# Evaluation of a Hybrid Algebra-for-Engineering Program: Identifying Strengths, Challenges, Lessons Learned and "Fit" in an Urban Education Landscape (Evaluation, Diversity)

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## Abstract

Algebra proficiency is a major obstacle to student participation and success in STEM in U.S. high schools particularly for minoritized low-income youth. Moreover, algebra is a key lever to promoting rich postsecondary opportunities. To address limited algebra proficiency in one urban school district, a mid-Atlantic university outreach center developed a strategy of extended learning time for ninth to eleventh graders and received funding from the NSF (DRL-2005790).

The program's curriculum entails online learning with math/algebra (reinforcement) lessons contextualized within engineering challenges (i.e., "missions"). Ten missions were originally developed with input from stakeholders and students though only six were tested. Each mission includes four sections: an 'intro' session; a 'play' session in which students experiment with materials; a 'learn' session in which students review and practice relevant algebra standards; and a 'build' component, in which students build a design using algebra skills. Example mission topics are technical rescue, machine learning, soundproofing, business optimization, and urban heat islands. Moreover, ten role model videos feature predominantly minoritized professionals describing their work in engineering careers, how their interests developed, challenges they encountered, and how they persisted. The program also included two field trips to the sponsoring university to learn about college admissions and scholarships, tour an engineering design lab, and interact with undergraduate STEM students.

Data were passively collected from students via the online learning management system (LMS) every year of implementation (2021-22, 2022-23, 2023-24). Data included time spent in the LMS and number of role model videos viewed. Additional data collected includes measures of student algebra proficiency (i.e., graded rubrics of student work) and pre-post survey instruments (measuring math self-efficacy, STEM interests, STEM outcome expectations, and STEM choice goals). Interviews with 25 students were collected using a semi-structured protocol to capture reasons for electing to participate, barriers to participation, and reactions to the role model videos and field trips. Finally, external evaluators characterized program implementation and identified accomplishments and lessons learned by interviewing Program Leadership and key members of the Operations and Content Development Teams.

This program was designed to be fully online; following the pandemic and responding to students' needs, the curriculum evolved from fully online (i.e., online instructor with individual take-home kits) in Year 1, to hybrid (i.e., in-person instructor weekly at school) in Years 2 and 3, to a hybrid for-credit elective class during the school day (i.e., in-person instructor twice a week, teacher of record guiding online learning three days) in Year 4. Iteratively, the curriculum was revised through data review, student feedback in participatory design sessions, and input from gamification experts.

Strengths of the program included teachers, leadership support, real-world applications, program flexibility, curriculum, and engaging field trips. Challenges included overall student engagement and retention and aspects of the curriculum. Lessons learned around 1) establishing the team, 2) developing research and evaluation approaches, 3) partnering with public school districts over time, and 4) utilizing technology in service of relationship-rich learning are discussed. The program holds promise to support access and inclusion efforts for underrepresented groups in STEM.

## I. INTRODUCTION

Algebra proficiency is a major obstacle to student participation and success in STEM in U.S. high schools, particularly for minoritized youth [1], [2], [3]. Moreover, algebra is a key lever to promoting rich postsecondary opportunities [4]. To address limited algebra proficiency in one urban school district, the Johns Hopkins University School of Engineering's outreach center and Baltimore City Public Schools' Office of Math Learning developed a strategy of extended learning time for ninth to eleventh graders and received funding from the NSF (DRL-2005790). Baltimore Online Algebra for Students in Technology (BOAST) provides opportunities to develop mastery and confidence in algebra through an applied problem-based curriculum framed by Social Cognitive Career Theory (SCCT) [5].

The program rationale rests upon prior research on extended learning time, evidence-based teaching practices, and career planning, particularly for minoritized urban youth. Multiple studies indicate that using expanded opportunities for algebra in high school is effective for bolstering math skills [6], [7], [8]. Particularly for students who have not mastered algebra skills, increased dosage improves algebra assessment scores in the short-term [6], as well as long-term effects such as higher number of credits earned in high school, higher probability of graduation, and a higher likelihood of college enrollment [7]. Out of school time (OST) programs have been shown to significantly improve student achievement [9]. For STEM-focused OST programs, participation is capable of both encouraging and maintaining STEM interests [10], a precursor to aspiring to a STEM career [11]. Research indicates that school-day opportunities for algebra remediation had a detrimental impact on higher-ability peers who would otherwise be advancing onto new skills [12]. Moreover, budding literature on the effectiveness of online programs pre-pandemic [13] indicated an innovative avenue for research and program development. Thus, the original conceptualization of BOAST in 2019 was as an asynchronous, fully online afterschool program.

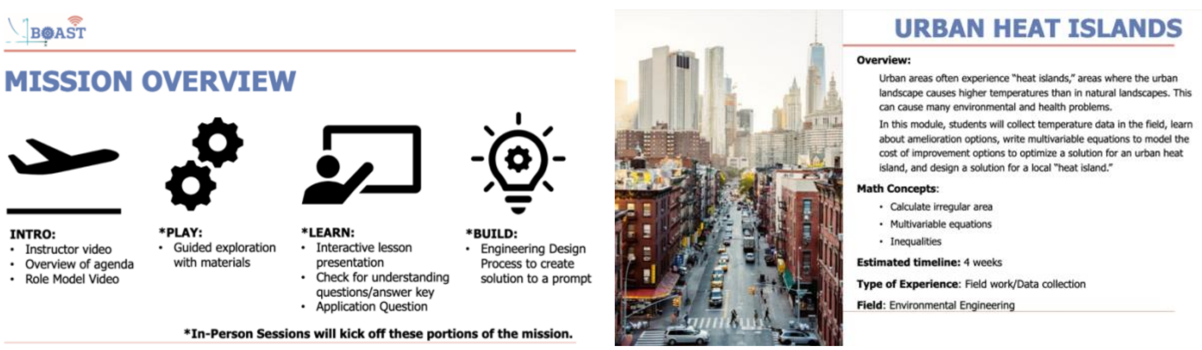
Instead of *more* math, the program developers aimed for *contextualized* math through an algebra-for-engineering, problem-based model. Culturally relevant teaching [14] is demonstrated to impact STEM self-efficacy, STEM identity, and STEM career aspirations [13], [15]. Applying math skills to culturally relative, cognitively demanding [16] tasks was intended to boost motivation, mathematics self-efficacy, and interest in STEM careers. Lastly, limited visibility of minoritized STEM role models appears to limit minoritized students' ability to envision themselves in STEM fields and subsequent intentions to pursue STEM [17], [18], [19]. This constellation of literature informed the program components.

### *A. Program Components*

The program's curriculum entails hybrid learning with math/algebra (reinforcement) lessons contextualized within engineering challenges (i.e., "missions"). Ten missions were originally developed with input from stakeholders and students. Students accessed online learning via a learning management system (LMS). Each mission includes four sections: an ‘intro’ session; a ‘play’ session in which students experiment with materials; a ‘learn’ session in which students review and practice relevant algebra standards; and a ‘build’ component, in which students build a design using algebra skills, following the Engineering Design Process [20]. Example mission topics are technical rescue, machine learning, soundproofing, business optimization, and urban heat islands. The course was conceptualized as an Algebra I applications course; each mission integrated relevant Algebra I standards (refer to Appendix A) and built on the Engineering Design Process (Ask, Research, Imagine, Plan, Create, Test, Reflect, and Improve). Moreover, the course functioned as a survey course to engineering fields including environmental, electrical, computer, cyber security, industrial, mechanical, systems, and civil engineering.

**Figure 1**

*Engineering Design Process (left) & Example Mission (right)*




*Note*: Each mission launched with a storyline-driven, problem-based mission. Students then played with materials, practiced underlying Algebra I concepts through the LMS, and utilized these concepts in the build. For example, “Urban Heat Islands” provided opportunities to learn algebra standards and provided career exposure to environmental engineering.

