# The Billion Oyster Project and Curriculum and Community Enterprise for Restoration Science Curriculum: STEM+C Summer Institute Experiential Learning

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**Abstract**

The Billion Oyster Project and Curriculum and Community Enterprise for the Restoration of New York Harbor with New York City Public Schools (BOP-CCERS) program is a National Science Foundation (NSF) supported initiative and collaboration led by Pace University. One of Pace University's NSF projects is STEM+C (Science, Technology, Engineering, and Mathematics plus Computing) designed to work with teachers and students in New York City public schools. This article presents results of a study conducted on the STEM Summer Institute at Pace University in Summer 2022. The purpose was to engage both teachers and students in harbor restoration and experiential learning in New York City including learning about vital ecology projects related to New York's harbor such as oyster restoration, which is critical to cleaning pollutants in the New York Harbor. Findings revealed that students indicated improved oyster knowledge and restoration skills, scientific skills, collecting and analyzing data, and knowledge about STEM careers. Participating teachers indicated a positive impact on their knowledge of content and harbor restoration, pedagogical knowledge used to engage students in hands-on scientific learning, and methods of engaging and motivating their own students. Moreover, teachers indicated a positive outcome for exposing their students to STEM career options.

**Keywords:** STEM education, STEM teachers, experiential learning, summer institute

## 1. Introduction

### *1.1 Background and Purpose*

The Billion Oyster Project and Curriculum and Community Enterprise for the Restoration of New York Harbor with New York City Public Schools (BOP-CCERS) program is a National Science Foundation (NSF) supported initiative and collaboration led by Pace University. One of Pace University's NSF projects is STEM+C (Science, Technology, Engineering, and Mathematics plus Computing designed to work with teachers and students in New York City public schools. This article presents results of a study conducted on the STEM Summer Institute at Pace University in Summer 2022. The purpose of the Summer Institute was to engage both teachers and students in environmental restoration and experiential learning in New York City including learning about vital ecology projects related to New York Harbor such as oyster restoration, which is critical to cleaning pollutants. The purpose of the study was to determine the efficacy of the Summer Institute in regard to the impact on student STEM content and experiential leaning and teacher content and pedagogical knowledge. The STEM Institute is held at Pace University in New York City, and is a two-week program for high school students, which is supported by the National Science Foundation (NSF) through the STEM+ Computing grant (STEM Institute, 2023).

The 2022 Pace University Summer STEM Institute took place over the course of two weeks in July 2022. It was fully implemented in a hybrid format with three face-to-face days. On the first two days it included a visit to Governors

Island, and the last day was used for the final presentations. Pace University enrolled 37 students, 32 of which completed the program. The students were grouped into six teams that used data science methodologies and code in Python to answer restoration science research questions. Examples of student created projects can be found at the website: https://bopuiprod.azurewebsites.net/technology/stem-institute

Content included the following: Exposure to coding tools such as Github, Google Colab and Python; fundamentals of Python including declarations of variables, lists, tuples, and functions; Python libraries including NumPy, Seaborn, Pandas, Matplotlib, and SciPy; data science algorithms through Python; an overview of data science (data frames and series); data visualization through pie charts, histograms and scatter plots; statistics involving correlation, linear regression, exploratory analysis; and design thinking through team building and visualization activities. Students were exposed to BOP programming and field science activities, and they used BOP data to answer their research questions. Pace University student mentors and restoration scientists provided guidance to students participating in the Summer Institute. Students had the opportunity to interact with current Pace undergraduate students, data scientists, restoration ecologists, and professionals from the industry to be exposed to university life and career opportunities in STEM.

