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Board 302: Implementation of an Equitable and Inclusive After-school STEM Program

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Implementation of an Equitable and Inclusive After-school STEM Program

Abstract

The SUPERCHARGE project (STEM-based University Pathway Encouraging Relationships with Chicago-area High schools in Automation, Robotics, and Green Energy) is an after-school STEM program at four high schools in the Chicago Public Schools (CPS) district. The project is aimed at addressing the underrepresentation of Black, Latinx, and low-income students in STEM fields. Through hands-on activities, workshops, teacher professional development, and campus visits, the program aims to foster students' STEM identities and awareness of postsecondary pathways, particularly in the areas of renewable energy, robotics, and technology. The program has recently completed its first year of implementation in the high schools. The purpose of this article is to report on the first year of implementation, including challenges and lessons learned. Initial assessments indicate positive student engagement and satisfaction. Lessons learned from the first year include the importance of early program initiation, community relevance, and immersive hands-on activities. Future iterations will aim to further enhance student engagement and broaden participation in STEM fields, contributing to greater diversity and inclusion in the STEM workforce.

I. Introduction

There is a booming need for professionals in STEM fields in the United States. Employment in STEM fields grew by 10.5% between 2009 and 2015, compared with only 5.2% for non-STEM occupations [1]. This rapid job growth is especially pronounced in the clean energy industry, which added jobs 70% faster than the overall economy from 2015-2019 and now employs 2.25% of all workers in the US [2]. However, not all segments of the US population are earning STEM college degrees at the same rate. While Hispanic, Black, and American Indian or Alaska Native persons collectively account for 37% of the US population between ages 18–34 as of 2021, the same group accounts for only 26% of science and engineering-related bachelor's degrees and 24% of science and engineering master's degrees earned by US citizens and permanent residents [3].

In an attempt to make incremental progress toward reducing this disparity, an interdisciplinary team of faculty, staff, and students at Illinois State University is collaborating with teachers at four high schools in the Chicago Public Schools district and four non-profit Community-Based Organizations (CBOs) in the surrounding communities to create an after-school STEM program known as SUPERCHARGE: STEM-based University Pathway Encouraging Relationships with Chicago-area High schools in Automation, Robotics, and Green Energy. The objective of the after-school program is to increase the number of students from underrepresented groups who choose to pursue STEM fields at the postsecondary level. The program is guided by the framework of the National Research Council's STEM Learning Ecosystem Model [4], with the goal of creating a network of connected groups that support and encourage the students' interest in STEM topics.

The four goals of the program are:

1. SUPERCHARGE Scholars (high school student participants) will increase their knowledge of STEM domains and careers; specifically, those related to renewable and sustainable energy systems, robotics, and technology. Simultaneously, they will increase their understanding of the secondary and post-secondary pathways that lead to attainment of STEM careers.
2. SUPERCHARGE Scholars will increase their interest toward STEM careers and will demonstrate improved self-efficacy for career-related skills and for attainment of STEM careers.
3. SUPERCHARGE Designers (undergraduate STEM-related majors at the university) will increase their awareness of "societal and contextual factors [that] constrain the opportunities for students from underrepresented groups to develop identities as STEM learners and professionals, and to participate in activities that can stimulate those interests and identities." [5]
4. SUPERCHARGE Teachers (school-based teachers in after-school programming) will increase their knowledge of STEM domains and careers and will improve their knowledge of resources for students who are interested in pathways to STEM careers.

The goals of the program are being addressed through several types of newly created programming and infrastructure. First, the high school students meet after school once per week for approximately ninety minutes to perform engaging hands-on activities that are designed by the undergraduate students under the guidance of faculty at Illinois State University. Second, the undergraduate students are paid to spend up to 10 hours per week designing new after-school STEM activities related to automation, robotics, and renewable energy for the following school year. Undergraduate students meet with the faculty team once per week to discuss progress. The involvement of STEM undergraduates who are on STEM career pathways at the time of their participation also serves to develop the awareness of STEM professionals of the issues around access to STEM professions among underrepresented groups. Developing awareness among STEM professionals of the need for supporting greater diversity in, and access to, STEM careers is an important part of creating career pathways. Third, the team organizes a series of workshops, both for high school students and teachers. The purpose of the high school student workshops is to connect the students with a network of mentors at the postsecondary level, to help them develop a STEM identity [6], and to help them visualize themselves pursuing a postsecondary education in a STEM field. The workshops with high school students are held once per semester and an additional two days during the summer. The purpose of the professional development workshops with the teachers is to familiarize them with emerging careers in STEM fields, allow them to learn more about the breadth of postsecondary STEM career pathways available to their students, and to familiarize the teachers with the activities that will be performed by their students in the upcoming year. Furthermore, the workshops exist to develop a community of mentors that will collaboratively support the development of the high school students' STEM interests, as described by the STEM Learning Ecosystem Model [4]. Teacher professional development workshops are held each summer for 1-2 days with continuing education credits provided.

