The Billion Oyster Project and Curriculum and Community Enterprise for Restoration Science Curriculum: Summary of STEM+C and ITEST Program Impacts on NYC Teachers and Students

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Abstract

For over a decade, the Billion Oyster Project and Curriculum and Community Enterprise for the Restoration of New York Harbor (BOP-CCERS) Educational Program has supported New York City teachers and students through experiential learning in science education. The program has been supported by over $10 million dollars of award support from the National Science Foundation (NSF) and has involved multiple community stakeholder collaborations led by Pace University. Within the University, the initiative spanned three different schools and colleges with collaboration through many academic departments. Two grants in the project have been the Science, Technology, Engineering, and Mathematics plus Computing (STEM+C) and Innovative Technology Experiences for Students and Teachers (ITEST) program. The purpose of this article is to summarize the major impacts this integrated program has had on New York City teachers and students designed to provide teachers with experiential education support and engage students to improve their STEM education and encourage further STEM studies and career pathways. Results from over a decade of programming, vast amounts of data collection and analysis, and multiple research studies have indicated considerable achievements for the program involving both support for teachers and engagement for students. The long-term outcome is improved student STEM achievement and recruitment and retention of diverse students in STEM college programs and careers.

Keywords: STEM education, STEM careers, experiential learning

1. Introduction, Background, and Purpose

The Billion Oyster Project and Curriculum and Community Enterprise for the Restoration of New York Harbor (BOP-CCERS) program has supported New York City teachers and students through experiential learning in science education for over a decade. The program has been supported by over $10 million dollars of award support from the National Science Foundation (NSF) and has involved multiple community stakeholder collaborations led by Pace University. The initiative spanned three different schools and colleges at Pace University with collaboration through many academic departments at the university. Two grants in the project have been the Science, Technology, Engineering, and Mathematics plus Computing (STEM+C) and Innovative Technology Experiences for Students and Teachers (ITEST) program. As the current state of the project comes to an end, the purpose of this article is to summarize the major impacts this integrated program has had on New York City teachers and students designed to provide teachers with experiential education support and engage students to improve their STEM education and encourage further STEM studies and careers. Results from over a decade of programming, vast amounts of data collection and analysis, and multiple research studies have indicated considerable achievements for the program involving both support for teachers and engagement for students. The long-term outcome is improved student STEM achievement and recruitment and retention of diverse students in STEM college programs and careers.

The BOP-CCERS program has been providing programming and development of over 400 of New York City science teachers and approximately 15,000 students over the last decade with a major focus on harbor restoration science in the New York City Harbor. Teachers have learned how to engage students with hands-on and experiential learning that connects science education to ecology and climate change. Participants engaged in oyster restoration, an important element for cleaning pollutants within the harbor. The goal has been two-fold: support teachers in their own development to create engaging, impactful, and interesting lessons and engage students in ways that promote STEM success through achievement, interest, and pursuits in STEM education and careers. The project has been supported by millions of dollars of NSF support through two major grant awards, and has produced considerable data and assessments that provide evidence of the efficacy of the programming and impact on New York City teachers and students. As the project nears its funding completion, the stakeholders are pursuing new ways to continue and fund the program. Moreover, this transition is an appropriate time to provide an overall assessment of the programming that has impacted 800 hundred New York City STEM teachers and thousands of students.