The following are the project learning outcomes for the Summer Institute:

- Be more knowledgeable about Data Science
- Be introduced to basic statistics and data science algorithms
- Be familiar with the Python language fundamentals
- Be familiar with the most common Python data structures and libraries for Data Science
- Be able to create visualizations with Python
- Be able to use Python to carry out statistical modeling and analysis
- Be familiar with Design Thinking
- Have developed teamwork and communication skills
- Have formulated a research question for data analysis
- Have applied knowledge on a project based on real data

**Table 1.** Comparison of Years

| Numbers | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| # students | 19 | 58 | 55 (50 completed | 37 (32 completed) |
| # teams | 5 | 10 | 8 | 6 |
| Ratio | 3.8 students/ mentor | 5.8 students/ mentor | 13.8 students/ mentor | 6 students/ mentor |
| # mentors | 5 | 10 | 6 | 6 |
| # instructors | 3 | 3 | 5 | 4 |
| # staff | 2 | 2 | 2 | 2 |
| # slack messages | 563 | 12 893 | 6200 | Several thousands |
| Length | 10-day | 10-day | 8-day | 10-day |
| Format | face-to-face | online | online | hybrid |

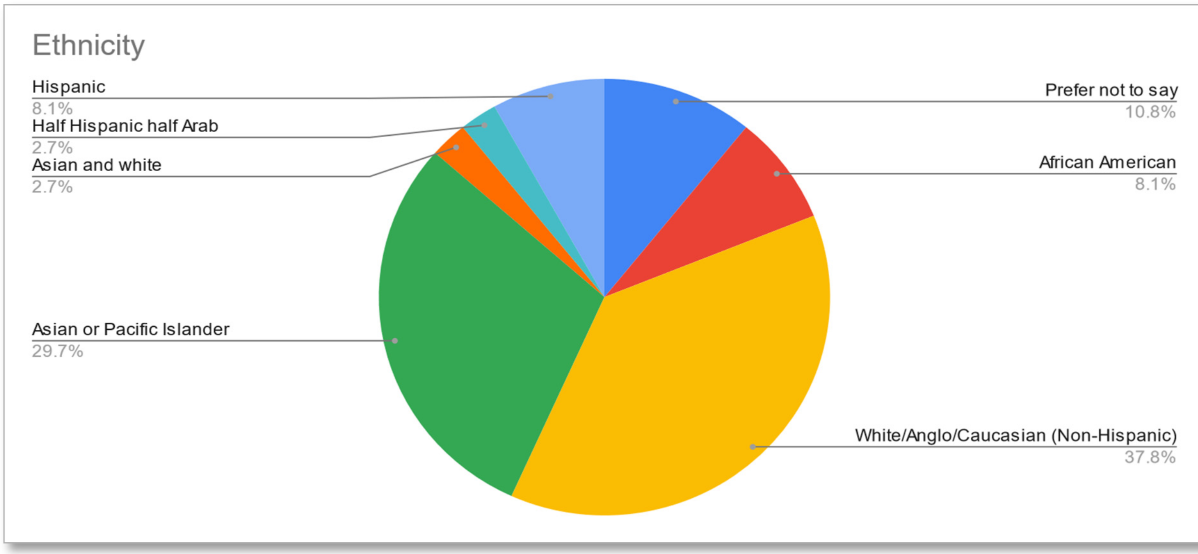



**Figure 1.** Student Demographics

*1.2 Theoretical Framework and Literature Review*

The research team has been conducting research on activities related to multiple NSF grants since 2017 (e.g., recent publications such as Birney et al., 2021a, 2021b, 2022), and the driving theoretical framework across this research has been based on Bandura's (1986, 1997) self-efficacy and social cognitive theory in which student cognitive and social development happens through social interactions between students through collaborative work and teacher/student interactions, which has broad implications for student sense of self-efficacy. Nava and Park (2021) had indicated that real-world STEM learning through hands-on activities and field-based experiences can improve content knowledge and self-efficacy. This has implications for improved critical and creative thinking in problem-solving for students (Widiyanti et al., 2020). When self-efficacy is high, students have an increased likelihood of having higher levels of motivation to achieve in their academic goals as well as the additional benefit of working to solve problems (Bouffard-Bouchard et al., 1991; Multon et al., 1991; Pajares, 1996; Schunk 1995). Liem et al., (2008) stated that an additional advantage of academic self-efficacy can allow students to learn material at deeper levels.