This project aims to excite students about career opportunities in the STEM workforce and within the clean energy field, in particular. To do this, students are given design challenges that mirror real-world problems, and a portion of each of the workshops are devoted to a discussion about how the subject material relates to real-world challenges faced by scientists and engineers. The project also incorporates the digital and physical skills needed to prepare students for success in the so-called “4th Industrial Revolution” [7]. A portion of the high school student summer workshop (the first one of which will be held in summer 2024) will be devoted to an exploration of STEM pathways and career fields. This will be accomplished with field trips, tours, and guest speakers from STEM partners located within the students’ own communities.

The SUPERCHARGE project is currently in the midst of the first year of implementation in the four partnering high schools. The purpose of this article is to serve as an update to the progress that has been achieved on the project thus far and provide lessons learned and next steps.

II. Student Demographics

The four partnering high schools consist predominantly of Black and/or Latinx students, two groups that are largely underrepresented in STEM careers and post-secondary programs. In addition, the high schools and surrounding neighborhoods have high numbers of low-income students. These factors speak to the potential impact that the project will have in broadening the diversity of students pursuing post-secondary education and subsequent careers in STEM fields. A summary of the partnering schools’ demographics is given in Table 1.

Table 1. Demographics of partnering high schools

School	Farragut HS	Roosevelt HS	Simeon HS	Westinghouse HS	CPS District	State of Illinois
Enrollment / Attendance	651 / 85%	954 / 89%	1338 / 88%	1203 / 93%	363,954 / 93%	1,984,519 / 94%
School Demographics	86.2% Hispanic, 12.9% Black, 8.2% Asian, 0.8% White, 0.2% Two or more races	70.4% Hispanic, 12.8% Black, 8.2% Asian, 5.8% White, 1.3% Pacific Islander, 1% American Indian, 0.5% Two or more races	1% Hispanic, 98.6% Black, 8.2% Asian, 0.1% Pacific Islander, 0.3% Two or more races	39.4% Hispanic, 52.8% Black, 4.7% Asian, 2% White, 1.1% Two or more races	46.6% Hispanic, 36.6% Black, 4.1% Asian, 10.5% White, 0.2% Pacific Islander, 0.3% American Indian, 1.6% Two or more races	26.4% Hispanic, 16.7% Black, 5.1% Asian, 47.6% White, 0.1% Pacific Islander, 0.3% American Indian, 3.8% Two or more races
Low Income	97.4%	94.0%	88.6%	77.0%	77.9%	48.8%
English Language Learners	28.4%	34.1%	0.1%	3.0%	19.4%	12.1%
Graduation Rate	57%	70%	92%	94%	77%	86%
Post-Secondary Enrollment in 12 months	48%	60%	68%	87%	68%	73%
Science Proficient / Not Proficient (State Science Assessment)	4% / 94%	6% / 89%	0% / 95%	16% / 81%	34% / 65%	49% / 51%
SAT Math (% meeting standards)	6%	8%	3%	41%	27%	35%

