The Benefits of Informal Learning Garnered Through Participation in the Curriculum and Community Environmental Restoration Science (STEM + Computer Science) Project

Lauren Birney[1,*] & Denise M. McNamara[2]

[1]School of Education, Pace University, New York, United States

[2]The College of Staten Island, United States

*Correspondence: School of Education, Pace University, New York NY, 10038, United States. Tel: 1-212-346-1512. E-mail: lbirney@pace.edu

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Abstract

The Curriculum and Community Environmental Restoration Science (STEM + Computer Science) Project has several goals, with its primary focus on connecting the students of New York City with the enormous potential of restoring New York Harbor to its former self. Through the collaboration of numerous partners representing all of the facets of the city to the marginalized students living in hundreds of under-resourced communities, out-of-school experiences such as participation in the annual Science Symposium and the environmental fieldwork conducted along the shores of New York Harbor flourished. The CCERS STEM + C Project enables the merging of these entities for the good of its participants and the enormous benefit to the environment's restoration. This study consists of student surveys administered to and completed by 513 students attending schools throughout New York City's five boroughs. Of those who responded to the ethnicity section of the survey, 43.7% represent minority students. Data indicated a significant increase in STEM motivation by the CCERS STEM + C participating students, particularly those who identify as members of the under-represented minority group.

Keywords: informal learning, field research, environmental science, science symposium, authentic STEM/Science research, restoration HUB

1. Introduction

The Curriculum and Community Environmental Restoration Science (STEM + Computer Science) Project, hereafter known as the CCERS STEM + C Project, is an extension of the Billion Oyster Project - Curriculum and Community Environmental Restoration Science Project conducted from 2014 through 2018. The project's crux is to create an ecosystem restoration and education project designed to restore one billion live oysters to New York Harbor. Participating New York City Schools and Community Science Partners seek to increase underrepresented groups' skills, content knowledge, and confidence in STEM through hands-on, authentic restoration and research activities. Schools, organizations, businesses, and community scientists each get a waterfront Oyster Research Station and a small cage filled with oysters, which they use to collect data on oyster growth and mortality, local biodiversity, and water quality. The project has five pillars (See Figure 1), one of which is the Digital Platform, an open-sourced online dashboard. Through the Platform, students and teachers enter and publish data, develop field research projects, and create the STEM curriculum that links keystone species restoration in New York Harbor to teaching and learning in New York City Schools. The CCERS STEM + C Project expanded on the original by integrating computer and data science into oyster restoration research in New York Harbor. A vital component of the project's growth is the expansion and development of restoration STEM Hubs in the New York Harbor that include Coney Island, Brooklyn Bridge Park, Bush Terminal Park, Canarsie, and other sites where the project maintains oyster reefs and oyster research stations to monitor oyster restoration (See Appendix A). The Hubs support field research experiences for the students at sites throughout the New York Harbor and provide opportunities for authentic STEM research.

The field research conducted by the students is both significant and beneficial in several respects. Students are indoctrinated into informal learning, an integral part of lifelong learning. Students acquire attitudes, values, skills, and knowledge from the educational influences and resources in the environment and from the experiences they encounter as members of the CCERS STEM + C Project. In addition to the fieldwork conducted by the students, working alongside their teachers, field researchers, and environmental scientists is The Billion Oyster Science Symposium. At the end of each school year, this culminating event is the keystone experience used to highlight the original environmental science research projects conducted by individual students in the program. Many of these projects help students link pressing environmental issues to social justice issues in their communities, potentially motivating students in STEM-related careers. There is more emphasis on the personal, hands-on, collaborative, activity-based joys (and difficulties) associated with the process of informal production and less emphasis on a standard product as an end in itself (Golding, Brown & Foley, 2009).

