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Developing and Evaluating a High School Summer Research Program in an Urban District Through a University-School Partnership (Evaluation)

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The COVID-19 pandemic was disruptive to the education system across the world in countless ways. And while remote and virtual learning tried to address the challenge of content delivery, hands-on laboratory experiences which provided authentic science inquiry for high school students were impossible to replace during the pandemic. Additionally, the valuable afterschool and summer programs that supplemented such in school training (e.g., science fairs, robotics competitions, Science Olympiad) were not available as well. Research tells us that such experiences are crucial to catalyze a high school students' interest in STEM careers [1], [2]. Even more detrimental is the fact that these activities are often identified as milestones for students who are college-bound. Without such opportunities, pursuit of post-secondary education for these individuals is likely to decrease.

After the pandemic, in an attempt to make progress on these skill gaps for students and the damage that has been done to their development, the Ohio Department of Education offered the "Summer Learning and Afterschool Opportunities Grant Program". The goals of this program were to address academic needs of students, support their well-being, and provide ongoing support for students through the creation or expansion of after-school and/or summer learning programs.

A high school summer research experience program was developed at The University of Akron in response to this call, in partnership with a local district, Akron Public Schools. The university, a comprehensive state university located within an urban environment, is well-connected and engaged at many levels with local schools. Owing to this close partnership between the university and the district, it seemed necessary for these organizations to work together so that the personnel and facilities resources at the university could be brought to bear to help the most vulnerable high school students close this skills gap associated with authentic science inquiry. Accordingly, these organizations applied for and received a state grant to develop and implement the Zips Rising STEM Scholars Program.

There is support in the literature that summer programs have positive benefits for engaging students in authentic science. For example, the report from the President's Council of Advisors on Science and Technology [3] outlined the importance of partnerships between colleges and K-12 schools to broaden access and opportunities for underrepresented students to participate in STEM. Research suggests that STEM summer experiences in high school are important in shaping students' career choices, and sparking their interest in STEM majors and careers, which is a national policy priority. A review of research [1] on summer STEM experiences for high school students at colleges and universities found that programs that engaged students in hands-on laboratory experiences were successful in increasing students' knowledge and skills. In addition, students who experienced real-world relevance of STEM were 1.8 times more likely to aspire to pursue STEM majors than a control group.

In particular, a robotics summer camp for high school students focused on research was utilized to introduce students to literature reviews and open-ended design, with qualitative outcomes indicating an increasing likelihood to pursue a STEM degree in college [4]. Additionally, an NSF-funded Young Scholars Program engaged high school students in an apprenticeship model for research focused on neural engineering, which showed positive development in both knowledge and research skills. [5] A Young Scholars Program at Northeastern University that has existed for around 30 years provides summer research experiences to high school students recently reported historical results, which includes strong impacts on enrollment in STEM and attainment of STEM degrees. [6]. More recently, a high school summer research program in semiconductors looked to increase knowledge, awareness, and interest in this important industry. Findings indicated progress in the first two areas, though interest did not show improvement from this intervention. [7]

Program Overview

The summer research experience grew from collaborations between university faculty and the Akron Public Schools district administrators. Several university STEM faculty had offered opportunities for high school students to conduct research on campus prior to the beginning of the program described here. However, our district partners observed that these opportunities did not reach underserved students who had the most to benefit from them. Reflection from prior programs also highlighted some of the challenges that faculty observed with hosting high school students, such as limited background knowledge and skills to engage in lab research meaningfully and the need for supervision. To address these challenges, and buoyed by the Ohio Summer Learning and Afterschool Opportunities Grant Program, university faculty and school personnel collaborated to develop a program that integrated a lab research experience with a teacher-led curriculum that integrated social emotional learning skills, research skills and provided a support structure for high school students.