III. Project Implementation

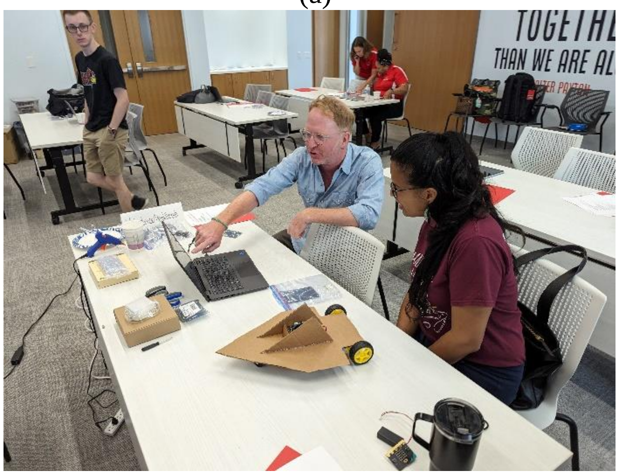
The informal curriculum for the first year of the program was developed by a team of five undergraduate students and refined by an interdisciplinary team of four faculty from Illinois State University during the 2022-2023 academic year. Periodically throughout the year, curriculum modules were sent to participating high school teachers for their feedback. Revisions to the curriculum were made in an iterative development process. During the summer of 2023, the team held two one-day professional development workshops for partnering teachers. Each workshop was held in-person at one of the partnering organizations. Professional development credits (CPDUs) were provided. Both teachers and representatives from the partnering Community-Based Organizations in the communities surrounding the schools attended the workshops. The workshops served as an introduction to the team and an orientation to the activities that their students would perform in the after-school program during the 2023-2024 school year.

The professional development workshops for teachers in the summer of 2023 were split into two one-day workshops. The first one-day workshop was held in June approximately one week after the school year ended. It was held at one of the partnering high schools. This workshop served to introduce teachers to the program and each other, and provided an orientation to the micro:bit device and the first two units of the year. The second workshop was held in August approximately one week before the school year began. This workshop was held at the office of one of the Community-Based Organization partners in a different part of the city. This workshop re-acquainted the teachers and CBO representatives with the program and oriented the teachers to the second two units of the year. Figure 1 shows several images taken from the August workshop.

In August and September 2023, team members worked together to recruit students to the after-school program during the first three weeks of the school year. A variety of recruitment tools were used including posters hung around the school (in both English and Spanish languages depending on the school), verbal advertising on the school's announcements, visual advertising with promotional slides on scrolling screens around the school, and announcements and word-of-mouth communication from the teachers to their students. The groups of high school students at each high school began meeting in approximately the fourth week of the school year. The clubs met once per week for approximately 90 minutes per session. They are mentored by a team of two to three teachers at each school.

The weekly activities that were developed by undergraduate students and faculty for the 2023-2024 school year are divided into four units. Students complete one activity per week, and approximately two units per semester. Students access the activity guides (instructions with pictures) through the program's website. Because the program website is publicly available, the activities could be scaled up and replicated at other schools, funding permitting. Most of the activities are relatively inexpensive (<$50 for a pair of students working together), however, some of the activities (e.g. weather station kits and IR cameras) are considerably more expensive. The outline of activities for the 2023-24 school year is:

(a) (b)



(c) (d)

Figure 1. (a,b) workshop leaders discussing the micro:bit remote-control car design challenge and the micro:bit weather station design challenge, and (c,d) workshop participants discussing how to construct and program their micro:bit remote-control car.

Unit 1: Turn Down the Heat

- 1.1 Introduction to SUPERCHARGE and First Micro:bit Challenge
- 1.2 Calculating Carbon Footprint
- 1.3 Hot & Cold: Using IR Tools to Measure Temperature in Your School
- 1.4 Investigating Thermal Properties of Materials
- 1.5 Community Connection-Green Infrastructure

Unit 2: Dragster Race

- 2.1 Party Lights
- 2.2 Battery Tester
- 2.3 Dragster Race Car Construction
- 2.4 Race Countdown Circuit
- 2.5 Dragster Race Track
- 2.6 Automatic Dragster Races
- 2.7 Remote Control Race Car

Unit 3: A Breath of Fresh Air

- 3.1 Introduction to Air Quality: Buildings to Communities
- 3.2 Kitronik Air Quality (AQ) Board Data Collection
- 3.3 Data Logging & Visualization
- 3.4 Neighborhood Air Quality & LED Visualizer Project
- 3.5 Community Connections-A Breath of Fresh Air

Unit 4: Smart Weather Station

- 4.1 Capturing Climate Data
- 4.2. Wireless Climate Monitoring Console
- 4.3 Wind Speed and Direction
- 4.4 Rain & Sun
- 4.5 Inside & Out
- 4.6 Extended Applications 1
- 4.7 Extended Applications 2

In mid-October, the high school students were taken on a full-day campus visit to Illinois State University for the first student workshop of the program. The purpose of the campus visit was to promote the development of the students' STEM identities by encouraging them to participate in activities typical of a college student studying in a STEM field. Simultaneously, the workshop included a session at the university's Admissions office to help guide them through the process of applying to college. Images of the campus visit are shown in Figure 2, and an agenda for the campus visit is given in Table 2. The reactions from the students and teachers during this visit were overwhelmingly positive. The students were enthusiastic and engaged in the activities. They asked insightful questions and appeared excited to participate. Feedback from the teachers was very positive as well. Several of them noted how much fun their students were having, and one teacher said (unprompted) he thought many of his students would apply to study STEM at the university.