The theoretical framework for this study is supported through Vygotsky's sociocultural theory of learning (Vygotsky, 1987), which provides a foundation in which teachers and students form a community of learners through community-building, collaboration, and rapport. Collaborative learning can allow for rich learning of content in which students learn together, learning new information, and obtaining feedback about the way in which they are learning (Micari & Pazos, 2020). Additionally, Bloom et al., (1956) described that when students are actively engaged in the learning process, three domains of learning: thinking/knowledge, doing, and feeling are enhanced. Active learning engages students in the learning process by requiring them to participate in meaningful and authentic learning activities while simultaneously reflecting and thinking about what they are doing (Prince, 2004).

More than ever, it is important to improve STEM education that leads to further STEM studies needed for the careers of the 21st Century that the United States will rely upon for continued scientific leadership and growth (Rotermund & Burke, 2021). Daggett (2010) indicated student unpreparedness for the demands of these careers needed for strong economic growth, However, literature supports the method of student engagement in this study by which "students learn science and mathematics through 'doing' in the way scientists and mathematicians conduct their own research, investigations, and practices (Brandt, 2016; Hoskins, 2019; Plank, 2017; Wilcox, Cruse, & Clough, 2015)" (Birney et al., 2021a, p. 29), and "not only do these experiences reflect the way in which STEM professionals conduct their work, but also they can be some of the most engaging and rewarding of a student's academic career (Mokter Hossain & Robinson, 2012)" (Birney et al., 2021a, p. 29). Thus, the researchers contend that one of the best ways of teaching science to students is through conducting science in the way that scientists conduct their own research and work (Gorghiu & Ancuta Santi, 2016; Tuss, 1996), which has the potential for positive learning and engagement outcomes. Moreover, the use of real-world learning and activities lead to better learning outcomes for students (Buczynski & Hansen, 2010). Freeman et al. (2014) found that students can directly benefit from active learning techniques and activities, particularly in STEM. Theobald et al. (2022) found this can be particularly beneficial for underrepresented students.

A community of practice ties STEM dimensions together, connecting: science inquiry, technological literacy, mathematical thinking, and engineering design (Chen et al., 2019). The authors described that STEM learning is organized around certain elements: ideas, concepts, or themes and can be enhanced through interaction. Therefore, Kelley and Knowles (2016), stated that acquiring knowledge of the skills alone is insufficient, students must also understand the process of how to acquire skills through authentic contexts and learn to use them to solve real-world problems. Authentic activities provide students with an organic experience to "represent and describe the knowledge or concepts, and revise their understanding and actions on the experience and results" (Brown et al., 1989, p.4). Newhouse (2016) further indicated the importance of embedding knowledge and skills within the curriculum while also assessing knowledge and skills in real-life contexts or problem-solving processes.