The goals of the program focused on exposing students to authentic science and engineering lab research, increasing their skills in conducting research, and increasing their interest in STEM and STEM careers. The program also focused on increasing students' confidence to conduct research, exposing them to strategies that promote perseverance, and using positive problem-solving skills. In addition to the research component, the program integrated social emotional learning (SEL) activities daily. Students completed a mindfulness program, and a curriculum focused on goal setting, self-awareness, and career explorations. Guest speakers were scheduled throughout the eight-week program to expose students to various STEM fields in industry and academic settings, and spanned fields such as aerospace engineering, forensic science, material science, chemical engineering, ecology, biomimicry, health sciences, as well speakers that discussed general college admission and career planning.

SEL Framework

We used the CASEL framework to develop the social emotional learning curriculum. This framework outlines competencies that support social emotional learning, which include self-awareness, self-management, social awareness, relationship skills, and responsible decision-making [8]. The focus on SEL was initiated by our school district partner, given the importance of affective factors in student development. A meta-analysis of research studies [9] showed that SEL programs implemented in classrooms can increase academic achievement by 11%, enhance social skills by 25% , and decrease behavioral disruption by 10%. In addition, brief mindfulness training was shown to significantly improve working memory, visuo-spatial processing, and executive functioning, as well as improve mood and reduce fatigue and anxiety [10]. Therefore the purposeful inclusion of activities that address social emotional learning is essential in helping students grow their STEM skills.

Student and lab Recruitment

The program was open to rising juniors and seniors in high school, who were at least 16 years old by the first day of the program. The student recruitment and selection process was organized by partners at the district. In January, notices were sent out to students about the research opportunity. Teachers were also asked to encourage students to apply to the program. Students were required to fill out an application and have a teacher provide a recommendation. An important part of the application was a commitment by the student and parent (or legal guardian) to the entire eight weeks of the program. Final selection of students was based on students' application content and teacher recommendations.

Students were given a stipend for the program so that the need to earn an income in the summer did not prevent them from participating in the research experience. The stipend was supported by grant funding and was crucial in providing this opportunity for students who are economically disadvantaged. The stipend was paid out in three increments over the course of the eight week program. Research groups were given a budget for the program that could either be used to pay a graduate student to assist in the mentoring within a research lab and/or cover expenses related to the project.

Research groups were recruited based upon the interests indicated on the students' applications and the research group's previous experience working with high school students and undergraduate students. Graduate students in these groups were required to complete a background check and to go through orientation sessions before the summer program began. During the first week of the program, while the high school students were going through their orientation, the graduate students spent a few hours with the program staff reviewing expectations and discussing strategies to support students during the program, including problem solving strategies for dealing with challenges.

Weekly Schedule:

The program was held over an eight-week period. Week 1 included workshops to introduce the students to STEM research skills, and team building activities to help the staff get to know the students; throughout the week program staff observed different pairs of students as they completed various STEM related activities. By the end of the first week the students were placed into labs (two students per research group) based on compatibility and their research interest. During Weeks 2-7 students were in the lab Monday through Thursday and followed the daily schedule described below. Friday of each week during Weeks 2-7 was usually spent on a field trip. During the last week of the program students prepared their final report and presentations, and practiced their presentations in front of the program staff and each other.

Daily Schedule:

Each day the students were transported from a school near their home to The University of Akron campus by school bus. Students arrived by 8:30 each morning, checked in with a staff member, had breakfast provided by the program and spent the next hour working on an SEL activity and getting focused on the objectives for the day. If students did not show up and had not notified program staff that they would be absent, staff members called the student or the student's parent to confirm their location. At 9:30 the students walked to their labs and spent the next 2.5-3 hours working in the lab. Students returned from the lab and had lunch provided by the program. The students spent the next couple of hours either working on project deliverables (poster, paper, etc.) or meeting with presenters (researchers, student groups, etc.). Each day concluded with an SEL activity. Students were dismissed from the program at 3:15 pm each day and returned to a school near their home by school bus.