There are several upcoming workshops in the near future. In April 2024, students will participate in an after-school workshop. At this workshop, students will participate in hands-on extension activities related to the activities that they are doing in the program, and engage with guest speakers who are currently working in fields related to STEM, including environmental engineers and renewable energy project developers. Guest speakers are drawn from the same communities that the students live and attend school in.

In the summer of 2024, the project team will hold a two-day student workshop and a one-day teacher professional development workshop. At the student workshop, students will use the design projects that they built during the year to collect data and extend their knowledge to other situations. They will also go on field trips to visit people in their community who are working in STEM fields. At the teacher professional development workshop, teachers will be introduced to the activities for the 2024-2025 school year, which will include solar energy, electric motors, and the design and construction of a dual-axis solar tracking system.

(a) (b) (c) (d)

Figure 2. (a) Students building solar-powered cars, (b) students racing their solar-powered cars against each other, (c) students learning about robots in the Integrated Manufacturing Lab, and (d) students learning about the university admissions process from the Admissions Office.

Table 2. Agenda for high school students’ October 2023 on-campus visit

Varies	Bus pick-up at each high school and travel to ISU campus
9:45 – 10:15	Arrival and Welcome at Student Center
10:15	Campus Tour en route to Technology Department Building
10:30 – 11:15	Split into two groups: Robotics Lab Activity / Renewable Energy Lab Activity
11:15 – 11:30	Groups switch / transition to other lab
11:30 – 12:15	Renewable Energy Lab Activity / Robotics Lab Activity
12:15	Walk to Dining Center
12:30 – 1:15	Lunch at Dining Center
1:15 – 1:30	Return to Technology Department Building
1:30 – 2:00	Guest Speaker from Rivian (EV manufacturer)
2:00 – 2:15	Campus Tour en route to Admissions Office
2:15 – 2:45	Admissions Office presentation
3:00	Bus pick-up at ISU, travel, and drop-off at each high school

IV. Assessment

Project assessment is performed in several ways. Rudimentary assessment of individual activities is accomplished by asking the students to complete a short survey embedded at the end of each activity. Broad-based program assessment is performed using interviews of the undergraduate students and the high school teachers, and through the use of the PEAR Common Instrument Suite (PEAR-CIS) survey taken by both high school teachers and high school students. The interviews and PEAR-CIS surveys occur twice per year: once at the beginning of the school year, and again at the end of the school year. Because the project is currently in its first year of implementation, the team has not yet collected a full set of before-and-after data.

The survey embedded at the end of each activity consists of two questions, as shown in Figure 3. In the first question, students are asked "How did you feel about this activity?" In response, students move the vertical slider up or down to change the emoji's face to match their feelings on the activity. Moving the slider up transforms the face into a smiling face, indicating that they felt positively about the activity. Moving the slider down changes the face into a frowning face to indicate that they felt negatively about the activity. The slider has five positions, turning the question into a 5-point Likert scale question about the students' feelings about each week's activity. The range of emoji faces is shown in Figure 4.