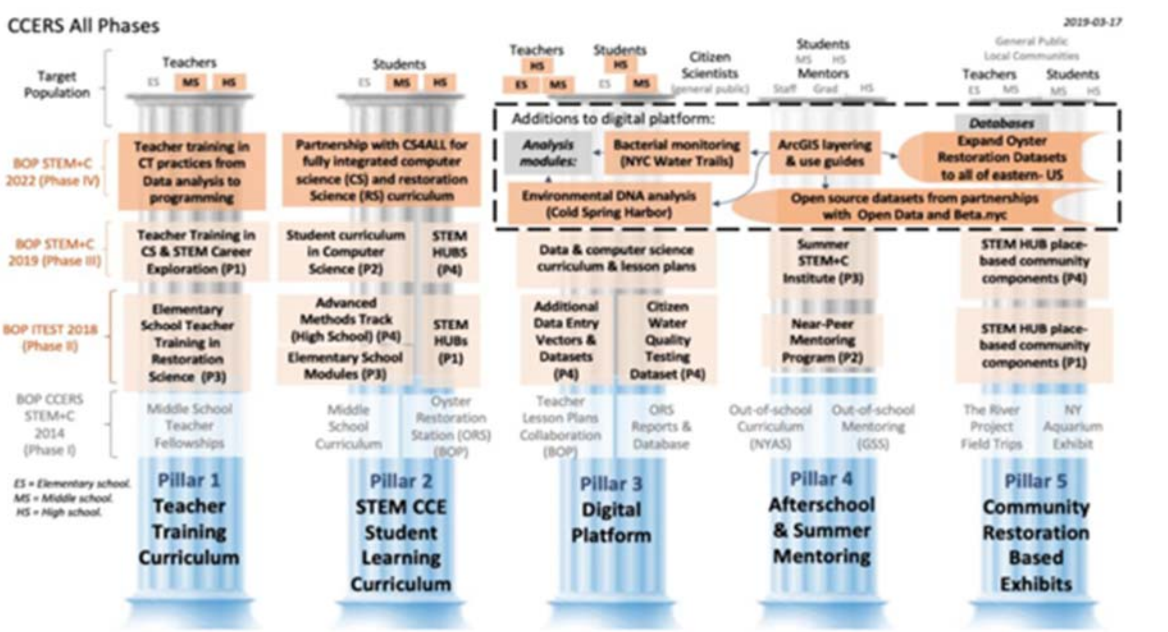

Figure 1. The Five-Pillar Model for CCERS. The five-pillar model for CCERS outlines how the activities of the program work to support outputs. Reference the Phase II row in Figure 1 above for ITEST transitional pillars P1-P4.

A key programming feature was the use of Summer STEM Institutes and Symposia. The Pace University Summer STEM Institutes take place each summer in July. Participants have the opportunity to visit Governors Island, engage in hands-on learning, and students present their final presentations on the last day of the Institute. Students were given the opportunity to use data science methodologies and computer programming skills in Python to answer restoration science research questions. Moreover, students had the opportunity to engage in research symposia throughout the program in which they had opportunities to collaborate on group projects and present their findings to their instructors, fellow students, and other stakeholders in the scientific community.

Another key feature of the program was the creation of a BOP-CCERS Digital Platform, which serves as the central technology hub for the BOP-CCERS. Information that is stored on the Digital Platform includes the following: "Data and Research conducted by the project team, teachers, scientists and students, events and activities supporting the current research, Symposia, trainings and forums, curricula, materials and resources to support teachers in the classrooms, STEM laboratory classroom guides, NY Harbor species identification guides and reporting of project information for the NSF" (Birney et al., 2022). Students learned to use the platform to collect and analyze their data and use technology in a manner in which scientists do. The BOP-CCERS Digital Platform represents a major product outcome of the project and was a key feature for student usage throughout the project along with a focus of the research studies conducted in the program. The Platform allows for global accessibility from any and all communities within the Environmental Science industry, thus, giving populations the capacity to work with one another, engage with each other and ultimately share data, learning experiences and research design modalities.

The project was focused on supporting students who have been traditionally underrepresented in STEM areas and careers. The results have been encouraging with positive outcomes for participants who come from underrepresented backgrounds. A major goal of the project is to encourage and motivate underrepresented students to pursue STEM majors and careers, and to further develop long-term changes in self-efficacy and interest in order to sustain retention in STEM majors and careers.