1.1 Why Is This Important?

In the book, "Experience and Education," Dewey (1938) introduced experiential education as the foundation of the educational process, highlighting the acquisition of experience. He promoted concepts such as experimentation, purposeful learning, freedom, and social and interactive learning processes, which make education more progressive. According to Dewey, the quality of experiential education is vital, and experiential education should be an interactive process between teachers and students, infusing direct experience into the learning environment and content. Environmental undertakings, such as sustainability and restoration projects, lend themselves to informal education. Since most living environments exist outside manufactured structures, the nexus of informal, life-long learning and environmental restoration science is unmistakably apparent. Informal education has the potential to provide students with the skills, competency, and empowerment to thrive as environmental stewards in an ever-changing landscape. This type of informal education can support and supplement students' formal education in the classroom. Throughout the ongoing evolution of environmental education, informal education is an essential framework for conducting education for sustainability. At the secondary level of schooling, much of the work of environmental education is centered on environmental citizenship and stewardship. The informal setting provides students with both the knowledge base and the skills needed to foster them as advocates for a sustainable environment and as agents of change for the future.

Table 1. Possible Ideal Types of Formal and Informal Learning (Colley, Hodkinson & Malcolm 2002)

FORMAL	INFORMAL
Teacher as authority	No teacher involved
Educational premises	Non-educational premises
Teacher Controlled	Learner Controlled
Planned and structured	Organic and Evolving
Summative Assessments	No Assessments
Propositional knowledge	Practical and process knowledge
Fixed and mediated timeframe	Open-ended engagement
Learning predominantly individual	Learning predominantly communal
Learning to preserve the status quo	Learning for resistance and empowerment

1.2 Relevant Scholarship

Pedagogies, including place-based education, civic ecology education, eco-justice pedagogy, and socio-scientific inquiry-based learning, can build students' competencies for the deep civic participation necessary to realize environmental and social change. Studies investigating the ecological perspective of science learning, both in and out of the school setting, found that these environments provide everyone, regardless of background, with opportunities to learn (Corin, Jones, Andre, Childers, & Stevens, 2017). Within an educational ecosystem, learners construct unique learning pathways guided by personal goals and supported by a plethora of social, cultural, and physical factors, including activities and resources with which the learner can engage to support their interests and learning goals (Bathgate, Shunn & Correnti, 2014). This study found that compelling STEM out-of-school experiences:

1. Contribute to young people's interest in and understanding of STEM,
2. Connect young people to caring adults who serve as role models
3. Reduce the achievement gap between young people from low-income and high-income families.#

Many national philanthropic foundations, federal programs, and statewide education systems provide STEM learning outside the traditional classroom setting. These have become pivotal education opportunity alternatives for out-of-school learning and lifelong learning. In addition, they positively affect the experiences in the classroom. Informal STEM learning needs to be undertaken with sensitivity to the young people historically underserved by STEM learning programs, including girls, ethnic minorities, and economically marginalized communities (National Research Council, 2009). Linking informal learning to the student's life experiences in their communities is an effective civic and environmental engagement method.

Every community has a unique set of learning resources available to students. Visits to nature centers, zoos, museums, and gardens all qualify as informal learning settings and contain unique opportunities for educational experiences. New York City is no exception and is home to abundant informal learning opportunities. Home to over 1,700 parks, 80 museums, 30 nature centers, five zoos, and one aquarium, informal learning opportunities abound. The most populous city in the United States, New York City, is where the Hudson River meets the Atlantic Ocean. Home to one of the world's largest, most diverse natural harbors, New York was once known as the "Oyster Capital of the World" and had as many as 220,000 acres of oysters in the 1600s. Through over-harvesting and massive pollution, New York Harbor was nearly lifeless by 1906, with the last commercial oyster beds closing in 1927 (Kurlansky, 2006). Several attempts have been made to restore the water quality of New York Harbor, with the Clean Water Act of 1972 (USEPA, 1972) having an enduring and sustainable impact. Efforts to restore the aquatic life have also been met with varying success. The Billion Oyster CCERS STEM + C Project is arguably the effort that has been met with tremendous success, restoring aquatic flora and fauna that had yet to be seen in many areas of the Harbor for decades.