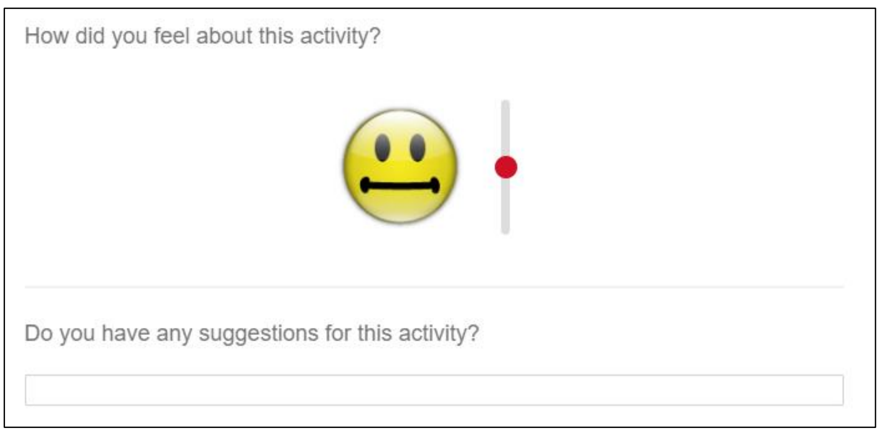
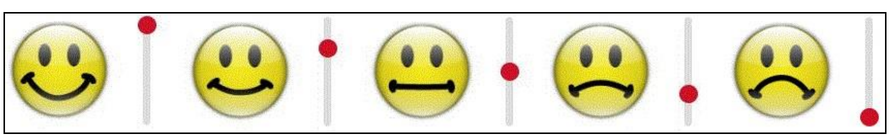


Figure 3. Two-question survey that student participants are asked to complete after every weekly activity



a. Feeling=5 b. Feeling =4 c. Feeling =3 d. Feeling =2 e. Feeling =1

Figure 4. Likert-scale adjustable faces that students use to show their feelings on the activity

Feedback survey results for the first unit of activities are provided below in Table 3 for Unit 1.1, Table 4 for Unit 1.2, Table 5 for Unit 1.4, and Table 6 for Unit 1.5. There were no surveys completed for Unit 1.3, likely because the activity instructed students to walk around the school surveying temperatures with an infrared camera and laser thermometer. Therefore, they were likely away from their computer and did not return to complete the survey.

Table 3. Survey question 1 for Unit 1.1: Introduction and first micro:bit challenge

Feeling value	Count
1	0
2	0
3	0
4	2
5	9

Table 4. Survey question 1 for Unit 1.2: Calculating your carbon footprint

Feeling value	Count
1	0
2	1
3	2
4	12
5	3

Table 5. Survey question 1 for Unit 1.4: Investigating thermal properties of materials

Feeling value	Count
1	0
2	0
3	2
4	1
5	5

Table 6. Survey question 1 for Unit 1.5: Community Connection – Green Infrastructure

Feeling value	Count
1	0
2	0
3	0
4	1
5	2

Although the survey results are generally positive, the use of the survey tool dropped off toward the latter part of Unit 1. The teachers have been asked to remind their students to complete the survey at the end of each activity.

V. Conclusions and Lessons Learned

The overarching purpose of the SUPERCHARGE project is to increase the population of underrepresented groups who choose to study STEM fields in college. By extension, the project seeks to improve equity and inclusiveness in STEM fields. To do this, we are implementing after-school programs at high schools that have large populations of underrepresented groups in STEM and providing STEM experiences to students from underrepresented groups in the field, which will hopefully propel them into STEM fields of study and careers. We are also seeking to make the program inclusive by making the program as specific to the students' communities as possible. For example, we are including non-profit Community-Based Organizations (CBOs) from the four communities in the project planning team and bringing local guest speakers to speak to the students. The final activity in each unit is a "Community Connections" week. This activity serves as a review of concepts and helps the students understand how the concepts are relevant for their particular community.

As the project nears the end of the first year of implementation in high schools, several lessons have emerged. We plan to use these lessons to improve the project in future years.

1. In summer 2023 we held two one-day teacher professional development workshops: one in June and one in August. While this spread-out format is appealing and has advantages, we found that it was much more challenging to schedule teacher PD workshops in August than in June. As a whole, the teachers in the project have significantly more availability and flexibility after the school year ends in June than before the school year begins in August. There were numerous schedule conflicts in August. For example, the Computer Science teachers in the program were unable to attend the August workshop due to an all-district Computer Science mandatory professional development. We selected a date in August when at least one teacher from each school could attend, and asked attendees to share their knowledge with their colleague(s) who could not attend. In the future, we hope to avoid these conflicts by holding workshops shortly after school ends in June whenever possible.

2. The travel time from most of the high schools to the Illinois State University campus is approximately two hours, so it was difficult to predict how many high school students would participate in the October on-campus visit. We rented one 55-person bus for the day. Forty-seven students, six teachers and one university employee rode the bus to campus, nearly filling the bus to capacity (54 of 55 seats occupied). We are very pleased with the attendance at the on-campus visit. For the second year of the program, we hope to fill two buses for the visit.

