**19**	**4.5**	**14**	**3.3**	**13**	**3.7**

Science Self-Concept Statements												
I have a lot of pride in my accomplishments in science and/or math.	19	3.7 (1.3)	19	4.0 (1.2)	21	4.2 (0.7)	19	4.7 (0.5)	14	3.6 (0.9)	13	4.0 (1.1)
I see myself as a science and/or math person.	19	2.6 (1.3)	19	2.9 (1.4)	21	4.2 (0.9)	19	4.4 (0.8)	14	3.1 (1.2)	13	3.5 (1.2)
I am a very good science and/or math student.	19	3.3 (1.5)	19	3.5 (1.4)	21	4.1 (0.8)	19	4.3 (0.8)	14	3.4 (1.1)	13	3.8 (0.7)
My former teachers think of me as a science or math person.	NA	NA	NA	NA	21	4.0 (1.0)	19	4.1 (1.0)	14	3.4 (1.4)	13	3.6 (1.1)
My friends think of me as a science or math person.	NA	NA	NA	NA	21	3.9 (1.1)	19	4.3 (0.8)	14	3.4 (1.3)	13	3.7 (1.2)
My family thinks of me a as a science or math person.	NA	NA	NA	NA	21	3.9 (1.2)	19	4.1 (1.0)	14	3.1 (1.1)	13	3.4 (1.1)
I am active in organizations or groups related to science, technology, engineering, or math (STEM).	18	3.1 (1.5)	20	3.2 (1.4)	21	3.8 (1.1)	19	4.0 (1.0)	14	3.2 (1.0)	13	3.6 (0.8)
When I think of scientists, mathematicians, or engineers, I think they are a lot like me.	NA	NA	NA	NA	21	3.7 (0.8)	19	3.7 (0.5)	14	3.1 (0.8)	13	3.8 (1.1)
When it comes to scientific knowledge and understanding, I can compete at the highest levels.	19	3.3 (1.4)	19	3.5 (1.3)	21	3.7 (0.8)	19	3.9 (0.9)	14	3.2 (1.0)	13	3.8 (0.7)
Science Self-Concept Composite Score	**19**	**3.2**	**19**	**3.4**	**21**	**4.0**	**19**	**4.2**	**14**	**3.3**	**13**	**3.7**

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grandparents. Furthermore, Project Prize counselors had to expend a lot of effort to obtain signed permission slips from parents. To overcome this, in year 3 we enrolled 24 students (over the 20-student capacity) to have backup when students inevitably withdrew from the program. (However, only 14 students completed the program that year.) We are considering changing our population of students and/or the location of the experience to better ensure capacity utilization. It is possible that targeting students already interested in STEM could lead to a greater retention of registrants. Targeting a younger audience (middle school students) could potentially increase retention but brings new obstacles such as a lack of maturity and care using expensive equipment as well as a difficulty in obtaining permission for students to travel to a college campus. Bringing the workshop to the students' school could also help but would remove student exposure to college campus life.

The reasons we chose the Edvotek® project were: (a) the kits are modestly priced, (b) most college labs are outfitted with the basic molecular biology equipment required for this project, and (c) the project can be replicated in other settings. The experiment is reliable in producing results and is used in college-level biotechnology courses. We divided the project into hands-on modules that were further informed by lecture presentations. We found that the project is doable within a week without rushing while providing ample time for students to reflect. During the morning session, students learned a variety of scientific techniques including pipetting, DNA extraction, PCR and gel electrophoresis. After lunch, the second half of the day was used for content reflection to reinforce the techniques learned in the morning and to prepare their final presentations. Students had ownership of the project because they chose which food samples they wanted to analyze from their own homes; because they brought food from their own kitchens, students were instantly engaged. Finally, because diverse foods are tested, this allows students to think scientifically and hypothesize which foods would show evidence of genetic modification.

The final presentations were extraordinary, and our faculty were impressed by the students' knowledge and use of scientific language. Some students even invited their families to attend the final day of the workshop. The students were comfortable using complex, scientific terminology due to the repetition (introductory lecture, hands on, preparing their PowerPoint) and reinforcement of concepts. Students were proud of their work, which is reflected in their self-concept scores and general feeling toward STEM activities and coursework (Table 4). This pride will carry

over to their everyday lives and will hopefully improve their confidence when they are exposed to unfamiliar tasks and new challenges.

This experience increased students' confidence and knowledge of STEM. In all three years, students reported a higher STEM interest composite score after their involvement in the boot camp (Table 4). Additionally, whether participants were initially interested in STEM or not (2015 had the lowest score (2.6) and 2016 had the highest (4.2)), the overall science self-concept score also increased. In fact, in all three years, all nine categories (Table 4) showed an increase, including pride and confidence in science/math accomplishments, and competition and feelings that their friends, family, and teachers would recognize them as "science people."

Students also responded to open-ended questions in the survey. Many students indicated that the hands-on activities were their favorite part of the experience. One student replied, "I enjoyed learning about GMOs and extracting DNA, but performing the actual steps is what engaged me the most." Another participant "really enjoyed learning how to use the pipette." The majority of students were satisfied with the experience. When asked what they would do to change or improve the boot camp, very few students suggested anything. Those who did answer suggested that we change the length of the program or add additional work. For example, one student said they would like to "make the program a bit longer so you could learn more."

Overall we were successful in opening the minds of our participants towards pursuing a degree in a STEM field while providing a mentoring experience for college students. Students found the project interesting and greatly benefited from the hands-on experience. In 2016 and 2017, several participants identified as siblings, cousins or friends of past students, indicating that participants felt the program worthwhile enough to recommend to others. All of our 2015 participants have graduated HS and are potentially enrolled in college. Six have enrolled at QCC; however, we have been unable to contact. We were able to contact 17 out of the 21 participants from 2016. Sixteen of the contacted students graduated high school in 2018, and three of these 2016 participants are currently enrolled at QCC. Thirteen of the 14 students who participated in year 3 are now scheduled to graduate. Several participants have reached out for letters of recommendation/support for employment and college admission applications. One student from the 2016 cohort even enrolled in one of the boot camp instructor's biology courses at QCC, where she excelled. This student is currently applying to a summer research program. All six

QCC student mentors have graduated and are either currently pursuing their bachelor's degree at CUNY senior colleges or pursuing graduate degrees in STEM. All have been able to include this experience on their CVs or use this opportunity as a topic of discussion in interviews.

We feel that the biotechnology boot camp experience served at-risk, underprivileged students in our community quite well. We were uncertain how well this project would fair due to the initial struggle regarding recruitment. However, once the students were on campus, the biggest complaint was that they wanted to stay longer and learn more. At the end of the project, there was an amazing sense of accomplishment for both the students and their parents. To see most of these at-risk students apply to and get accepted into CUNY and SUNY colleges was extremely gratifying and made all the effort worthwhile. Some of them are in our Queensborough classrooms right now. The sense of student accomplishment carries over to the faculty as we write to renew the grant and seek institutional funding to keep the program on campus.

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