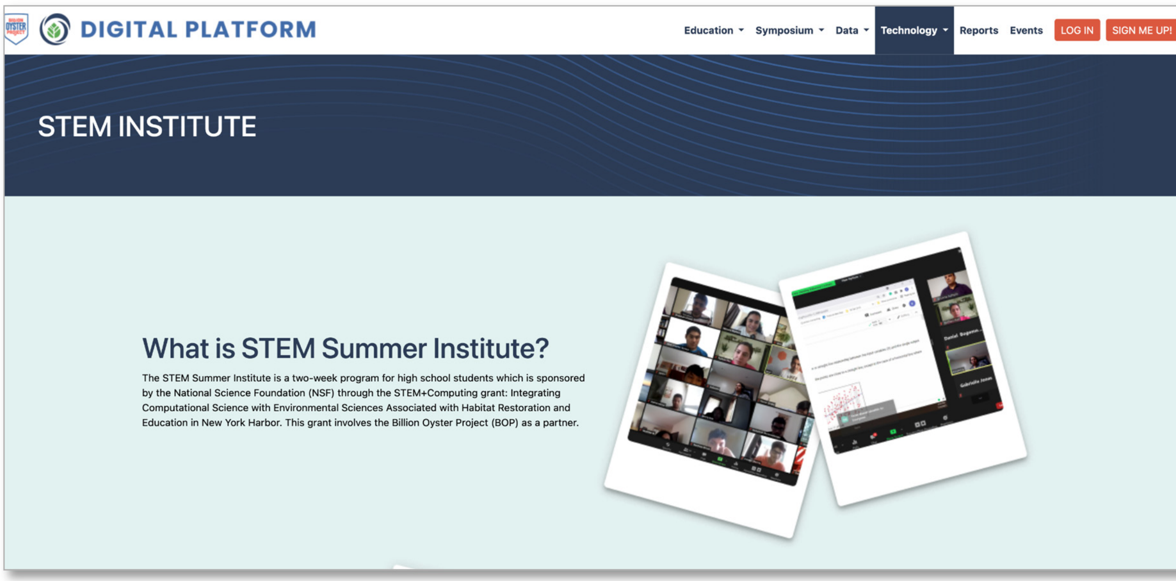


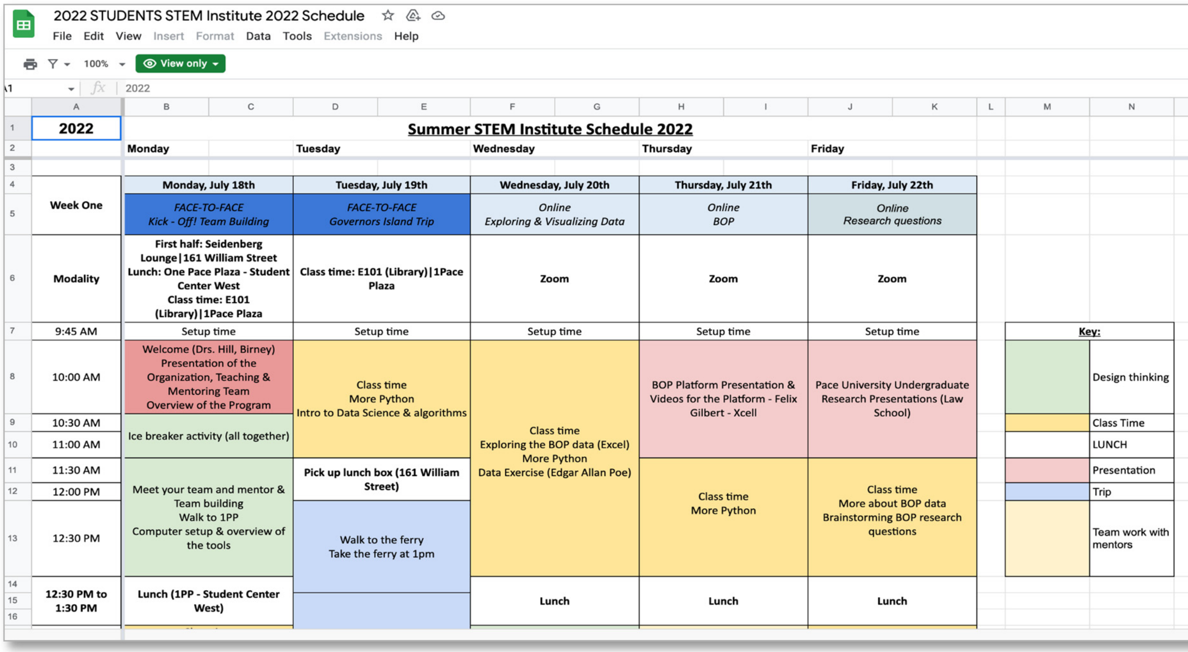

**Figure 2.** The BOP CCERS Digital Platform

## 2. Methodology

Measurement of outcomes from the Summer Institute in 2022 was conducted through survey research by Gaylen Moore Program Evaluation Services, which served as a consultant for the STEM+C National Science Foundation (NSF) grant project. Teachers and students engaged in hands-on experiential learning activities with focus on learning science through ecology and harbor restoration in the New York City Harbor. In particular, oyster restoration was a theme and focus for this work since oysters have an important role through cleaning pollutants in the New York Harbor. It should be noted that the Summer Institute in 2022 was able to be conducted in-person unlike the previous year due to the COVID-19 pandemic which were both online and hybrid.