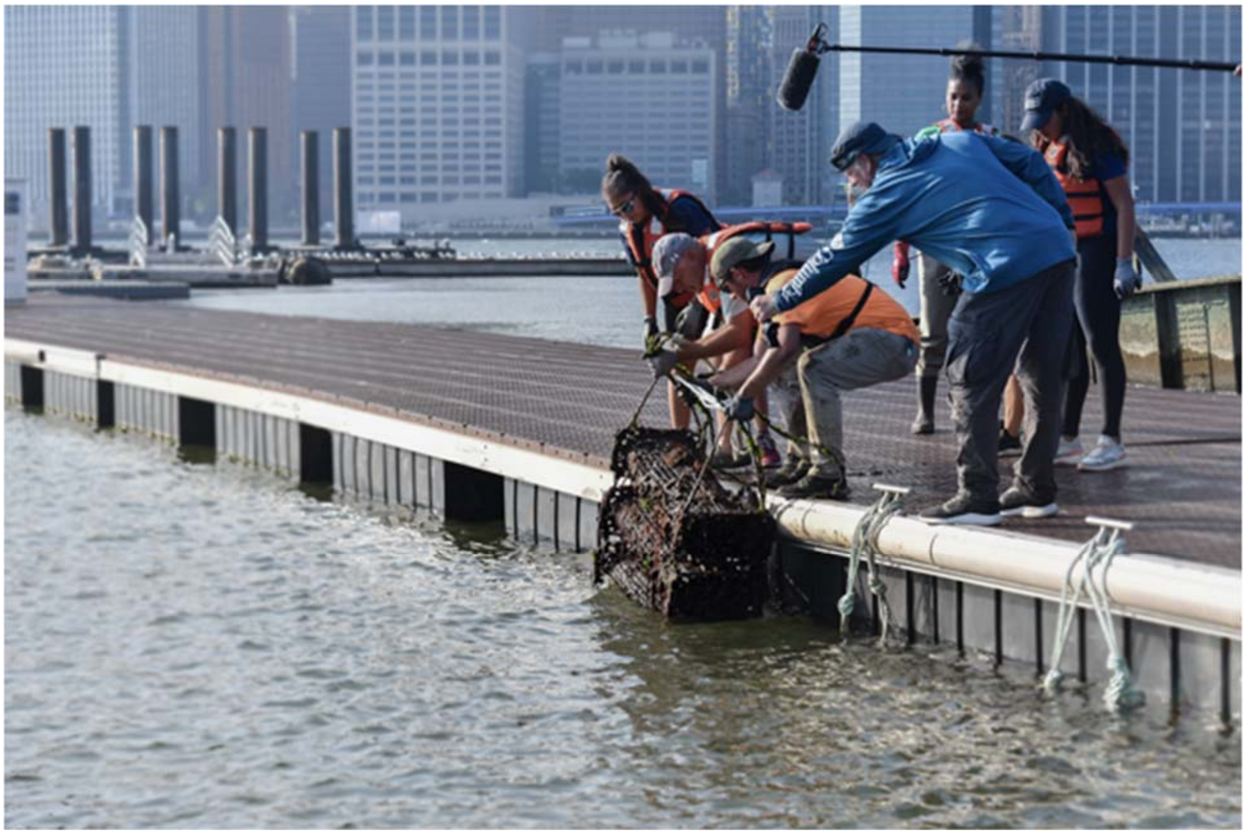

Figure 2. Pulling up Oysters Cages to Collect Data while Filming, New York City

2. Theoretical Framework and Literature Review

The BOP-CCERS project and study (e.g., recent publications such as Birney et al., 2021a, 2021b, 2022) has rested on a theoretical foundation with Bandura's (1986, 1997) self-efficacy and social cognitive theory in which student cognitive and social development occurs through social interactions between students and interactions with the teacher, who functions as a coach or guide for student inquiry. The BOP-CCERS project is grounded by this framework to create a community of learners and develop self-efficacy in line with Vygotsky's (1987) sociocultural theory of learning. This supports collaboration and community-building among the students. Moreover, the line of research relies on building self-efficacy among students and is related to student motivation and engagement (Bouffard-Bouchard et al., 1991; Evans, 2011a, 2011b; Multon et al., 1991; Newton et al., 2012; Pajares, 1996; Schunk 1995). The driving idea behind the project is one 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).