Project Presentations

The program culminated in a presentation of learning through a poster session that resembled a mini science fair competition. Students worked on research papers and prepared posters that they presented to expert judges (university faculty, graduate students, science teachers), and their families. The purpose of the event was to provide opportunities for students to practice communicating scientific findings and engage in science discourse where they justify their findings to people with some expertise in the area they are researching. Students were also expected to have artifacts ready for submission to the state science fair.

We also had an exit interview with each student and their lab mentor, where they discussed students' development related to professional skills, using a published internship Professional Skills rubric [11] as a framework for the reflection. Students who demonstrated proficiency in the various skills earned a seal that can be used for high school graduation requirements. This exit interview was the culminating event that demonstrated students' social and emotional skills in relation to the experience.

Program Revisions

We iterated the program design based on evaluation results over three years. Some key changes included the following:

1. Structuring the experience during four days and scheduling field trips on Fridays allowed graduate student mentors to have a day in the lab to focus on their work without supervising high school students.
2. During the first year, we found that students needed explicit support in writing. We added multiple workshops in the afternoons that guided students in technical writing. We also had program teachers read drafts and provided feedback, which reduced the demand on the graduate student mentors.
3. We added explicit instruction on the elements of the professional skills rubric each week. When concern arose with student engagement, we specifically referred to the rubric and outlined steps the student could take to address the concerns.

Program Evaluation

This paper reports on a component of a holistic program evaluation triangulating multiple quantitative and qualitative data sources [12] to examine the program's influence on students' research skills, attitudes towards STEM, STEM postsecondary and career planning, and key mentor outcomes.

Evaluation Questions

Four evaluation questions addressed in this paper were:

1. To what extent did students and mentors report students grew in their research skills (understanding of the research process, working collaboratively and effectively, data analysis skills, and communicating about research)?
2. After completing the program, how many students earned an internship graduation seal reflective of their professional skills?
3. In what ways did students and mentors describe the program's impact on students' research skills?
4. How satisfied were the mentors with the different components of the program?

Data Collection

Four data sources were collected from the students and mentors: 1) student pre-post program evaluation survey; 2) Mentor pre-post survey; 3) Professional skills rubric [11] ratings, and 4) Post program student focus group interviews. Before data collection, the university Institutional Review Board reviewed and approved the project as "exempt" status. students and mentors completed their pre-post surveys during the final week of their 8-week summer program. The survey consisted of multiple sections and validated STEM-related outcome scales. Mentors rated students' professional skills using the professional skills rubric composed of 15 indicators students must demonstrate proficiency in to meet the criteria to receive a graduation seal. On the final day of the program, students in the 8-week program participated in one of three focus group interviews facilitated by the evaluator. Interviews were conducted in person at the university and lasted 45-60 minutes.

A semi-structured interview protocol consisting of eight open-ended questions was designed to align with the broader program evaluation, focusing on strengths, areas for improvement, and impacts. Specifically relevant to this study, and to inform evaluation question 3, students were asked to describe any knowledge or skills they gained from participating in the program. The number of students, both within and across focus groups, who provided at least one example of knowledge or skills gained as a result of the program was recorded. The external evaluator analyzed the focus group interview transcripts, identifying students' descriptions of knowledge and skills gained.

Participants

This study focused on the Summer 2024 Cohort. All 20 students (100%) enrolled in the 8-week program also participated in the evaluation. Students self-reported their gender, race, and ethnicity as: 12 females (60%) and 17 (85%) Not Hispanic or Latino, 1 Hispanic or Latino (5%), 2 (10%) Prefer not to answer; 6 (30%) White, 6 (30%) Black or African American, 5 (25%) of Two or More Races, and 3 (15%) Asian. Out of 14 mentors, 13 (93%) participated in the evaluation survey and 14 (100%) rated their students on the professional skills Rubric [11]. Seventy-five percent (N=15) of students participated in a focus group interview as well.