Student and teacher surveys were used to gather data on the experiences participants had during the Summer Institute in 2022. There were 24 student participants who completed the student survey that was designed to measure student learning and engagement during the program, and 24 teacher participants who completed the teacher survey that was designed to measure skills teachers gained in content and experiential and pedagogical learning. The student survey had a 5-point Likert scale ranging from strongly disagree to strongly agree and the teacher survey had a 6-point Likert scale ranging from strongly disagree to strongly agree. The survey instrument was created by Gaylen Moore Program Evaluation Services, which has decades of experience in survey design and implementation. The survey instrument's validity and reliability were determined by STEM experts on the project, and was designed to measure the effectiveness of the Summer Institute's impact on student STEM content and experiential leaning and teacher content and pedagogical knowledge.

*The Summer STEM Institute* at Pace University website can be found here: https://www.pace.edu/seidenberg/academics/pre-college-summer-programs/stem-summer-institute


2022 STUDENTS STEM Institute 2022 Schedule

**Summer STEM Institute Schedule 2022**

| 2022 | Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|---|
| | Monday, July 18th | Tuesday, July 19th | Wednesday, July 20th | Thursday, July 21th | Friday, July 22th |
| Week One | *FACE-TO-FACE Kick - Off! Team Building* | *FACE-TO-FACE Governors Island Trip* | *Online Exploring & Visualizing Data* | *Online BOP* | *Online Research questions* |
| Modality | First half: Seidenberg Lounge\|161 William Street Lunch: One Pace Plaza - Student Center West Class time: E101 (Library)\|1Pace Plaza | Class time: E101 (Library)\|1Pace Plaza | Zoom | Zoom | Zoom |
| 9:45 AM | Setup time | Setup time | Setup time | Setup time | Setup time |
| 10:00 AM | Welcome (Drs. Hill, Birney) Presentation of the Organization, Teaching & Mentoring Team Overview of the Program | Class time More Python Intro to Data Science & algorithms | Class time Exploring the BOP data (Excel) More Python Data Exercise (Edgar Allan Poe) | BOP Platform Presentation & Videos for the Platform - Felix Gilbert - Xcell | Pace University Undergraduate Research Presentations (Law School) |
| 10:30 AM | Ice breaker activity (all together) | | | | |
| 11:00 AM | | | | | |
| 11:30 AM | Meet your team and mentor & Team building Walk to 1PP Computer setup & overview of the tools | Pick up lunch box (161 William Street) | | Class time More Python | Class time More about BOP data Brainstorming BOP research questions |
| 12:00 PM | | Walk to the ferry Take the ferry at 1pm | | | |
| 12:30 PM | | | | | |
| 12:30 PM to 1:30 PM | Lunch (1PP - Student Center West) | | Lunch | Lunch | Lunch |

| Key: | |
|---|---|
| | Design thinking |
| | Class Time |
| | LUNCH |
| | Presentation |
| | Trip |
| | Team work with mentors |

**Figure 3.** 2022 Student STEM Institute Schedule

## 3. Results

The results of this study fall into two areas: student results and teacher results. The study intended to measure and understand the outcomes obtained by both student and teacher participants in this study. Please see Table 2 for a summary of results.

### *3.1 Student Results*

The findings in this study revealed that after engaging in activities during the Summer Institute in 2022, students reported improved knowledge about oysters and gained oyster restoration skills. Moreover, students reported gaining improved scientific skills and knowledge about oyster restoration, which includes collecting and analyzing data. It was found that participants in the activities had a statistically significantly higher level compared to the control group of students with average response 0.24 points higher than a control group. In particular, 73 percent of students agreed with the statement, *I know about careers in marine, engineering, and environmental science by participating in this activity*.

Students also reported gaining a better understanding and knowledge about STEM careers, which was reported by nearly half of participants and almost three-quarters indicated agreement with this or possible agreement. In addition, participants indicated more knowledge about marine, engineering, and environmental science careers than the comparison group with an average response that was 0.28 points higher.