Moreover, ten role model videos were created and integrated into the program. Role model videos featured predominantly minoritized professionals and students describing their work in engineering careers, how their interests developed, challenges they encountered, and how they persisted.

**Figure 2**

*Role Model Videos*


Instructors provided synchronous learning time and online office hours. Lastly, the program also included two field trips to the sponsoring university to learn about college admissions and scholarships, tour an engineering design lab, and interact with undergraduate STEM students. Students who completed most of the missions were eligible for letters of recommendation to utilize for college, internship, or work applications.

*B. Iterative Modifications to Program Components*

This program was designed to be fully online; following the pandemic and responding to students' needs (primarily "zoom fatigue"), the curriculum evolved from fully online (i.e., online instructor with individual take-home kits) in Year 1, to hybrid (i.e., in-person instructor weekly at students' schools) in Years 2 and 3, to a hybrid for-credit elective class during the school day (i.e., in-person instructor twice a week, teacher of record guiding online learning three days) in Year 4.[1] Iteratively, the core curriculum remained stable, yet the modality was revised through data review, student feedback in participatory design sessions, and input from gamification experts. Over the course of the project, different LMS platforms were adopted: Blackboard, Blackboard ultra, and Schoology.[2] Lastly, the full 10 missions proved to be too much content for October to May; the curriculum in Years 2 and 3 was reduced to six missions. Table 1 below captures these changes over time.

**Table 1**

*Timeline of BOAST Program Changes*

| Year | Modality | Staffing | Platform | Research | Note |
|---|---|---|---|---|---|
| Planning Year (2020-2021) | Online with take home kits | Online instructor & school coordinator | Blackboard | N/A | School closures due to COVID-19 pandemic |

[1] The Year 4 process and evaluation outcomes data are not reported on in this paper.
[2] The LMS service approved and contracted by the school district changed every year of the program.

| | | | | | |
|---|---|---|---|---|---|
| Year 1 (2021-2022) | Online with take home kits | Online instructor & school coordinator | Blackboard | QUANT (like-school pairs) => qual | Jan. 2022 schools re-open |
| Year 2 (2022-2023) | Hybrid with personal kits (stored at school) | In-person instructor for after school meet-ups (1 day/week) & school coordinator | Blackboard Ultra | QUANT (like-school pairs) => qual | |
| Year 3 (2023-2024) | Hybrid with classroom kits | In-person instructor for after school meet-ups (1 day/week) & school coordinator | Schoology | QUANT (like-school pairs) => qual | |
| Year 4 (2024-2025) - No Cost Extension | Hybrid with classroom kits | In-person instructor for school day elective math class (2 days/week) & teacher of record (5 days a week) | Schoology | QUANT (pre-post cohort) + QUAL | Students receive letter grade on transcript for class ("Project X") |

*Note:* In the No Cost Extension year (Year 5 of the grant), the yearlong curriculum was modified to a semester-long elective math class (90-minute time blocks). In Years 1-3, QUANT refers to emphasis on quantitative methodology in research design, using like-school pairs to approximate randomization, followed by qualitative design to elaborate upon quantitative findings. In Year 4, QUANT + QUAL design refers to equal weighting of methodologies; of note, no control group was utilized in this year.

*C. Eligibility and Recruitment*

Schools were recruited for a two-year commitment, with one school as treatment group and the other as control group (with roles flipping the subsequent year). Schools with minimal STEM pathway offerings were prioritized in recruitment. Interested students indicated their interest in participation by completing an online application. The only requirements for participation were having already completed Algebra I with a final report card grade of C- or better and being enrolled in a high school that had agreed to host the program.

The student body in 2021-2022 was majority Black/African American (75.7%) and Hispanic/Latino (14.2%), followed by White (7.5%), two or more races (1.3%), and Asian/Asian Pacific Islander (less than 1%), American Indian/Alaska Native (less than 1%), or Native Hawaiian/Other Pacific Islander (less than 1%) [21]. Notably, this mid-Atlantic school district is challenged by concentrated poverty. A third of youth come from families whose income is below the federal poverty level; 18% of families live in deep poverty, defined as incomes less than half the poverty level [22]. In many Baltimore City schools, 100% of students receive Free and Reduced Priced Meals [23]. The composition of the student body did not change drastically (i.e., more than 3%) in school years 2022-2023 or 2023-2024.

### *D. BOAST Teams: Research, Operations, and Leadership*

The BOAST teams included an Operations Team (comprised of a Program Administrator, Instructional Designer, and Instructional Coach/Curriculum Writer), Leadership Team (comprised of Principal Investigator and co-Investigators, with engineering, education, and mathematics content expertise) and Research Team (co-Investigator and graduate student). Moreover, to hold the team accountable, assist with challenges, and advise on sustainable program models, an Advisory Board comprised of STEM experts, mathematics educators from higher education, leadership from the school district's Mathematics Office, and STEM non-profit leaders met bi-annually. Lastly, external evaluators denoted progress and made recommendations in Years 1-4.

## II. METHODOLOGY

To thoroughly evaluate the program, the Research Team conducted outcome evaluation and external evaluators conducted process evaluation. The method and findings sections are organized by outcome and process evaluations.

### *A. Outcome Evaluation*

To study the programs' effects, a convergent parallel mixed methods research design[3] was employed based upon Lent and colleagues' Social Cognitive Career Theory [24]. The guiding research questions were:

- RQ1: What effect does program participation have on math proficiency, as indicated by mastery of the algebra I benchmark skills targeted?
- RQ2: What effect does BOAST have on students' math self-efficacy?
- RQ3: What effect does BOAST have on students' STEM choice goals?
- RQ4: What are the effects of math self-efficacy on change in STEM career goals?

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[3] Randomization of students and schools was infeasible, due to school leaders' ethical concerns about encouraging students to apply to the program without knowing ahead of time what participation would mean. Thus, analysis was performed to create like-school pairs to approximate random assignment, to reduce the potential for unobserved variable bias.

- RQ5: How do socio-environmental factors and perceptions influence participants' STEM interest and postsecondary goals?

Table 2 provides an overview of constructs and measures utilized:

**Table 2**

*Summary of Research Constructs and Measures*

| Construct | Operational Definition (Citations) | Measure |
|---|---|---|
| ***Socio-environmental Factors*** | | |
| Perceived STEM Course Quality | Student experiences in science and math courses, related to access, rigor, and enjoyment [25] | Qualitative interviews |
| Mentorship or Advising Opportunities | Identification of adults who provide emotional, psychosocial, and academic encouragement into STEM pathways [26] | Qualitative interviews |
| Family Support | Reported emotional or social support received by parents, siblings, cousins, etc. for career plans | Qualitative interviews |
| Peer Support | Peer relationships providing various types of reinforcement (including friendly competition, instrumental help, compassion, etc.) [27], [28] | Qualitative interviews |
| Mastery experiences (i.e., participation in BOAST) | Number of hours spent in missions; number of role model videos students viewed; attendance at field trips | Data collected passively via LMS; attendance captured via logs |
| ***Individual Factors*** | | |
| Math Self-Efficacy | One's belief about their capabilities to perform certain mathematical behaviors or tasks [29] | Math self-efficacy scale [30] (pre-post survey) |
| STEM Interest | Interest in pursuing a STEM career (specifically engineering subscale) | SIC-STEM Survey [31] (pre-post survey) & qualitative interviews |
| STEM Outcome Expectations | Personal beliefs about consequences of performing certain behaviors | SIC-STEM Survey [31] (pre-post survey) & qualitative interviews |

| | | |
|---|---|---|
| STEM Choice Goals | Focus on “wanting to do something” aligned to STEM activity or career; plans after high school | SIC-STEM Survey [31] (pre-post survey) & qualitative interviews |
| Barriers to participation in BOAST | Self-reported reasons why students did not fully participate in BOAST | Qualitative interviews [32] |
| Student satisfaction with BOAST | Self-reported engagement and satisfaction with missions, including analysis of activities, materials, videos, interactions with instructors and students | Micro-surveys collected within LMS at the end of each mission; Likert scale 1-4 and open-response |

Data were passively collected from students via the online learning management system (LMS) every year of implementation (2021-22, 2022-23, 2023-24). Data included time spent in the LMS and number of role model videos viewed. Additional data collected includes measures of student algebra proficiency (i.e., graded rubrics of student work) and pre-post survey instruments (measuring math self-efficacy, STEM interests, STEM outcome expectations, and STEM choice goals). Interviews with 25 students were collected using a semi-structured protocol, heavily adapted from an existing protocol [32], to capture reasons for electing to participate, barriers to participation, and reactions to the role model videos and field trips.