Data Analysis

Rating scale items were analyzed using descriptive statistics. Open-ended survey responses and interview transcripts were analyzed using content analysis [13] and evaluation coding [14]. A first-cycle review was conducted to familiarize the evaluator with the interview data. Qualitative evaluation coding [14] was conducted given that a purpose of the focus groups was to evaluate the worth of the program specifically in terms of its influence on students' STEM knowledge and skills. In the second-cycle review, inductive content analysis [15] was used to identify initial parent codes or categories of knowledge and skills that included domain-specific knowledge, research skills, communication skills, and real-world. Sub-codes were then created within each category to further define specific skill types such as knowledge of various science-related topics (domain-specific knowledge), software/machine/technology skills (research skills), and oral communication skills (communication skills). During the third-cycle review, the evaluator coded transcripts line-by-line using these categories and sub-codes. Finally, repetitive sub-codes were collapsed and exemplar impacts on knowledge and skills were identified for reporting.

Results

Key findings are reported related to the student and mentor perceptions and descriptions of the program's influences on the students' research knowledge and skills.

Evaluation Question 1: Reported Gains in students' Research Skills

Mentors' (N=13) and students' (N=20) mean ratings on a 1.0 to 4.0 Likert-type gain scale are illustrated in Figures 1-4. *Moderate* to *a lot of gain* was reported by mentors and students across all four areas of research skills. Taken together, the mean rating across indicators was highest for Communicating About Research (M = 3.57, *a lot of gain*) followed by Working Collaboratively and Effectively (M = 3.34, *moderate*). Understanding Research and Experimental Design and Data Analysis skills (M = 3.33, *moderate gain*) had slightly lower mean ratings across indicators. These findings are not surprising given that all mentors (100%, N = 13) reported that lab experiences involved writing research results and nearly all mentors (92.31%, N = 12) reported that lab experiences involved presenting research and reading literature.

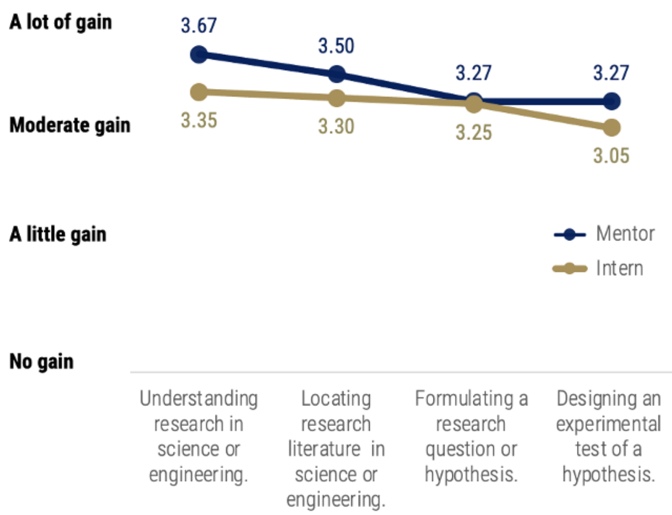

Figure 1. Reported growth in students' understanding of the research process.