### *3.2 Teacher Results*

After participating in the Summer Institute, participating teachers reported that the experiences had a positive impact on their content knowledge and in particular gained skills in harbor restoration, which was reported by nearly three-quarters of teachers. Teachers also reported gains in pedagogical knowledge needed in order to engage students using hands-on experiential and scientific learning, and learned valuable skills with engaging and motivating students. Teachers also reported that the activities helped them better understand how they could encourage and expose and support their own students in exploring STEM career options, and over half of the teachers indicated this as a main motivation for them engaging in the program. Almost all teachers indicated the project helped them motivate their students to go into STEM careers. It was found that almost 9 out of 10 teachers (88 percent) indicated they would use program lessons, activities, and materials in their own classrooms. Teachers indicated between agree and strongly agree in regard to learning how to better teach students how to conduct research.

**Table 2.** Summary of Results after Summer Institute

| Student Results | Teacher Results |
|---|---|
| Improved knowledge about oysters and oyster restoration skills. | Positive impact on content knowledge especially related to harbor restoration. |
| Improved scientific skills. | Positive impact on pedagogical knowledge including engaging and motivating students with hands-on experiential learning. |
| Improved collection and analyzing of data skills. | Learned how to better expose students to STEM career options and motivate students to pursue STEM careers. |
| Gained better understanding and knowledge about STEM careers | Would use program lessons, activities, and materials in their own classrooms. |
| Gained better understanding and knowledge about marine, engineering, and environmental science careers in particular. | Learned how to better teach students how to conduct research. |

## 4. Discussion

Overall, the findings in this study revealed that students indicated improved oyster knowledge and restoration skills, scientific skills, collecting and analyzing data, and knowledge about STEM careers. Participating teachers indicated a positive impact on their knowledge of content and harbor restoration, pedagogical knowledge used to engage students in hands-on scientific learning, and methods of engaging and motivating their own students. Additionally, it was found that teachers indicated a positive outcome for exposing their students to STEM career options.

The results of the study are encouraging for future summer programming for high school students and teachers. Previous research had found the connections between hands-on experiential learning activities and student interest and learning in STEM (Birney et al., 2021a, 2021b, 2022; Brandt, 2016; Hoskins, 2019; Plank, 2017; Wilcox, Cruse, & Clough, 2015). Grant funding had provided the needed resources to provide both the professional experiences for teachers and learning opportunities for students. Sustained and long term funding is needed to provide the momentum for the current cohort of teachers and students, along with future teachers and students.

The results indicated the importance of real world experiential learning in authentic activities, supporting a curriculum embedded with knowledge and skills (Newhouse, 2016). Furthermore, as indicated in student surveys, students were able to gain better knowledge of the field of STEM and make connections with STEM careers. Through student and teacher interactions, students gained a deeper understanding of STEM careers. In this immersive learning experience, students developed a holistic perspective of STEM careers due to authentic active learning. This directly supports and brings light to the sheer importance of self-efficacy, which in turn drives student motivation. Bandura (1987,1997) elucidated the positive impact of student and teacher interactions and its influential impact on self-efficacy. Teacher surveys reported the impact of pedagogical knowledge on experiential and scientific learning on student learning. Teachers indicated that throughout the experiential learning activity, students demonstrated an increase in motivation, thereby validating that hands-on activities improves content knowledge and, also importantly, self-efficacy (Nava & Park, 2021).

As evidenced from student surveys, it is clear students learned more from doing and being actively engaged. Additionally, learning through collaborative work with teachers allowed students to understand a STEM career path. This is a crucial takeaway and it is through real-world learning that students can understand their own work, problem solve, and think critically in order to think and do like scientists and mathematicians think and do. Student work can be viewed on the website https://bopuiprod.azurewebsites.net/technology/stem-institute. Note: Parents/guardians and students gave consent and assent on use of pictures in Figure 4.