Previous studies have found that students benefit from active learning techniques and activities in STEM courses (Freeman et al., 2014), and in particular, underrepresented students, which was found in a study at the University of Washington (Theobald et al., 2020). Martin-Hansen (2018) found a strong STEM identity is a predictor of future STEM career choice. Moreover, problem-based learning demonstrates positive results in self-efficacy, self-confidence, and interest in learning, suggesting that hands-on learning and field-based experiences increase content knowledge for learning (Nava & Park, 2021). Implementation of real-world learning for STEM skills through problem-based learning has the potential to enhance both creativity and innovation, which supports the utilization of critical thinking, reviewing research, creative thinking in problem-solving, and synthesizing information (Widiyanti et al., 2020). Research on scientific identity has indicated that its development has the potential to improve student motivation to learn science and increase persistence (Estrada et al., 2011; Smith et al., 2015). Vincent-Ruz and Schunn (2018) found scientific identity was directly related to the pursuit of STEM careers. Moreover, it was found this to be particularly true for students from underrepresented groups.

Figure 3. Professional Learning and Trainings, Governor's Island, New York City

The BOP-CCERS project seeks to develop a community of practice that connects STEM dimensions together such as the following: science inquiry, technological literacy, mathematical thinking, and engineering design (Chen et al., 2019). STEM learning is organized around certain elements: ideas, concepts, or themes and can be enhanced through interaction. Kelley and Knowles (2016) found acquiring knowledge of the skill sets alone is not sufficient. Students must learn to use the skills they acquire to solve real-world problems. BOP-CCERS uses authentic real-world activities that provide students with a fuller 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).

Figure 4. New York Harbor, New York Teacher Trainings

3. Methodology

The design of the multiple studies to come out of this project (see Birney et al., 2021b) was through survey research conducted by the National Science Foundation (NSF) grant-funded research and evaluation firm, The Mark, which serves as a consultant for the NSF project. Additionally, Gaylen Moore Program Evaluation Services served as a consultant to conduct program evaluation on the teacher participants in the project, which was done through survey and observational data collection methods.

Multiple facets of the larger study evaluated the experiences and outcomes for hundreds of teachers and thousands of students as it related to experiential learning in harbor restoration and ecology in the New York City Harbor. Experimental/treatment groups were used with control groups of students and teachers who did not receive the programming to measure program impact on participants.

The project used Bybee's 5E model of learning and teaching (Bybee, 2009) that incorporates five ideas: *engage* student interest, *explore* the subject through cooperative activities, *explain* by eliciting articulation of the ideas in the student's own words, *elaborate* by leading activities that help students correct misconceptions and generalize their knowledge, and *evaluate* student understanding and skills. This model was employed with teachers and students who engaged in BOP-CCERS programming and involved learning about harbor restoration through ecological projects in and around New York's harbor and included oyster restoration, an important element for cleaning pollutants within the harbor.

Survey research used a 5-point Likert scale ranging from "Strongly disagree (1)" to "Strongly agree (5)." Lower scores represent lower levels and higher scores represent higher levels. Statistical analysis across the studies of this project was conducted using linear modeling and chi-square analysis and can be found in the previous publications (e.g., Birney et al., 2021a, 2021b, 2022).

Figure 5. Oyster Cage Preparation for the Water, New York Harbor

4. Results

4.1 Student Outcomes

Previous research on the program has demonstrated positive results on student scientific identity, experiential scientific skills and knowledge, knowledge about STEM careers, data collection and analysis, and knowledge about oysters and harbor oyster restoration. A major and impactful finding was on the benefits obtained by students from underrepresented groups in science. Underrepresented students reported having higher levels of interest in STEM and science than did students who did not come from underrepresented backgrounds. Moreover, it was found that initially, underrepresented students had lower expectations for success in STEM courses and interest in STEM careers. It was found that underrepresented students ultimately chose to engage in a greater number of activities in the program compared to students who do not come from underrepresented groups.