Quantitative analysis involved statistical bivariate comparisons and multivariate regression, estimating changes in mathematics self-efficacy, STEM career interests, outcome expectations, and choice goals. Qualitative data was analyzed with a deductive approach. The outcome evaluations for two program years (2021-2022 and 2022-2023) for participants ($n$ = 89) in ninth to eleventh grade were published [33], [34] and will be summarized below.

*B. Process Evaluation*

Process evaluation questions included the following components related to fidelity of implementation, using data collected formatively by the Operations Team.

**Table 3**

*Process Evaluation Indicator Matrix*

| **Process Evaluation Question and Related Component** | **Process Evaluation Indicator(s)** | **Data Source(s)** | **Data Collection Tool** | **Frequency** |
|---|---|---|---|---|
| Fidelity of Implementation – *Dosage* | Physical and online for office hours | Meet-up logs | Excel spreadsheet, filled in by | Weekly |

| | | | | |
|---|---|---|---|---|
| To what extent were BOAST students present at in-person meet-ups? To what extent did BOAST students utilize office hours? | | | instructors weekly | |
| Fidelity of Implementation – *Quality of Program delivery*<br><br>What is the quality of interaction between BOAST students and instructors? | Student and instructor interaction | BOAST students | Microsurveys, formative feedback survey | After each mission (6), End of program (at field trip) |
| Fidelity of Implementation – *Participant Responsiveness*<br><br>To what degree were students engaged in activities (i.e., complete mission sections, including Intro, Learn, Play, Build)? | Level of student engagement | BOAST work completion | Student gradebook from LMS, denoting work completion | End of each Mission (6) |

Finally, external evaluators characterized program implementation, strengths, and challenges by interviewing Program Leadership and key members of the Operations and Content Development Teams [35]. During each year of implementation (2021-2022, 2022-2023, 2023-2024), interviews were conducted privately over Zoom and recorded by two evaluators using an interview protocol (refer to Appendix B). Because of redundancy of themes over the three years, the most recent (2023-2024) findings will be reported. This evaluation included three BOAST Project Leadership Team members, two members of the Operations Team, and one instructor interviewed between February and March 2024. Interview participants ($n$ = 6) were involved for three to five years of the program (including the curriculum writing/planning year).

## III. FINDINGS

### *A. Outcome Evaluation (Research) Findings*

Outcome evaluation, or research, findings are summarized below according to research question.

RQ1 was “What effect does program participation have on math proficiency, as indicated by mastery of the algebra I benchmark skills targeted?” Due to low project submission rates across all years of the program, the authors were unable to answer this question.

RQ2 was “What effect does BOAST have on students’ math self-efficacy?” On average, each hour of LMS participation was associated with .02 points growth in self-efficacy. However, with controls in the model, there were no net effects of BOAST on math self-efficacy change. Moreover, contrary to SCCT, math self-efficacy did not predict change in STEM choice goals, nor interest and outcome expectations.

RQ3 was “What effect does BOAST have on students’ STEM choice goals?” With controls in the model, change in the treatment group’s STEM goals was .55 higher than the control group. In other words, participation in the BOAST program had no significant effect on math self-efficacy, STEM interest, or STEM outcome expectations in comparison to the control groups; however, student program participants had significantly higher levels of STEM choice goals. Thus, they had more ambitions to have STEM jobs after participating, but not all the other antecedents predicted in the SCCT model.

RQ4 was “What are the effects of math self-efficacy on change in STEM career goals?” Contrary to SCCT, math self-efficacy did not predict change in STEM choice goals, nor interest and outcome expectations.

RQ5 was “How do socio-environmental factors and perceptions influence participants’ STEM interest and postsecondary goals?” Through the lens of the SCCT framework among a low-income, predominantly Black high school student population, socio-environmental factors were particularly salient to how students’ postsecondary plans develop or fail to develop. These factors are displayed in Table 4. Moreover, predominant reasons for not completing or persisting in BOAST included transportation challenges, responsibilities at home or work, athletic commitments, or weak motivation because the program was not for a grade or paid time.

**Table 4**

*Joint Display*

| Socio-Environmental Factors | Math Self-Efficacy | STEM Interest | STEM Outcome Expectations | STEM Choice Goals |
|---|---|---|---|---|
| • Weak school support<br>• Unengaging instruction<br>• Negative peer influences | • Math self-efficacy conditional on positive classroom experiences | • Interest is positively associated with self-efficacy | • Weak connections between key steps and reaching goals | • Nascent or tenuous postsecondary goals |

| | | | | |
|---|---|---|---|---|
| • High-resource schools<br>• Deliberate school guidance<br>• Positive family role models | • Math self-efficacy reinforced by supportive school adults and experiences | • Interest cultivated and sustained by relevant opportunities | • Steps toward goals are apparent and perceived as actionable | • Concrete postsecondary and career goals |

*Note*: Table adapted from Durham and colleagues [33].

The results of the outcome evaluation study offered promising evidence that BOAST supported psychological constructs associated with productive career planning, though the effects were weaker than expected. Like school-embedded or afterschool programming, student engagement with BOAST was influenced by many external factors which impacted full program participation. Notably, student attendance has been a major hindrance to the program all years, but this problem extends beyond BOAST. Indeed, the district has an 85% attendance rate [36] and chronic absence levels are alarmingly high recently. For instance, roughly 46% of students missed 20 days of school or more in 2022-23 [37]. Chronic absenteeism [38], which has only increased and become commonplace post-pandemic, has crippled educational initiatives aimed at concrete student learning gains. Ultimately, due to the low participation in all three years of implementation, the efficacy of the BOAST program was not entirely achieved.[4]

*B. Process Evaluation Findings*

Process evaluation is helpful to monitor and document program implementation [39]. Fidelity of implementation questions (i.e., related to dose, quality of program delivery, and participant responsiveness) formatively supported the BOAST team, in iterative changes to program implementation, as well as summative uses (i.e., to add additional qualifiers or describe context to understand the research findings). Given the low participation rate and ambiguous or null findings related to the original research questions stated above, the process evaluation below assists the team in making sense of what works (or doesn't) in future iterations of the program. These process evaluation findings will be interpreted in the "Lessons Learned" section.