Productive out-of-school programs provide compelling, responsive, and connected learning experiences in STEM. They allow students to understand STEM as a cooperative, socially significant endeavor that is both relevant and vital to the community in which they live. A collaborative approach can promote institutional support of science outreach programs with local community partners and foster university-community relationships. Of utmost importance in STEM education is to close the achievement gap that affects diverse populations by providing culturally inclusive strategies. An essential goal for transforming education is undoing the inequities in the system and fully engaging with the entire community being served (Haynes-Mendez & Engelsmeier, 2020). Informal setting is part of this solution in the field of STEM. Project-based learning includes scientific inquiry, mathematical calculating, and engineering design (Wan, So & Zhan, 2020). The student-centered approach to problem-based learning is central to informal learning and helps to promote student empowerment, self-efficacy, and voice (National Research Council, 2015). Some of the opportunities provided in informal settings are:

1. Authentic Science/STEM Research
2. STEM Exhibitions, Competitions & Fairs
3. Citizen Science Fieldwork Opportunities

Various environmental, biological, and physical scientific goals can be addressed by inviting the public to join collaborative research projects through citizen science. Citizen science has the potential to significantly impact informal education by providing an avenue for the public to contribute to scientific research while also enhancing their understanding of the natural world. One of the critical aspects of citizen science is the opportunity for individuals to learn from their peers. In many citizen science projects, participants collaborate in teams to collect data, share their findings, and collaborate on project goals. By working in these collaborative teams, participants can learn from each other's expertise and knowledge (Hsu, Kao & Chai, 2023).

Research supports the idea that hands-on learning in informal, out-of-school settings has strong motivational effects (Braund & Reiss, 2007). The effect on learning has proven to be meaningful (Salmi, Kaasinen & Suomela, 2016), and there is clear evidence that such hands-on pedagogy promotes a positive attitude towards STEM (Thuneberg, Salmi, & Fenyvesi, 2017) and STEM careers. The problem-based activities of the BOP-CCERS project, including hands-on data collection and analysis, provide an opportunity for students, significantly underrepresented students from schools with less access to resources to experience STEM positively. Upon examination of after-school programs, several studies found that they enhance STEM skills (Alexandre, Xu, Washington-Nortey & Chen, 2022a). Two factors attributed to the success of after-school programs for enhancing STEM learning are the program's duration and quality (Burke, 2020). Sufficient resources and a strong foundation are also crucial for success. Investing in after-school programs also improves student outcomes (Santhosh et al., 2023). Support for the staff and the amount of professional training for staff and others who help with the after-school programs is also a factor in student outcomes. Positive STEM outcomes were also reported when after-school programs created meaningful content connections for students, such as opportunities to interact with actual artifacts (Paraskeva-Hadjichambi et al., 2020). This systematic review confirms the importance of informal learning for children's STEM knowledge and skills development, as supported by the existing literature (Bell, Lewnstein, Shouse & Feder, 2009).

Grassroots initiatives by CCERS STEM + C successfully spark community involvement through scientific outreach. Communicating environmental restoration principles effectively to preK-12 school students through informal and formal immersive teaching is possible even within a virtual setup. With the incorporation of teacher feedback and critical self-reflection, we are improving our materials for broader distribution as the program continues to expand. (Luecke, et al., 2023). The long-term objective of the model aims at broader, more systemic outcomes whereby students are encouraged and equipped to pursue meaningful, viable STEM career pathways beginning in elementary school and continuing in concrete ways through the middle and high school curricula. BOP-CCERS is grounded in theories of place-based learning to motivate and empower underrepresented communities in particular and help schools make the necessary connections between formal curriculum and students' lived experiences (Calabrese-Barton & Berchini, 2013).

The Community Based Restoration Hubs are in place and functional. These are six regional oyster reef restoration sites located across New York Harbor in which middle and high school students work directly with professional researchers and scientists to monitor the progress of ongoing restoration and their own smaller, situated experiments. The community-based oyster restoration sites, STEM Hubs, offer students hands-on, experiential learning opportunities to collect data on oyster growth and water quality (See Appendix B). The work done in this pillar (Pillar V) connects the project and student learning outcomes to the community. Not only does this promote science education in the broader community, but it also helps support student learning in their daily environment. The hubs provide a geographical focus, physical space for local schools to work with scientists and graduate students, and technical learning focus around particular environmental monitoring methods and technologies employed at a particular site. Hands-on technical workshops are held at nearby shoreline facilities or laboratories. Place-based education, which occurs at the HUB field stations, engages students in cross-curricular or multidisciplinary methods, where knowledge is co-constructed through hands-on, real-world learning experiences (American Institute for Research, 2005). Field days and workshops have been held with community-based organizations (CBO) and schools at several STEM Hub locations. These oyster restoration sites have been instrumental in extending the environmental restoration project through dedicated field work and show the reach of Pillar V and its influence in the community (See Appendix 1).