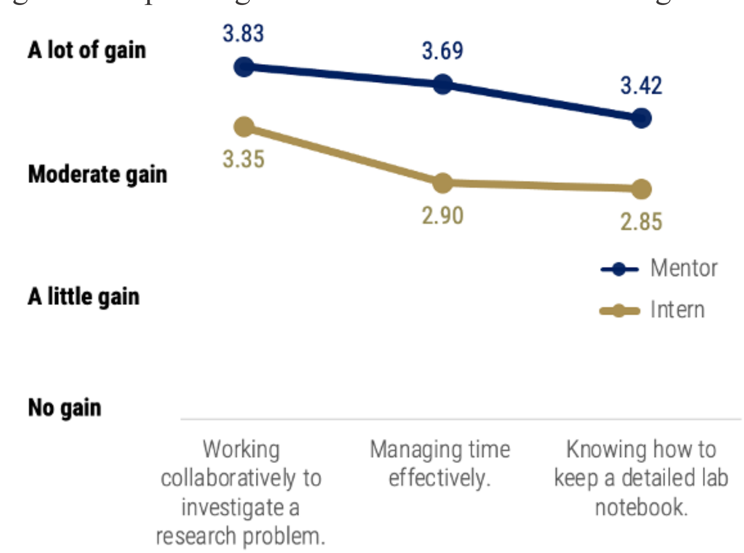

Figure 2. Reported growth in students' skills in working collaboratively and effectively.

Because mentors and students rated the same indicators across the four areas of research skills, their mean ratings can be compared. On average, mentors' ratings tended to be slightly higher than students' self-reported ratings for indicators of Understanding Research and Designing Experiments, Working Collaboratively and Effectively, and Data Analysis Skills (see Figures 1-3). students rated their growth higher than mentors, on average, for three indicators related to Communicating About Research (see Figure 4). Specifically, students reported *a lot of gain* while mentors reported *moderate — a lot of gain* for three indicators: (1) *Orally communicating the results of science research projects*; (2) *Creating a science research poster*; and (3) *Discussing science research with teachers or other professionals*.

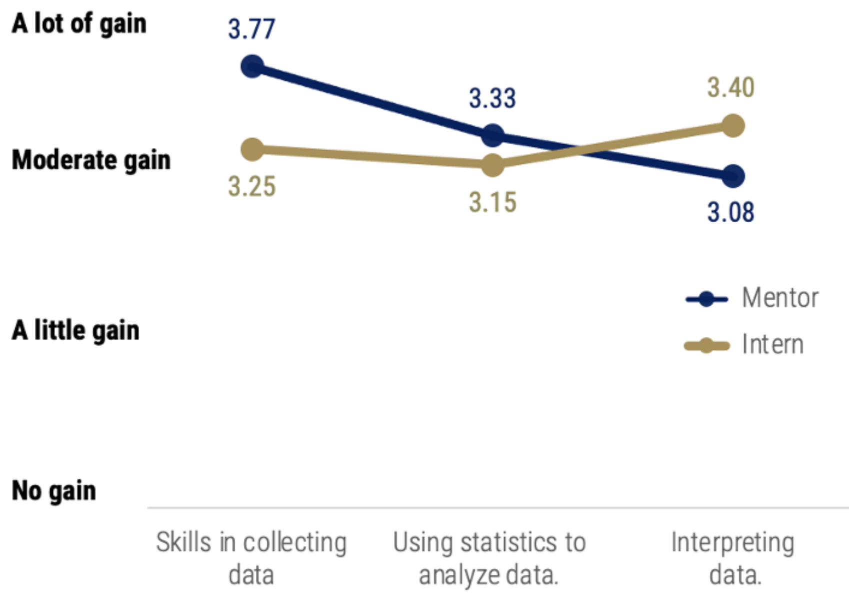

Figure 3. Reported growth in students' data analysis skills.