3. Despite our best recruitment efforts, the program did not gain traction with students at one of the four high schools. At this school, there were a small number of students who attended the after-school program at the beginning of the school year, but over the fall semester the attendance dwindled to zero. The project team tried several strategies to boost the after-school program attendance. A short description of the program was read on the school's verbal announcements, and a recruitment slide was posted on the school's visual announcements that scroll on monitors inside the school. The partner teachers at the school talked about the program in their classes. The project team made posters about the program in both English and Spanish languages, and the teachers hung them up at the school (this particular school is mostly English-speaking so the teachers used the English posters). Several members of the project team from the university and the Community-Based Organization made visits to the school to talk to teachers and students about the program. The project team also discussed the program with the Science department chair at the school and provided recruitment materials directly to her, and she distributed them to her colleagues and students.

At the end of the fall 2023 semester, the project team made the difficult decision to move the program to a different high school located in the same community. The project team (including university and CBO representatives) are currently reaching out to two nearby high schools to gauge interest from STEM teachers in the schools. Both of the nearby schools have demographics very similar to the original partner school. Our intention is to identify two teachers at the new partner school to lead the program, and bring the teachers into the program over the spring and summer of 2024. The teachers at the school will attend the professional development workshops in the summer of 2024. Student recruitment efforts will begin in August 2024, and the after-school program will launch shortly thereafter.

The project team conducted an interview with one of the teachers at the original high school to learn more about why the program did not succeed at this school. The teacher made several observations, including:

i. Retention was an issue: he was able to get students to show up once or twice but could not get them to keep showing up. This had a snowball effect because other students were not interested in attending unless their friends were already attending.
ii. He recommended getting the club started as early as possible in the school year so that the club becomes part of the students' weekly routine.
iii. On a broader question related to the best ways to help students build STEM identities, the teacher said that focusing on future careers and life paths opened by study in STEM is the best path to cultivating interest in the subject.

As program designers, we can take away several lessons from this conversation. As we are simultaneously developing activities for the second year of the program, we will try to boost program retention by redoubling our efforts to make the weekly activities as engaging, interactive, and fun as possible. However, inconsistent program attendance presents a challenge for program designers. To remain interesting and build competence, the weekly activities should build on previous activities, which is challenging if students attend inconsistently. As the project team designs the second year of activities, we will seek to strike a balance between challenging the students who attend each week with "stackable" activities that build on one another, and instructions that are clear enough that students should be able to perform the activities with no prior background. This could be accomplished with optional "extension" activities that are added to the end of the standard activity.

The program team recognizes the need to start the program as early as possible in the school year and tie the program's activities to careers and life paths. The first-year activities were designed with these concepts in mind, but we will refine the program to focus even more on these areas in future years of the project.

4. The program is designed so that the weekly activities for year n of the after-school program are designed by the team of undergraduate students and faculty in year $n-1$. Managing this year of planning while also supporting the implementation of the current-year activities in the schools is challenging but critically important. There is often a temptation to dive too deeply into the planning and design of a particular activity or set of

activities and spend too much time on the planning and design of a single week's activity. This typically leads to activity instructions that are too dense, and it also compresses the planning timeline for subsequent activities. The team must remind itself that while quality and clarity of the activity instructions are extremely important, sometimes less is more. After the essentials of a concept are covered, it is important to leave room for students to explore and discover. This is a delicate balance, and it is learned by experience.

The first year of implementation of the SUPERCHARGE program has not been without challenges. Nevertheless, the team feels that the first year of implementation of the project has been a significant success. In the next step for the program, we look forward to working with the teachers and high school students to improve the program and make subsequent years of the program even more beneficial. In future work, the project team anticipates analyzing the feedback data collected during this first year of implementation to draw conclusions about the most effective methods of engaging high school students in STEM activities and fostering the growth of the students' STEM identities. By providing positive experiences with STEM, exposure to STEM careers, and the formation of a supportive STEM network in their community, we hope that many of these students choose to study STEM fields in college and ultimately pursue career pathways in STEM fields. This would provide an incremental step toward reducing the current level of underrepresentation in STEM fields.

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