Scientists, educators, and youth development experts from Pace University, public colleges and universities in New York, Columbia University, University of Maryland, New York Academy of Sciences Good Shepherd Services, and The River Project collaborated in a joint effort to create and implement low-budget restoration science-based STEM+C curriculum for after-school and summer school settings in underserved communities. Based on factors such as students' ages and backgrounds, collaborators tailored out-of-school lessons to enhance and reinforce students' in-school learning experience, especially for those from groups underrepresented in science (Kricorian, Seu, Lopez, Ureta & Equils, 2020). Pairs of after-school educators and scientist-mentors lead after-school programs, summer camps, and oyster clubs and require fewer resources than in-school programs. Students learn about oysters, science, and the history of New York Harbor by participating in hands-on and stimulating activities to facilitate learning.

Many informal science learning programs allow participants to engage in authentic science (Flowers & Beyer, 2016). The significant components of authentic science research include students' connection to real-world science and to pertinent environmental or social issues that affect them. Student-directed research is a powerful tool to promote cross-disciplinary content and 21st-century skills such as problem-solving, leadership, collaboration, and communication (An & Mindrila, 2020). Students were exposed to BOP programming and field science activities and used BOP data to answer their research questions. Students had Pace University student mentors and guidance from restoration scientists who helped inform their work. Students could interact with current Pace undergraduate students, data scientists, restoration scientists, and professionals from the industry to be exposed to university life and career opportunities in STEM. Giving the students access to undergraduate mentors helps promote science self-efficacy and social integration into the science community, particularly among under-represented minority students (Estrada, Hernandez & Schultz, 2018). Authentic research experiences allow students to enact a STEM identity and make their competence visible to others. Engagement in authentic research (performance) contributes to gains in the mastery of skills and practices of science (competence), including data collection and analysis, experimental design, and the ability to communicate the findings of the investigation (Thirty, Weston, Laursen & Hunter, 2012). Participants operationalize their science identity in three ways: (1) by engaging in rigorous research (performance); (2) by gaining mastery of the skills required to self-direct their learning (competence); and (3) by communicating their research to scientists, educators, and to the public at large at a culminating public poster presentation held in one of the museum halls (recognition) (Habig & Gupta, 2021).

The New York State Science Learning Standards (New York State Education Department, 2016) include student performance expectations. In the three-strand approach to science, engineering and science practices compose one strand. This strand includes asking questions and defining problems, using mathematics and computational thinking, planning and carrying out investigations, analyzing and interpreting data, and obtaining, evaluating, and communicating information. These skills are necessary for developing and presenting a science fair project, which provides students with opportunities to develop and strengthen these abilities in an authentic and dynamic setting.

The Annual Research Symposium is a celebration and scientific meeting for students of all ages and adults who study oysters and NYC's waters to present their research to fellow researchers and visiting scientists. For many students, the BOP Science Symposium represents a vital opportunity to interact with practicing environmental scientists. It also provides a unique setting for students to meet peers from various schools and backgrounds with similar interests. Through these interactions, students can discuss their research and theories and, from there, may revise the original plan for further experimentation. The BOP Science Symposium represents a partnership between science-rich organizations with a wealth of experience and resources in preparing teachers and students to perform science research. Pace University, the New York Academy of Science, the Lamont-Doherty Earth Observatory, the Hudson River Project, the New York Aquarium, and the City University of New York are among its many partners.

A study measuring the efficacy of high school science fairs/symposiums (Grinnell, Dalley & Reisch, 2020) found that approximately 60% of the more than 300 students who competed in fairs and symposiums in 2017 and 2018 expressed interest in a career in science or engineering. They also indicated that participating in science fairs increased their interest in science or engineering. As students navigate through the initial process of selecting a problem, developing a hypothesis, designing and implementing experiments to answer the question, analyzing and drawing conclusions from the experiments, and explaining the findings to others through interviews, poster presentations, and experimental design while preparing for a science fair or symposium, they experience the challenges and rewards associated with the practice of science (McComas, 2011).