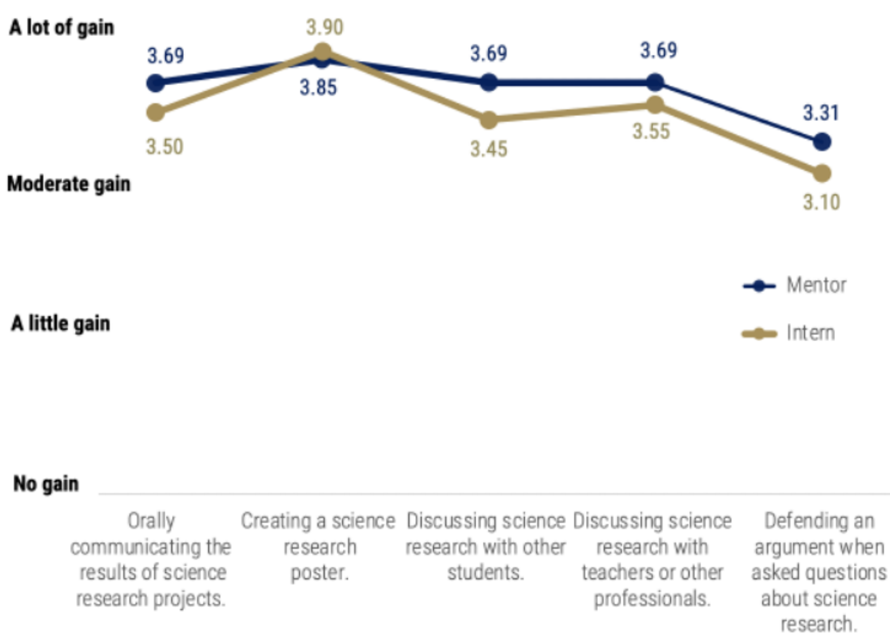

Figure 4. Reported growth in students' communicating about research.

Evaluation Question 2: Mentor Ratings of students' Professional Skills

A total of 15 (75%) of the students were rated as earning proficient scores across all criteria of the professional skills rubric. students' median performance rating was "Proficient" across all 14 readiness indicators. The five indicators that students scored the highest on by the mentors, on average, were: global/intercultural fluency, learning agility, punctuality, teamwork/collaboration and leadership, and oral and written communication.

Evaluation Question 3: Descriptions of Knowledge & Skills Gained

All (100%) of the students participating in the focus groups provided examples of knowledge and skills gained from participating in the program. These findings further support that the program had a positive impact on the high school students' research skills. The students described learning knowledge about a variety of science-related topics across a variety of fields including biology, organic chemistry, ecology, and biomedical engineering. They shared how this knowledge came from their experiences working in the lab, field trips, and guest speakers. The students also described numerous examples of specific knowledge gained. As one example, across all three focus groups, students shared learning what a polymer is and the basic structure of a polymer.

Across all three focus groups, students provided multiple examples of research skills they gained due to the program. The students described learning to use software (e.g., Excel, R, XMALab) and machines (e.g., chromatography machine, hemofilter, UV spectrophotometer). Also, students shared specific research skills they achieved through participating in the lab experience. For example, one student described that they "learned how to analyze graphs from GPC readings and NMR readings" (FG1). Another student described skills gained while working on a human heart valve research project.

Other examples of specific skills learned included coding, removing oxygen from water, testing different types of thermoplastic elastomers, conducting stretch tests, creating new variants of a heart valve, and using NMR. Two students in focus group 2 explained that they do not have a lab in their high school so this experience taught them how to navigate a lab safely:

When asked how their lab experiences in this program compared to their high school lab experiences, there was consensus across all three focus groups that their lab experience was more real-world and hands-on compared to their high school science classes. Example labs in the school were more basic such as an egg drop, making a rocket, making slime, using a microscope, dissolving zinc into hydrochloric acid, or dissecting animals. They explained that these labs all had a clear outcome and were shorter (a day or a few days). Some students described their high school labs as mostly paper-pencil work or limited due to classmates' behaviors. The program lab experience allowed them to work among the "dangers" in a real lab using different tools that are not accessible in their high school labs. Some basic similarities between the program and high school lab experience were recognized by the students such as the lab safety procedures, required writing (about procedure, observations, and results), and needing to conduct online research.

In addition to gaining STEM knowledge and research skills, all three (100%) focus groups shared examples of improving their communication about research. As one student summarized, "*It's important that you have to be clear with your words and know what you're talking about when you're communicating about your research...So, it taught us that*." (Focus Group 1). Students described how they learned to communicate about their research project and results through the research paper and poster boards, and learning to communicate about their research to different audiences like the community (their family) and experts (judges). Across all three focus groups, students shared strategies they learned for effectively orally presenting: avoiding "filler words," "talking slowly," avoiding memorizing the presentation, speaking confidently, and making an "educated guess" if you are not sure of the answer when asked question during your presentation, and speaking confidently.