*1) Student Participation*

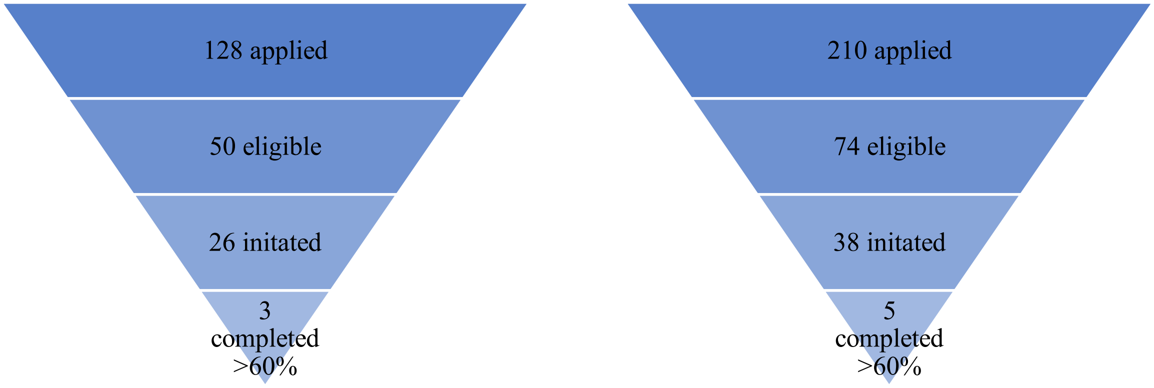
While the intended audience included 40 students in Year 1, 80 in Year 2 and 3, each year student participation fell substantially below those numbers. Figure 1 shows actual student participation and persistence in Years 2 and 3, from initial application (inclusive of both treatment and control students), to eligibility (based on C- or better in Algebra I), to initiation (logging into LMS by December), to program completion (defined as >60% of the program).

**Figure 1**

*Funneling Effect: Student Participation to Persistence*

**Student Participation (Year 2, SY22-23)** **Student Participation (Year 3, SY23-24)**

[4] At time of authorship, data from SY23-24 has not been included in analysis. However, work completion remained low in this year and is not expected to drastically shift the pooled data.



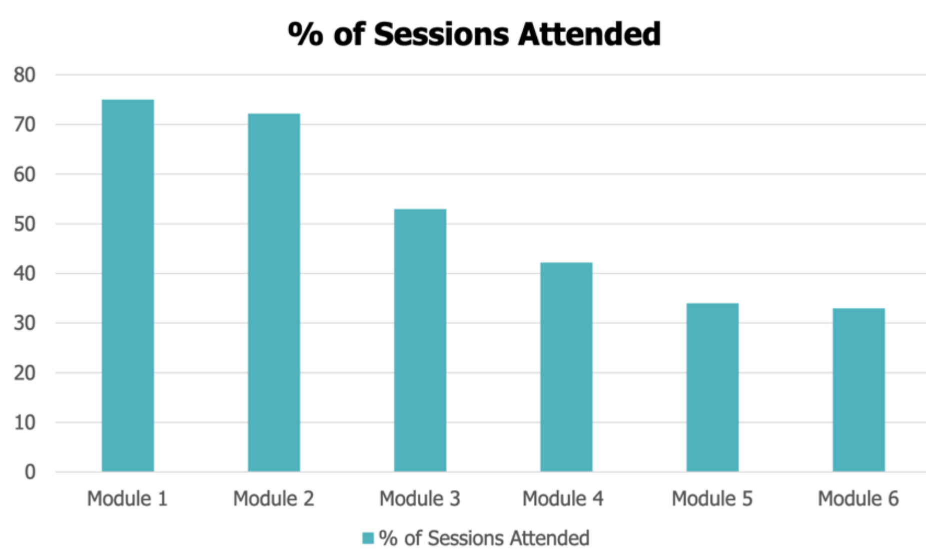

*Note.* Barriers to overcome at each stage of the funnel included receiving a passing grade in Algebra 1 (i.e., from application to eligibility), accessing the LMS during or outside afterschool meet-ups (i.e., eligibility to initiation), and successfully turning in answers/work (i.e., initiation to completion). This work completion rate impacted the ability to answer Research Question 1.

2) *Implementation Fidelity*

*a)* *Dosage*: The following graph shows the extent to which BOAST students were present at afterschool meet-ups. While offered weekly, no BOAST students utilized office hours across all three years. Student attendance reduced over time (refer to Figure 2).

**Figure 2**

*Student Attendance in Afterschool Meet-ups (Year 3)*



*b)* *Quality of Program Delivery*: While students were asked at the end of each Mission about ratings of their instructors in a microsurvey, the response rate was too low to report results. BOAST students (*n* = 9) who attended the final field trip instead completed a formative survey, to answer the question of quality of interaction between BOAST students and instructors. On a scale of one to ten, students provided ratings of their instructors. Below are some illustrative quotes:

- "10- she was beyond amazing she was … there when we needed help and made sure everyone had everything and wasn't judgmental about me missing some days because she knew my situation"
- "5 cause he's that guy his personality combined with teaching and honesty bring the most out of the most antisocial kids in the school helping with their weaknesses"

Overall, student data to determine quality of program delivery was not comprehensively available, particularly representative of students with low to moderate participation. Neither strong dissatisfaction nor satisfaction with instructors emerged in student interviews, perhaps indicating a neutral feeling towards instructors.

*c)* *Participant Responsiveness*: To understand to what degree students engaged in activities (i.e., complete mission sections, including Intro, Learn, Play, Build), the Operations Team analyzed levels of completion by mission. Figure 3 focuses on Year 2 of implementation and Figure 4 on Year 3 of implementation. This level of student engagement in activities/work completion was consistent in Year 1 (not pictured). These figures highlight the number of students who completed no work (though they may have attended after school meet-ups), partially completed work (meaning they logged on, clicked through the Intro and began the Learn and/or Play), and students who completed work (defined as 60% or more, meaning they accessed the Intro and submitted work in the Learn, Play, and/or Build sections).

**Figure 3**

*Mission Completion in SY 2022-2023*

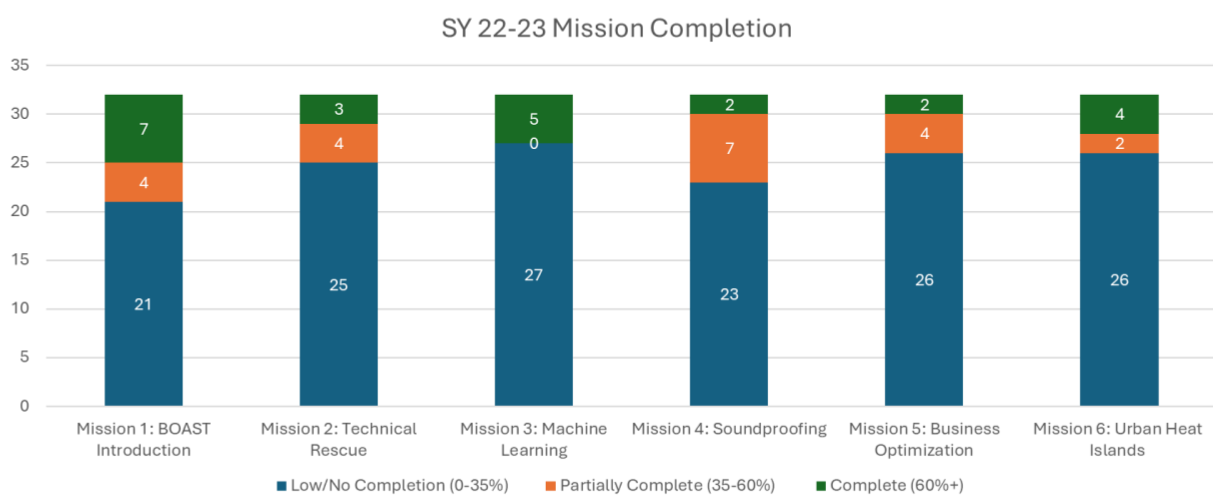
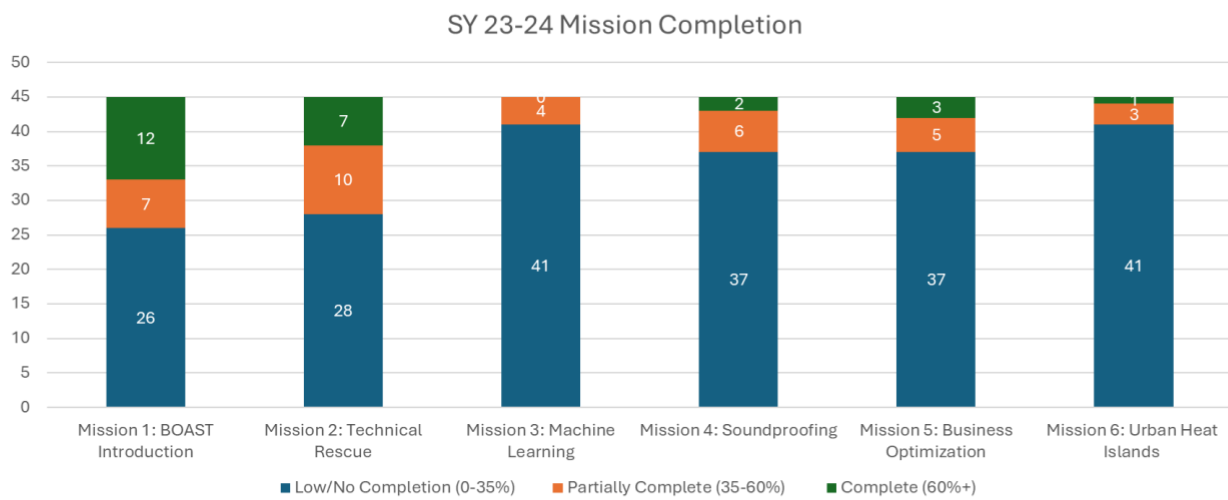