Experiential education through the action of external communities has become a key factor for students to gain experience and knowledge and foster a positive attitude about the environment (Kensler & Uline, 2017). Experiential communities, such as the partners in the CCERS STEM + C Program, play a vital role in students’ environmental awareness and appreciation and might also reduce the gap between what they learn in school and what real life demands from them (Robina-Ramirez & Medina-Merodio, 2019). Experiential learning at formal and informal field trip venues increases student interest, knowledge, and motivation (Behrendt & Franklin, 2014). Moreover, field trips build connections between the local community and science to enhance the relevance of learning to students’ lives (DeFelice et al., 2014).

Students who have been historically under-resourced in STEM tend to refrain from entering symposiums and fairs. Students who conduct high school research and participate in national and international science fairs receive substantial experiences that catapult them into STEM fields. A direct relationship exists between students' STEM after-school clubs, science fair participation, and their college STEM major choice (Todd, 2022). Community exhibits complement and extend the learning of science, restoration efforts, and related history. Finally, they are also created for the general public, educating about oysters and biodiversity in the local environment. Community exhibits simultaneously promote the program and drive students, educators, and the general public toward the digital Platform for more sharing.

The CCERS program takes a comprehensive approach to student learning and growth. It consists of five original education-resource pillars that function in combination and independently of each other to support middle and high school student learning and teacher training in five physical settings. In all five pillar settings, the beneficiary population is primarily middle and high school students who live in high-poverty neighborhoods of New York City and are traditionally underrepresented in the STEM fields, including African Americans and Latinos, English language learners, and children from economically disadvantaged households.

To accomplish the original five pillars of the CCERS model, research and evaluation teams determined transitional pillars specific to unique program phases. The 2018 ITEST project (Phase II) has four unique transitional pillars (Pillar I-Pillar IV) and is illustrated in the original CCERS model. As shown below, the model has expanded over the years through different phases made possible by NSF funding.

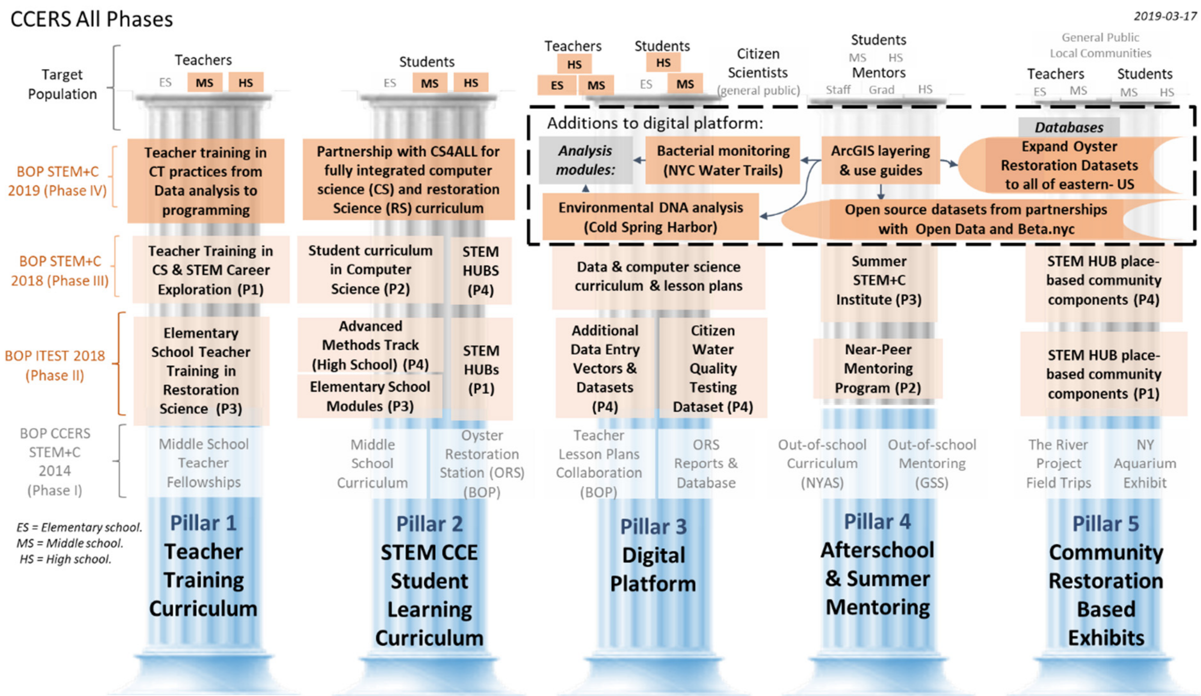

Figure 1. The Five Pillars of the CCERS STEM + C Project Outline How the Activities of the Program Work to Support Outputs