Evaluation Question 4: Mentors' Satisfaction with the Program

Mentors were asked five questions related to the students' and mentors' preparedness to participate in the program and the effectiveness of aspects of the program implementation (matching of students to labs/mentors, communication during the program, and the exit interview process). The 13 mentors (100%) participating in the survey responded to all five questions.

As shown in Figure 5, overall, the mentors reported that the students were *Well prepared* (62%) and or *Somewhat Well Prepared* (38%). The mentors also felt that they as mentors were *Well Prepared* (69%) or *Somewhat Well Prepared* (31%) to work with the students. When asked whether they had prior experience working with youth, seven mentors (54%) reported experience working with students at the elementary (N=2), middle grades (N = 2), and/or high school (N = 6) level. Six mentors (46%) reported no prior experience working with students.

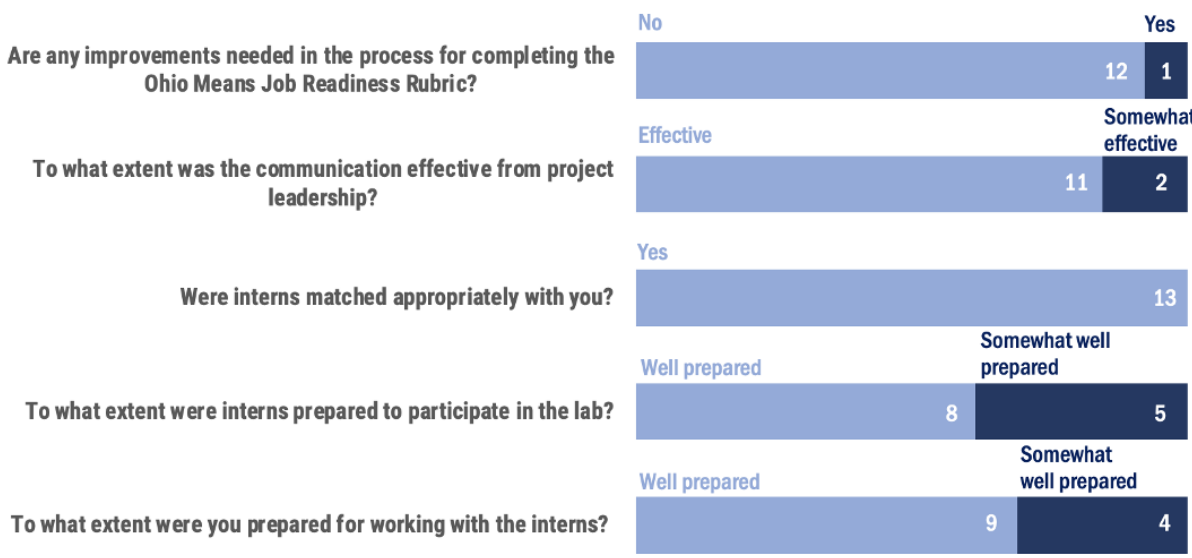

Figure 5. Mentors' perceptions of program implementation. (N=13)

All 13 mentors (100%) reported that the matching of students to mentors' labs was appropriate. Eleven mentors (85%) rated that the communication from project leadership was effective. Twelve mentors (92%) reported no improvements needed for completing the professional skills rubric. The mentors described what worked well in terms of the lab experience and final project, as well as potential areas of improvements (see Table 1).