**Figure 4**

*Mission Completion in SY 2023-2024*




It is noteworthy that a small handful of students participated in after-school meet-ups exclusively; they benefited from positive relationships with instructors and exposure to STEM role model videos, even though they were not able (or choose not) to complete the curriculum.

*3) External Evaluation: Achieving Intended Program Goals*

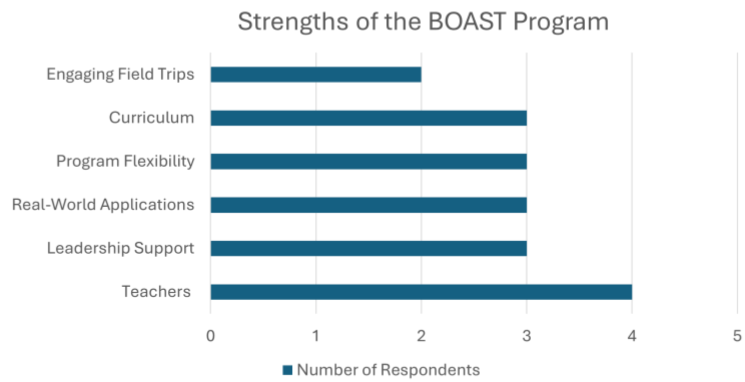
According to the external evaluators' report [35], among BOAST staff and leadership interviewed in 2023-2024 ($N = 6$), half of the interviewees did not believe the intended goals were achieved. One stated the contrary, and two were not aware of the program goals. Core concerns were attributed to COVID restrictions. Challenges referenced frequent pivots to address unexpected modifications, such as in-person meet-ups rather than virtual office hours.

*4) External Evaluation: Strengths of BOAST*

Strengths of the program included teachers, leadership support, real-world applications, program flexibility, curriculum, and engaging field trips.

**Figure 5**

*Strengths of the BOAST Program*




The interviewees overwhelmingly agreed on the strength of the instruction. The instructors held strong STEM backgrounds in Chemistry, Math, Computer Science, or other STEM degrees and were African American, forming engaging and nurturing relationships with students. They were committed, returning each year to provide continuity for students. The support of the leadership team and their ability to pivot as necessary, the use of real-world applications in the curriculum missions, the flexibility in the program to modify in real-time, and the Algebra curriculum embedded in engineering concepts were all strengths identified by half of the interviewees. Two respondents noted that the field trips were engaging and created a sense of connection among the students.

*5) External Evaluation: Challenges of BOAST*

Challenges included overall student engagement, retention, and aspects of the curriculum. Each of these challenges were identified every year of the program implementation.

a) *Student engagement*: Student engagement declined after COVID restrictions were lifted. After COVID, students were recapturing life and engaging in other after-school activities that divided their time and interest in BOAST. The program offered incentives, such as field trips or letters of recommendation, to attract students and their caregivers. However, there was limited evidence that student incentives improved the level of engagement. There is little incentive for the students to participate since this program did not offer a credit or grade upon completion.

b) *Retention:* Many students did not return to the program after fall and winter break, which affected retention goals and increased program absenteeism.[5] There is no evidence that additional efforts successfully addressed this issue. Recruitment and retention for this program may be better if it were a "during the school day" program. Moreover, BOAST is a solid program but should not stand alone. The curriculum and mission activities could be embedded within another program, and/or expanded to include geometry and algebra II to align the program with the ACT standards.

c) *Curriculum*: It was reported that several mission projects contained large amounts of work. The homework may have deterred participation because it resembled schoolwork

[5] Of note, chronic absenteeism was at a high nationwide in this return to school post-COVID [stats].

or added to an existing homework load. Additionally, some students needed a review of basic Algebra concepts. There was a gap in time between the program and completion of an algebra class. Some students began the program without a grasp of basic algebra skills. The missions did not include time for review.[6]

d) *Learning modality*: Online content was not well received or utilized by the participants. The students reported having grown weary of online learning content during COVID. Asynchronous learning was difficult for this particular group of high school students. Additionally, it was suggested that the content did not always fit the intended audience. The participants seemed to prefer the hybrid structure.

## IV. NEXT STEPS

The external evaluators provided recommendations to enhance BOAST or to support the success of future programs intending to adopt similar approaches. These recommendations included to 1) revise the projects and activities, to ensure they are enjoyable, age-appropriate, and culturally relevant, and match student interest and/or community needs; 2) consider a re-engagement strategy to tap into what motivated the students to sign up; 3) incentivize student participation, using tangible or intangible rewards; and 4) expand parental involvement.

On balance, the challenges, benefits, and student outcome data show that BOAST holds promise to support access and inclusion efforts for underrepresented groups in STEM. However, the "fit" of the curriculum in afterschool is a mismatch for Baltimore students. While devised to be flexible, mostly accessed at home, students desired social interaction, needed scaffolding from an instructor, and encountered too many barriers to participate in afterschool. The subsequent iteration of the program is integration into the school day.

In Fall 2024, BOAST (rebranded "Project X: Algebra Engineering Lab") was piloted in two high schools ($N = 41$) as a for-credit math elective class. Major changes from the afterschool version include the staffing model and grading. Project X is staffed by a teacher of record (i.e., a full-time staff member at the school, typically a seasoned math teacher) and Project X instructors (i.e., casual employees, usually undergraduate engineering majors who are novice teachers). Moreover, while our program did have predefined entrance criteria for student selection (i.e., C- or better in Algebra 1, interest in STEM as indicated on a brief survey), these criteria were inadequate to support success in the program; for this pilot, an above average school attendance rate (i.e., >85%) was included as a precondition. These changes, along with providing grades/credit towards graduation, have greatly enhance participation. Evaluation of this elective class model will be available in mid 2025.

## V. LESSONS LEARNED

This section seeks to capture wisdom, or lessons learned, from the entire BOAST project team, to share with administrators, educators, researchers, university-school district partners, and any other audience seeking to integrate innovative technology in urban schools (particularly serving minoritized youth) to advance STEM pathway access in education and careers. The

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[6] Instructional designers focused on applying Algebra 1 standards to novel problems/scenarios, as opposed to re-review of pre-requisite material, to achieve cognitively demanding tasks.

lessons learned involve 1) establishing the team, 2) developing research and evaluation approaches, 3) partnering with public school districts over time, and 4) utilizing technology in service of relationship-rich learning.