An important outcome was the positive impact the program had on scientific identity, which is the students' view of themselves as capable scientists and critical to motivate students to pursue STEM careers. It was found that the 11th grade students saw the biggest impacts on their sense of scientific identity. This indicated that it is possible that future programming should focus on 11th grade students on the development of scientific identity. Findings also indicated that students in the program were more likely to engage in science and read articles and watch videos created by scientists.

Another important outcome was the finding that 9th grade female students had the highest levels of STEM career interest compared to 10th, 11th, and 12th grade students in both treatment and control groups. This indicates that future project focus may be on 9th grade female students when activities are designed to encourage and support students in pursuing STEM careers. Langreo (2012) indicated that female student interest in STEM had significantly declined in the high school years from 17% to 12%. Future research should follow participants to determine if this decline is controlled or even reserved over the high school years.

Figure 6. Oyster Cages at Low Tide in New York Harbor, New York City

These data obtained and analyzed in the large project study will help create focus and impact for future iterations of this project and in particular if resources in future programming are more restricted.

4.2 Teacher Outcomes

Teachers involved in the programming have reported improved content and pedagogical knowledge, ability to teach through hands-on experiential learning, support STEM career options for students, and motivate their students. A significant outcome was that teachers expressed appreciation for learning how to use the Oyster Research Station (ORS), and they were appreciative for use of activities that had increased their own ability to work with students to conduct field research in the New York Harbor and teach students science and ecology through hand-on experiential learning lessons using pedagogical techniques in discovery and inquiry-based learning. Teachers learned how to employ lessons that allowed students to explore as scientists in ways in which scientists conduct their work. This allows students to truly experience the scientific process and encourage the further study of STEM in college and thus pursue STEM-based careers.

An important outcome was the increase in teacher confidence in engaging students in field science. Learning to teach using hands-on experiential learning can be challenging and especially when teachers may not be accustomed to these pedagogies. Teacher confidence is important to support teachers' continuous use in these methods that are both sustaining and effective. Future studies will explore if these methodologies had staying power when the grant-funded project was no longer available to the teachers. Finally, teachers had indicated their enjoyment of the activities and lessons along with the support they received from the BOP-CCERS personnel. They indicated the resources provided were more than adequate, which will be important to follow up on when there are fewer resources for future iterations of the project.

5. Discussion

The results across multiple studies for the BOP-CCERS are quite encouraging. 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). The multiple studies for the larger BOP-CCERS project demonstrate positive impacts on both teacher and student participants. The grant funding over the last decade had provided the needed resources to provide these experiences for teachers and learning opportunities for students. As we are in the end stages of the funding for this program, sustained and longer term funding is needed to provide the momentum for the current cohort of teachers and students, along with future teachers and students. However, findings from these studies indicate the areas in which the greatest impact can be found (e.g., underrepresented students, 11th grade students, and 9th grade females). With more limited future funding, focusing on students that the methods from this project had the greatest impact could direct limited resources in a manner that has significant impact. Post-project research should track both underrepresented students and those who do not come from underrepresented groups as they choose their college majors and career paths in order to determine if the project had a long term impact on recruitment and retention into STEM. Moreover, the staying power of scientific identity for 11th grade students and career interest among 9th grade female students in STEM should be examined in the long term. Results of this long-term project and research study as well as supporting activities, symposia and colloquia have been encouraging so far.

Post-project research should be conducted to determine the staying power in the changes experienced by the teachers as they teach new generations of students with the methods and processes they had learned from their participation in the program. Future research will need to determine if the changes among the teachers who participated were maintained long term, or if those changes were transitory and reduced as time beyond the program increased. It is likely that fewer resources will be provided to teachers, which means determining if the changes from the project can last even with fewer resources.