Table 1. *Lab and final project strengths and areas of improvements recommended by mentors.*

Program Component	What Worked Well	Improvements Recommended
Lab Experience	□ **Interns' collaboration** Progressed mentors' projects. □ **Independent assignment work** Interns working on assignments in the afternoon helped save time in the lab. □ **Interns' STEM skills** Ability to try different approaches to achieve desired outcomes. □ **Interns' professionalism** Demonstrated professionalism and excitement to work. □ **Interns' positive attitudes** Willingness to learn and positive attitude towards STEM research. □ **Timing** Three hours was sufficient to reach the project goals and maintain intern focus.	□ **Vary exposure** Connect interns with more labs. Provide more time for them to visit and discuss topics with other labs. More "visualize experiment." □ **Increase lab time** More days in the lab.
Final Project	□ **Poster template** Helped construct a professional product. □ **Clear instructions** Specific project requirements. □ **Collaboration** Among interns, mentors, and leadership. □ **Independent work** Interns completing their work (ex: paper). □ **Interns' positive attitudes** Demonstrated positivity. □ **End product** Reached the expected results and project completed in the short time span. □ **Intern learning experience** Communicating and presenting research.	□ **Science Fair rubric** Provide to mentors. □ **Require only a poster and paper** Remove the "quad board" so that interns can attend to editing and creating polished projects. □ **Adjust timing** Dedicate a full week to the poster and paper. □ **Require a mock presentation** So that interns can practice. □ **Consider interns' STEM skills** Data analysis and digital technology skills needed for the final project are difficult to develop in the short time span.

Discussion

Both students and mentors reported that the students showed at least moderate improvement across all items. These results are a testament to the hard work of the students, mentors and teachers and show that the overall goal for the program was met. A lot of gain was reported by both students and mentors in the students' ability to communicate about scientific results in multiple formats. These findings are not surprising given that the students' time in the lab involved writing about and presenting research results and that a significant amount of time was spent in the afternoons with the teachers working on reports, posters and oral presentations. The students spent at least one afternoon each week and then each afternoon during the last week of the program working with the teachers on their paper, poster and oral presentation. The students seemed comfortable asking the teachers questions that they might have been uncomfortable asking the mentors, especially early on in the program. They also received feedback on their written reports and revised their work accordingly.

The skills on the professional skills rubric that were rated the highest included global/intercultural fluency, learning agility, punctuality, and teamwork/collaboration and leadership. Having the teachers meet with the students first thing each morning 30 minutes before going to the lab and then work with the students in the afternoon provided an opportunity for the students to talk about interpersonal issues that were occurring between the students or between the students and the mentors. The teachers were able to help the students work through these issues in a professional manner and, as a result, the mentors rated the students as proficient in areas related to interpersonal communication.

Another aspect to emphasize is the importance of high expectations for students, which was communicated as a key value for the program. While it was challenging at times to have every group finish a written paper and prepare presentations in the short time they were on campus, having mentors and teachers communicate high expectations, with tools to overcome challenges, resulted in students gaining confidence in their abilities to accomplish a goal.

Implications

By all measures, the summer research program was a success for the twenty high school students that participated. To run a successful summer research program for a group of students with a broad range of social, emotional and learning needs requires financial resources to support the teachers who provide instruction and coaching (2 for every 20 students), the mentors who guide the students in the lab (1 for every 2 students), and the staff that coordinate the transportation, food and events (1 per program). Each person in these roles must make creating a positive learning environment for the students the top priority. Each of these roles do require different skill sets. Teachers have developed the skill set necessary to meet the students where they are and help make the content accessible. Mentors have the skill sets to manage research projects and incorporate students into the project in a meaningful way. Staff have the skill sets to be able to communicate with a wide variety of stakeholders and keep everything organized.

Conclusion

One of the key drivers of success for this project was the close collaboration between the Akron Public Schools district and The University of Akron faculty. Working with the administrator in charge of the STEM curriculum who is directly working with teachers and has relationships with students allowed us to co-design a program that meets the students where they are. Providing targeted scaffolding by school personnel who have expertise supporting high school students helped the students successfully complete a rigorous and authentic research experience. In addition, students gained confidence and the tools to participate in local, regional and state STEM competitions.

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