*6) Establishing the Team:* The BOAST team included a diverse group of educators with expertise in engineering and math instruction, online curriculum design, research-practice partnerships, and experience piloting and scaling new curricula. Most of the core team had previously taught in Baltimore City Schools, garnering valuable positionality as indigenous-outsiders [40]. Rich understanding of local context enabled the creation of a culturally relevant curriculum. In the case of NSF proposals, intellectual merit and broader impacts were outlined as equal pillars. This collaborative enterprise between researchers and community organizations or university partners is more art than science, but suffice it to say that they must be coherently woven together—with consideration for equity applied throughout—rather than a fragmented, jigsaw approach. On the one hand, prior interventions and an adequate theory of change [41] must outline what preconditions are needed to support success, what exact change(s) are anticipated; the research must inform plans for practice. On the other hand, community partners, educators, and those with on-the-ground experience bring a valid "what works" understanding, particularly for those underrepresented in the literature. Open, constructive, and consistent communication to merge these perspectives can lead to new interventions and meaningful innovations for increasing engineering engagement among marginalized populations.

Moreover, Social network theory [42] is essential to the diffusion of data-driven initiatives and scaling of effective programs [43]. As Levin [43] writes:

> The political dimension is sadly neglected in many discussions of education reform. Reforms cannot be adopted, or sustained once they are adopted, unless there is ongoing support from elected leaders, from school and district leaders and, in the end, from rank-and-file teachers, students, and parents. It is possible to implement changes without that support, but not to sustain them or for them to be effective, as has been shown by a great deal of research and experience around the world. (p. 7)

Thus, for those seeking to establish a team to launch a novel program or new curriculum, new teams are advised to consider the actors and structure of communication to mobilize momentum over time. The BOAST Advisory Board aided in both political mobilization and accountability of the project. The BOAST team benefitted from regular weekly meetings (operations), monthly meetings (leadership), and biannual meetings (advisory board). More frequent interactions among members of the network may substantially buoy the success of an initiative.

*7) Developing Research and Evaluation Approaches*: The initial research focused on an experimental, primarily deductive design, assuming a large sample size would be recruited in both treatment and control groups annually. While the original research questions could still be addressed minimally by pooling groups (to yield statistical significance), the researchers lack confidence in these findings given the low participant responsiveness and actual dosage received, as outlined above in the process evaluation above. The qualitative data yielded the greatest insights into the historical, cultural, and socioeconomic dimensions of students' experiences in STEM programs, supporting not statistical but practical significance. As such, those seeking to balance quality with pragmatic research are urged to adequately incorporate mixed methods. The qualitative interviews were a rich source of information regarding students' experiences in math and science classes, social supports, and planning processes, which has yielded greater insight for the BOAST team [34], [44].

*8) Partnering with School Districts*: School District offices often misinterpret or misappropriate ideas about what instructional improvement entails [45], due to their limited business and regulatory functions [46]. For the BOAST program, the inclusion of relevant leaders from the Math district office was essential to all stages of the program from ideation (i.e., addressing their problem of practice of low algebra proficiency) to implementation monitoring (e.g., including district office leaders in the Advisory Board), data dissemination (i.e., sharing publications for review and approval), and more. In Year 5, our partner from the Math Office led the approval process of the BOAST curriculum as a for-credit math elective class (renamed "Project X: Algebra Engineering Lab"). He and colleagues observed the class in action, fostering greater trust and support for the program. This open communication and support over time has been instrumental to the refinement over five years and future visioning.

*9) Technology in Service of Relationship-rich Learning:* While educational technology proliferates [47] and scalable technology-driven solutions—including classroom use of artificial intelligence [48]—draw substantial attention and funding, BOAST repeatedly demonstrated limitations of technology-rich learning. The population served generally did not engage with the online program independently and thoroughly, and so the program modified to include more teacher contact over time for community building and oversight of curriculum completion. Questions arose for our team, for example: 1) Is a hybrid course developmentally appropriate for early high school students? What supports do students need for time management, self-regulated learning, and other pre-requisite learner skills to engage with an asynchronous learning program? 2) Does the BOAST curriculum feel culturally relevant and cognitively demanding by users? Do students follow the storylines and bigger picture of the problem-based learning, or does the instruction feel task and compliance oriented? 3) What are the most effective practices for instructors as facilitators in a triadic relationship between instructor, student, and LMS? Through the lens of sociocultural learning, how can the deeply social, group-oriented processes of learning be adequately enmeshed with technological, individual-oriented learning mechanisms? While our team has not answered these questions, they represent tensions to address in future iterations of BOAST and other projects.

## VI. CONCLUSION

Strengths of a four-year, NSF-funded hybrid algebra-for-engineering program included teachers, leadership support, real-world applications, program flexibility, curricular components, and engaging field trips. Challenges included overall student engagement and retention, aspects of the curriculum, and operating in out of school time. Lessons learned around establishing the team, developing research and evaluation approaches, partnering with public school districts over time, and utilizing technology in service of relationship-rich learning were discussed. Moreover, this paper demonstrates how to design, refine, and test an evidence-based intervention during both minor and major disruptions (i.e., a global pandemic). Using not just formal, but also formative data sources aided in evaluation and strategizing tweaks to "fit" the population served; the program team is hopeful that the contextually developed, school-day elective program will lead to increased algebra proficiency and entryways into engineering career pathways.

## References


[1] A. V. Maltese and R. H. Tai, "Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students," *Sci Educ*, vol. 95, no. 5, pp. 877–907, Sep. 2011, doi: 10.1002/sce.20441.

[2] K. Morton and C. Riegle-Crumb, "Who gets in? Examining inequality in eighth-grade Algebra," *Journal for Research in Mathematics Education*, vol. 50, no. 5, pp. 529–554, 2019, doi: 10.5951/jresematheduc.50.5.0529.

[3] M. Leung, J. Cardichon, C. Scott, and L. Darling-Hammond, "Inequitable Opportunity to Learn: Access to Advanced Mathematics and Science Courses," *Learning Policy Institute*, no. May, 2021.

[4] W. Tyson, R. Lee, K. M. Borman, and M. A. Hanson, "Science, technology, engineering, and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment," *Journal of Education for Students Placed at Risk (JESPAR)*, vol. 12, no. 3, pp. 243–270, 2007, doi: 10.1080/10824660701601266.

[5] R. W. Lent, "A social cognitive view of career development and counseling," in *Career development and counseling: Putting theory and research to work.*, Hoboken, NJ, US: John Wiley & Sons, Inc., 2005, pp. 101–127.

[6] T. Nomi and E. Allensworth, "'Double-Dose' Algebra as an Alternative Strategy to Remediation: Effects on Students' Academic Outcomes," *Journal of Research on Educational Effectiveness*, vol. 2, no. 2, pp. 111–148, Apr. 2009, doi: 10.1080/19345740802676739.

[7] K. E. Cortes, J. S. Goodman, and T. Nomi, "Intensive Math Instruction and Educational Attainment," *Journal of Human Resources*, vol. 50, no. 1, pp. 108–158, 2015, doi: 10.3368/jhr.50.1.108.

[8] M. K. Stein, J. H. Kaufman, M. Sherman, and A. F. Hillen, "Algebra," *Review of Educational Research*, vol. 81, no. 4, pp. 453–492, Dec. 2011, doi: 10.3102/0034654311423025.