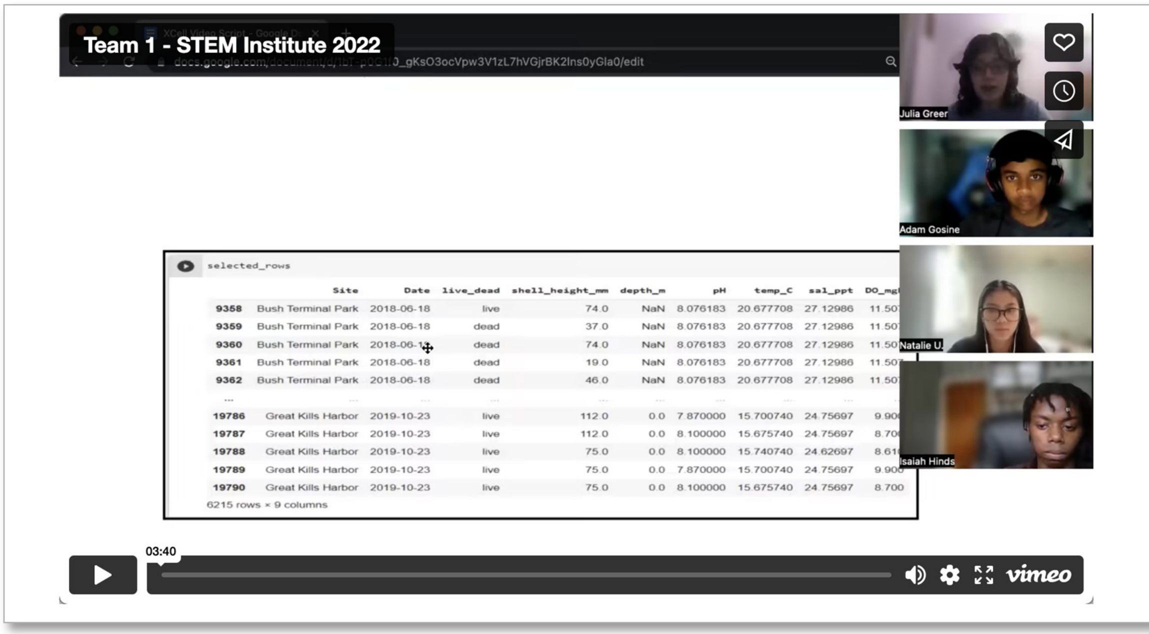



**Figure 4.** Explore STEM Projects

## 5. Conclusion and Implications

As the researchers had found throughout the ongoing experiential learning and hands-on project with teachers and students, experiential learning and engagement with real-world STEM learning have the potential to improve student engagement and interest, teacher knowledge, and stronger pedagogical techniques used in teaching and learning. This method of teaching is connected with previous research in which students engage with science in the manner that scientists operate (Gorghiu & Ancuta Santi, 2016; Hoskins, 2019; Plank, 2017; Tuss, 1996; Wilcox, Cruse, & Clough, 2015). The formula used in this study is the idea that improving STEM content knowledge along with building confidence and interest in STEM careers creates engagement with STEM and leads to better learning outcomes. Additional studies will be needed to follow up on student achievement and success in their science classes along with eventual college major and career.

Overall, the STEM Summer Institute was a great success. The program provided teachers with methods to teach and engage students in oyster restoration in the New York Harbor, build the student knowledge-base of oysters and oyster restoration, develop student research skills through the oyster restoration activities, and learn how to encourage students to use their new skills as an entry point into research. Moreover, the work allows students to see themselves as scientists and develop their awareness and interest in exploring and pursuing STEM careers.

Future research should look deeper into which activities in the Summer Institute had the broadest impact on student engagement and learning. Moreover, specific focus is needed on the types of content knowledge and pedagogical practices that teachers most need in the classroom to support hands-on experiential learning. Finally, longer term studies need to measure the lasting impact of such activities on students and teachers, and to understand how enduring such experiences are for both students and teachers. Nine out of 10 teachers had indicated they would use program lessons, activities, and materials in their own classrooms, and future research should determine if these are implemented and to what degree.

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