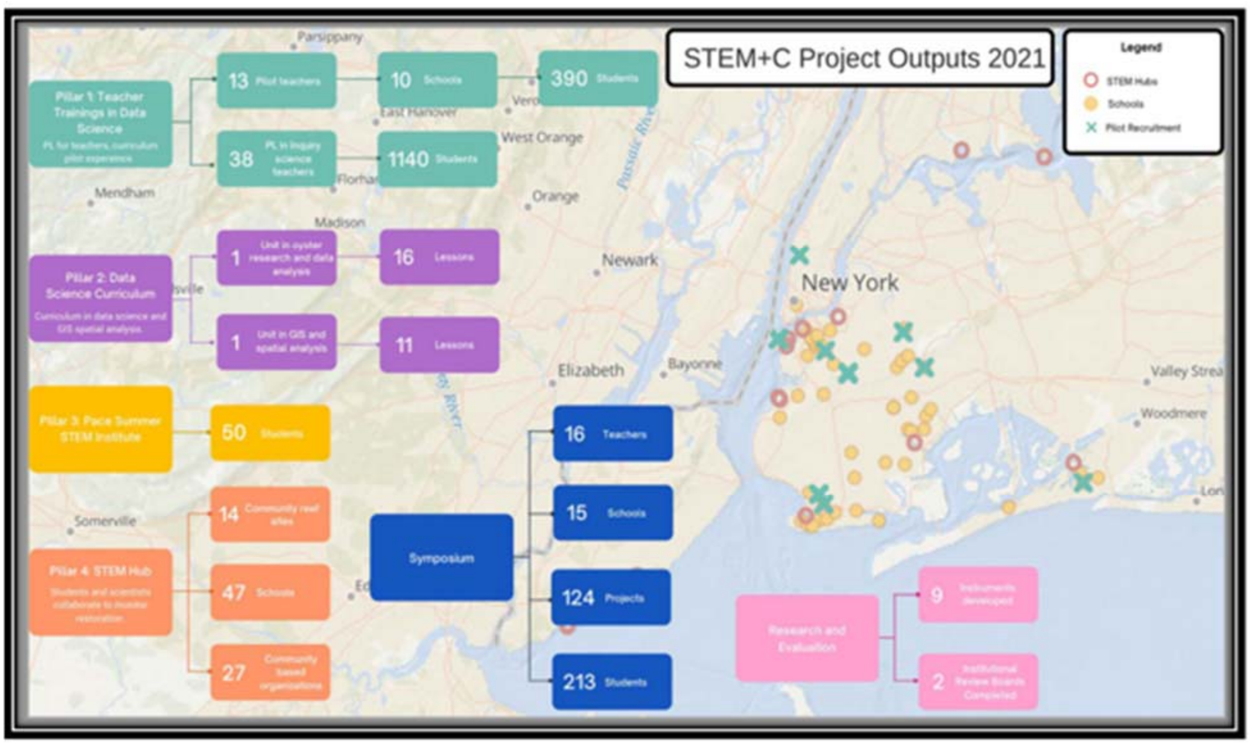

Figure 7. STEM +C Project Outputs 2021

6. Conclusion and Implications

The BOP-CCERS project has been ongoing for over a decade. Hundreds of teachers and thousands of students have participated in project activities and development through innovative pedagogy and hands-on experiential learning through harbor restoration and ecological protection. These activities and programming bring science to life for students and teachers, and the vast amounts of data have provided evidence of the program's efficacy. It is anticipated that as the funding lifecycle for the program comes to an end, there will be fewer resources supporting this work going forward. However, the evidence of success for the program does two things. 1) It provides considerable data and support for additional funding for this project and projects like it. This allows the program to expand to other locations outside of the New York metropolitan area. 2) The data collection and analysis has allowed the research team to understand where to place limited future resources and which profile of student on which the program has the greatest impact. The researchers have evidence on the activities and events that had the highest levels of impact upon students and teachers.

Figure 8. Oyster Cage Management, Data Collection and Research

Next steps for the project will be to track a sampling of teachers and students who participated in the program to gather a longitudinal sense of the long-term implications of the project. The purpose of the BOP-CCERS project was to connect teaching and learning to the restoration of New York Harbor to create positive educational and career outcomes for the students. While the results of the study have been promising to date, the researchers will need to understand the implications for both teaching and learning over time.