[9] P. A. Lauer, M. Akiba, S. B. Wilkerson, H. S. Apthorp, D. Snow, and M. L. Martin-Glenn, "Out-of-School-Time Programs: A Meta-Analysis of Effects for At-Risk Students," *Review of Educational Research*, vol. 76, no. 2, pp. 275–313, Jun. 2006, doi: 10.3102/00346543076002275.

[10] J. R. Young, N. Ortiz, and J. L. Young, "STEMulating Interest: A Meta-Analysis of the Effects of Out-of-School Time on Student STEM Interest," *International Journal of Education in Mathematics, Science and Technology*, vol. 5, no. 1, p. 62, 2016, doi: 10.18404/ijemst.61149.

[11] Y. Xie, M. Fang, and K. Shauman, "STEM education," *Annual Review of Sociology*, vol. 41, no. 1, pp. 331–357, Aug. 2015, doi: 10.1146/annurev-soc-071312-145659.

[12] T. Nomi, “The Unintended Consequences of an Algebra-for-All Policy on High-Skill Students,” *Educational Evaluation and Policy Analysis*, vol. 34, no. 4, pp. 489–505, Dec. 2012, doi: 10.3102/0162373712453869.

[13] J. E. Gilbert *et al.*, “Teaching algebra using culturally relevant virtual instructors,” *International Journal of Virtual Reality*, vol. 7, no. 1, pp. 21–30, 2008.

[14] G. Ladson-Billings and W. F. Tate, “Toward a critical race theory of education,” in *Critical Race Theory in Education: All God’s Children Got a Song*, A. D. Dixson and C. K. Rosseau, Eds., New York: Taylor & Francis, 2016, pp. 11–31. doi: 10.4324/9781315709796-4.

[15] A. Madison, “New directions for evaluation coverage of cultural issues and issues of significance to underrepresented groups,” *New Directions for Evaluation*, vol. 2007, no. 114, pp. 107–114, 2007, doi: 10.1002/ev.227.

[16] L. E. Matthews, S. M. Jones, and Y. A. Parker, “Advancing a framework for culturally relevant, cognitively demanding mathematics tasks.,” in *The brilliance of Black children in mathematics: Beyond the numbers and toward new discourse*, 2013, pp. 123–150.

[17] K. Kricorian, M. Seu, D. Lopez, E. Ureta, and O. Equils, “Factors influencing participation of underrepresented students in STEM fields: matched mentors and mindsets,” *International Journal of STEM Education*, vol. 7, no. 1, 2020, doi: 10.1186/s40594-020-00219-2.

[18] U. Nguyen and C. Riegle-Crumb, “Who is a scientist? The relationship between counter-stereotypical beliefs about scientists and the STEM major intentions of Black and Latinx male and female students,” *International Journal of STEM Education*, vol. 8, no. 1, 2021, doi: 10.1186/s40594-021-00288-x.

[19] M. Wyer, J. Schneider, S. Nassar-McMillan, and M. Oliver-Hoyo, “Capturing stereotypes: Developing a scale to explore U.S. college students’ images of science and scientists,” *International Journal of Gender, Science and Technology*, vol. 2, no. 3, 2010.

[20] T. Engineering, “Engineering Design Process.” [Online]. Available: https://www.teachengineering.org/populartopics/designprocess

[21] National Center for Education Statistics, “Baltimore City Schools District Directory Information.” Accessed: Apr. 18, 2023. [Online]. Available: https://nces.ed.gov/ccd/districtsearch/district_detail.asp?ID2=2400090

[22] Baltimore Education Research Consortium, “Gaining traction after high school graduation: Understanding the post-secondary pathways for Baltimore’s youth,” 2017.

[23] Maryland State Department of Education, “Free and reduced-price meal statistics,” 2024. Accessed: Apr. 10, 2024. [Online]. Available: https://www.marylandpublicschools.org/programs/Pages/School-Community-Nutrition/FreeReducedPriceMealStatistics.aspx

[24] R. W. Lent, S. D. Brown, and G. Hackett, “Social cognitive career theory,” *Career choice and development*, vol. 4, no. 1, pp. 255–311, 2002.

[25] X. Wang, “Why students choose STEM majors,” *Am Educ Res J*, vol. 50, no. 5, pp. 1081–1121, Oct. 2013, doi: 10.3102/0002831213488622.

[26] K. Qua, O. Pinkard, E. C. Kundracik, D. Ramirez-Bergeron, and N. A. Berger, “Near peer mentors to address socio-emotional issues among underrepresented minority high school students in research intensive STEM Programs: Perceptions of students and mentors,” *J STEM Outreach*, vol. 3, no. 1, 2020, doi: 10.15695/jstem/v3i1.06.

[27] M. J. Chang, M. K. Eagan, M. H. Lin, and S. Hurtado, “Considering the impact of racial stigmas and science identity: Persistence among biomedical and behavioral science aspirants,” *The Journal of Higher Education*, vol. 82, no. 5, pp. 564–596, Sep. 2011, doi: 10.1080/00221546.2011.11777218.

[28] L. Espinosa, “Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence,” *Harvard Educational Review*, vol. 81, no. 2, pp. 209–241, Jun. 2011, doi: 10.17763/haer.81.2.92315ww157656k3u.

[29] A. Bandura, *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, New Jersey: Prentice-Hall, 1986.

[30] E. L. Usher and F. Pajares, “Sources of self-efficacy in mathematics: A validation study,” *Contemporary Educational Psychology*, vol. 34, no. 1, pp. 89–101, 2009, doi: 10.1016/j.cedpsych.2008.09.002.

[31] S. A. Roller *et al.*, “Development and initial validation of the Student Interest and Choice in STEM (SIC-STEM) Survey 2.0 instrument for assessment of the Social Cognitive Career Theory constructs,” *Journal of Science Education and Technology*, vol. 29, no. 5, pp. 646–657, Sep. 2020, doi: 10.1007/s10956-020-09843-7.

[32] D. L. Blustein *et al.*, “Examining urban students’ constructions of a STEM/career development intervention over time,” *Journal of Career Development*, vol. 40, no. 1, pp. 40–67, 2013, doi: 10.1177/0894845312441680.

[33] R. E. Durham *et al.*, “Encouraging STEM careers among minoritized high school students: The interplay between socio-environmental factors and other social cognitive career constructs,” *Educ Sci (Basel)*, vol. 14, no. 7, 2024, doi: 10.3390/educsci14070789.

[34] R. E. Durham *et al.*, “Encouraging STEM Careers among Minoritized High School Students: The Interplay between Socio-Environmental Factors and Other Social Cognitive Career Constructs,” *ASEE Annual Conference and Exposition, Conference Proceedings*, 2024, doi: 10.18260/1-2--47257.

[35] K. Watkins-Lewis and C. Glass, “BOAST End-of-Program Final Report: External Evaluation Report 2024,” Baltimore, Maryland, 2024.

[36] Baltimore City Public Schools, “District Data Profile,” District Overview. Accessed: Apr. 15, 2023. [Online]. Available: https://www.baltimorecityschools.org/district-overview

[37] Maryland State Department of Education, “Baltimore City Public Schools, State Assessment Results.” Accessed: Jan. 15, 2025. [Online]. Available: https://reportcard.msde.maryland.gov/Graphs/#/Assessments/MathPerformance/UALG01/U/6/3/1/30/XXXX/2023

[38] M. A. Gottfried, “Chronic Absenteeism in the Classroom Context: Effects on Achievement,” *Urban Education*, vol. 54, no. 1, pp. 3–34, 2019, doi: 10.1177/0042085915618709.

[39] R. P. Saunders, M. H. Evans, and P. Joshi, “Developing a Process-Evaluation Plan for Assessing Health Promotion Program Implementation: A How-To Guide,” *Health Promotion Practice*, vol. 6, no. 2, pp. 134–147, 2005, doi: 10.1177/1524839904273387.