Funding for this project has been provided by corporate partners, STEM Industry leaders, non profit organizations, community based organizations, affiliated foundations as well as federal and state STEM related grants. The program has received increased visibility over the last ten years and continues to build itself with Global Partnerships. In September 2023, Prince William of the United Kingdom visited the project during the New York City Climate week 2023. During his visit, Prince William put on his waders to delve deep into the water to enjoy the full oyster experience in New York Harbor. He also visited the laboratories associated with the project, spoke with staff, scientists, faculty and students in addition to enjoying a boat ride throughout the Harbor to visit the STEM Research Hubs created by the project.

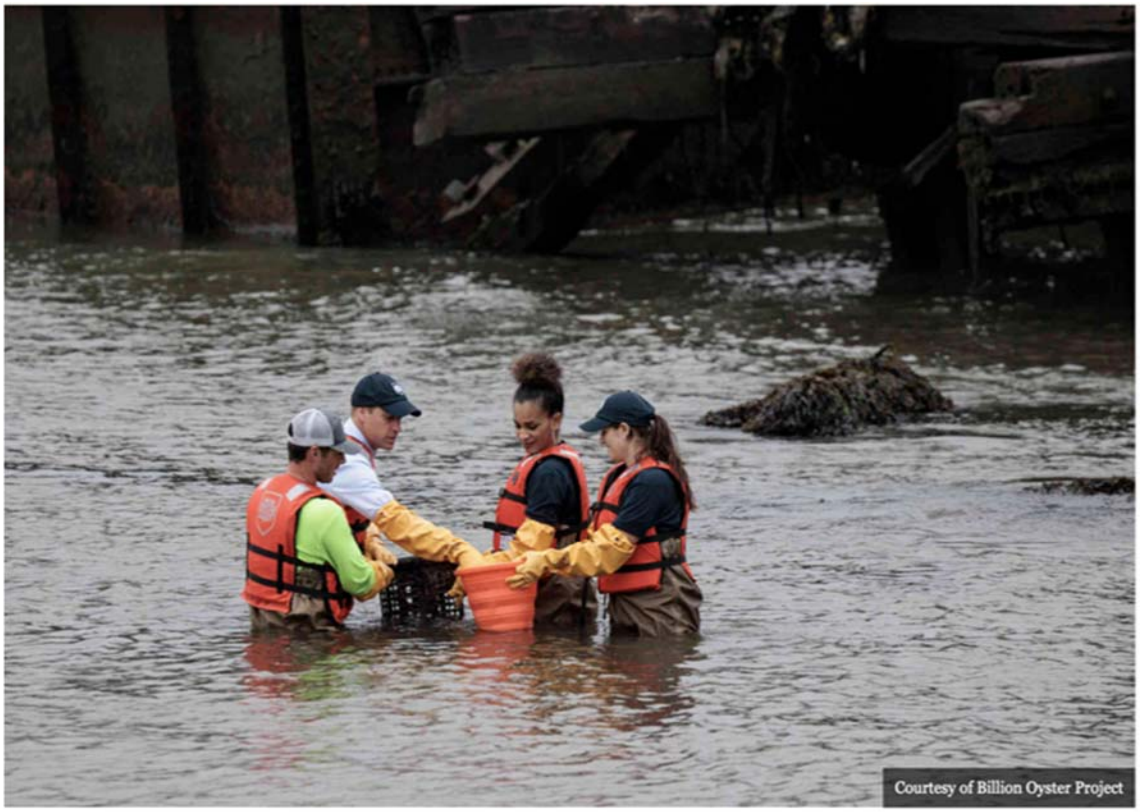

Figure 9. Prince William Visits Billion Oyster Project September 2023

Figure 10. Prince William on Governors Island, New York City

The BOP-CCERS Project continues to grow, flourish and create significant impacts in New York City. The intention of this project is to create a replicable model in other locales that face their individualized local issues. This educational model will hopefully serve as a template in which others can manufacture impactful learning, teaching, creative and innovative programs, experiential learning activities, localized exhibits, scientific studies and creating a community of togetherness unified and focused on making change!

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