[40] Banks, “Cultural Diversity and education; Researching race, culture, and difference Ch 7,” pp. 169–177, 1991.

[41] A. A. Anderson, “The community builder’s approach to theory of change,” *The Aspen Institute*, p. 37, 2005.

[42] K. S. Finnigan, A. J. Daly, and J. Che, “Systemwide reform in districts under pressure: The role of social networks in defining, acquiring, using, and diffusing research evidence,” *Journal of Educational Administration*, vol. 51, no. 4, pp. 476–497, 2013, doi: 10.1108/09578231311325668.

[43] B. Levin, “What Does It Take to Scale Up Innovations?,” Boulder, CO, 2013.

[44] A. G. Daniels, “Dream jobs, road maps, and support systems: Persistence of racially minoritized youth in STEM education,” Johns Hopkins University, 2024.

[45] M. Honig, N. Venkateswaran, P. McNeil, and J. M. Twitchell, “Leaders’ Use of Research for Fundamental Change in School District Central Offices: Processes and Challenges,” in *Using Research Evidence in Education*, vol. 2, K. S. Finnigan and A. J. Daly, Eds., Springer International Publishing, 2014, ch. Chapter 4, pp. 33–52. doi: 10.1007/978-3-319-04690-7.

[46] D. Tyack and L. Cuban, *Tinkering toward utopia: A century of public school reform*. Cambridge, Massachusetts: Harvard University Press, 1995. doi: 10.2307/j.ctvjz83cb.

[47] P. Hernández-Ramos, “How does educational technology benefit humanity? Five years of evidence,” *Educational Technology and Society*, vol. 9, no. 4, pp. 205–214, 2006.

[48] P. Awad and S. Oueida, “The Potential Impact of Artificial Intelligence on Education: Opportunities and Challenges,” *Lecture Notes in Networks and Systems*, vol. 920 LNNS, no. 23, pp. 566–575, 2024, doi: 10.1007/978-3-031-53963-3_39.

**Appendix A**

Standards Alignment

| Standard | Description | M1 | M2 | M3 | M4 | M5 | M6 |
|---|---|---|---|---|---|---|---|
| **Ratios and Proportional Relationships** | | | | | | | |
| 6.RP.A.3 | Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations. | | □ | □ | | | |
| 7.RP.A | Analyze proportional relationships and use them to solve real-world and mathematical problems. | | □ | | | | |
| **Number System & Quantities** | | | | | | | |
| 7.NS.A.1.C | Understand subtraction of rational numbers as adding the additive inverse, p - q = p + (-q). Show that the distance between two rational numbers on the number line is the absolute value of their difference,_-and apply this principle in real-world contexts. | | | | □ | | |
| HSN.RN.A.2 | Rewrite expressions involving radicals and rational exponents using the properties of exponents. | | | | | □ | |
| **Expressions & Equations** | | | | | | | |
| 6.EE.A.2.C | Evaluate expressions at specific values of their variables. Include expressions that arise from formulas used in real-world problems. Perform arithmetic operations, including those involving whole-number exponents, in the conventional order when there are no parentheses to specify a particular order (Order of Operations). For example, use the formulas $V = s^3$ and $A = 6s^2$ to find the volume and surface area of a cube with sides of length s = 1/2. | | | | | □ | |
| 6.EE.B.6 | Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. | | | | | □ | |
| 7.EE.A.2 | Understand that rewriting an expression in different forms in a problem context can shed light on the problem and how the quantities in it are related. For example, a + | | | | | | □ |

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| | 0.05a = 1.05a means that “increase by 5%” is the same as “multiply by 1.05.” | | | | | | |
| 7.EE.B.4 | Use variables to represent quantities in a real-world or mathematical problem and construct simple equations and inequalities to solve problems by reasoning about the quantities. | | □ | | | | |
| 8.EE.A.2 | Use square root and cube root symbols to represent solutions to equations of the form $x^2 = p$ and $x^3 = p$, where p is a positive rational number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that √2 is irrational. | | | | □ | | |
| **Geometry** | | | | | | | |
| 7.G.A.1 | Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale. | | □ | | | | |
| 7.G.B.6 | Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms. | | | □ | | | |
| 8.G.B.8 | Apply the Pythagorean Theorem to find the distance between two points in a coordinate system. | | | | □ | | |
| **Statistics and Probability** | | | | | | | |
| 6.SP.B.5.C | Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered. | | | | | □ | |
| 8.SP.A.1 | Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association. | | | | □ | □ | |
| 8.SP.A.2 | Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a | | □ | | | | |

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| | straight line, and informally assess the model fit by judging the closeness of the data points to the line. | | | | | | |
| **Algebra: Seeing Structure in Expressions** | | | | | | | |
| HSA-SSE.A.1 | Interpret expressions that represent a quantity in terms of its context. Interpret parts of an expression, such as terms, factors, and coefficients. Interpret complicated expressions by viewing one or more of their parts as a single entity. | | | | | | □ |
| HSA-SSE.A.2 | Use the structure of an expression to identify ways to rewrite it. | | | | | | □ |
| HSA.SSE.B.3.C | Use the properties of exponents to transform expressions for exponential functions. For example, the expression 1.15t can be rewritten as (1.151/12)12t ≈ 1.01212t to reveal the approximate equivalent monthly interest rate if the annual rate is 15%. | | | | | □ | |
| **Algebra: Creating Equations** | | | | | | | |
| HSA-CED.A.1 | Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions. | | | | | | □ |
| HSA.CED.A.2 | Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. | | | □ | | | |
| HSA.CED.A.3 | Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods. | | | | □ | | □ |
| HSA.CED.A.4 | Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R. | | | | □ | | |
| **Algebra: Reasoning with Equations & Inequalities** | | | | | | | |
| HSA.REI.B.3 | Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters. | | | | | □ | |

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| HSA.REI.D.10 | Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line). | | | ☐ | | | |
| **Functions** | | | | | | | |
| 8.F.A.2 | Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). | | | | | | ☐ |
| **Functions: Building Functions** | | | | | | | |
| HS.F-BF.B | Build new functions from existing functions. | | ☐ | | | | |
| **Functions: Interpreting Functions** | | | | | | | |
| HSF.IF.B.4 | For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.* | | | | | ☐ | |
| HS.F-IF.C.7a | Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases | | | | | | ☐ |
| HS.F-IF.C.7.c | Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior. | | | | | | ☐ |
| HS.F-IF.C.7.d | Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior. | | | | | | ☐ |
| **Functions: Linear, Quadratic & Exponential Models** | | | | | | | |
| HS.F-LE.A | Construct and compare linear, quadratic, and exponential models and solve problems. | | ☐ | | | | |
| HSF.LE.A.1 | Distinguish between situations that can be modeled with linear functions and with exponential functions. | | | | | ☐ | |
| HS.F-LE.A.2 | Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs | | | | | | ☐ |

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| | (include reading these from a table). as $(x^2 - y^2)(x^2 + y^2)$. | | | | | | |
| HS.F.LE.A.4 | For exponential models, express as a logarithm the solution to $ab^{ct} = d$ where a, c, and d are numbers and the base b is 2, 10, or e; evaluate the logarithm using technology. | | | | | □ | |

*Note:* Mission 1: Introduction, Mission 2: Urban Heat Islands, Mission 3: Technical Rescue, Mission 4: Machine Learning, Mission 5: Soundproofing, Mission 6: Business Optimization

**Appendix B**

Interview Questions

1. What was your role in the BOAST program?
2. How long have you participated in the BOAST program?
3. In your opinion, did the BOAST program achieve the intended goals?
4. What aspect of the BOAST program did not meet the intended program goals?
5. What are the strengths of the BOAST program?
6. What are the challenges of the BOAST program?
7. What are the lessons you learned from the BOAST program?
8. How was student interest in STEM and Engineering professions impacted by this program?