1.3 Hypothesis

a. All students participating in the CCERS STEM + C Project's Oyster Restoration Hub activities and the Science Symposium (informal education) will develop increased motivation and engagement in STEM.

b. Students who identify as URM and participate in the CCERS STEM + C Project's Oyster Restoration Hub activities and the Science Symposium (informal education) will develop increased motivation and engagement in STEM.

2. Method

A student survey instrument was used containing:

(a) Motivation to pursue STEM careers subscale

(b) Preparation for STEM careers subscale

(c) Engagement with scientists

Instrument refinement was conducted Using an existing survey to increase the response rate by reducing participant burden and time required to complete all necessary survey steps. Data collected from previous phases of the project were used to conduct item reduction analysis. The primary goal of this analysis was to obtain functional items (i.e., items that are correlated with each other, discriminate between individual cases, underscore single or multidimensional domains, and contribute significantly to the construct). The researchers determined the effect of deleting a given item or set of items by examining the item information and standard error function for the item pool. Key project personnel evaluated the refined instrument for content relevance, representativeness, and technical quality.

2.1 Measuring Key Constructs

Two key constructs were the foci of this research: motivation and preparation to pursue STEM careers. In order to measure motivation to pursue STEM careers, researchers used the following:

a. Scientific identity was used due to its effectiveness in predicting persistence in STEM careers for K-12 students. Scientific identity can be broadly defined as the aspects of the self that relate to science. Individuals who highly identify with science are more likely to make decisions that validate that identity and may be better able to maintain their motivation to persist in STEM fields. Respondents answered four questions on a Likert scale with ratings from 1=strongly disagree to 5=strongly agree regarding their scientific identity. Cronbach's alpha was run to examine internal validity, resulting in a score of.80, indicating good internal validity levels in the scientific identity subscale. Items were averaged to compute an index, with higher average scores representing higher scientific identity.

b. Students' STEM career interest was used due to a plethora of research identifying STEM career interest as a strong predictor of motivation and persistence to pursue STEM careers. Respondents answered two questions on a Likert scale with ratings from 1=strongly disagree to 5=strongly agree regarding their interest in pursuing careers related to STEM. Items were averaged to compute an index of career interest.

c. Preparation for STEM careers was measured using engagement as a proxy variable. Engagement was chosen as a proxy because research has long demonstrated the strong relationship between students' self-reported preparation to pursue STEM careers and their reported level of scientific engagement. Thus, researchers measured two types of engagement:

i. General engagement with a scientist – Respondents answered one question on a Likert scale with ratings from 1 = not at all engaged with a scientist to 5= highly engaged with a scientist regarding their general engagement with a scientist.

ii. Engagement in specific scientific activities – Respondents answered five yes or no questions on whether they had participated in various scientific activities in the past 12 months (e.g., attended scientist talks, read scientific articles, listened to a scientific podcast). Additionally, "yes" was coded as 1, and "no" was coded as 2 for this variable's responses, with higher scores meaning fewer engagement behaviors. This variable was reverse-coded for analysis purposes to make higher scores reflective of higher engagement behaviors.

2.2 Participants

Five hundred thirteen middle and high school students were sampled. Each obtained parental consent (if 17 or younger) and assented to complete the survey. Students participated in the research study through the general outreach efforts of the BOP team. Local New York middle and high school students were invited to participate in BOP science activities. Some of those activities included the CCERS curriculum, and others did not. Assignment into CCERS (treatment group) and comparison groups was made to determine the presence or absence of CCERS curriculum in BOP activities. Any student participating in at least one BOP event that included the CCERS curriculum was considered part of the CCERS (treatment) group. Those who participated in activities that did not include the CCERS curriculum were assigned to the comparison group. Project staff recruited student groups of comparable type and demographic representation to comprise CCERS and comparison groups. Researchers used information received from BOP and PI to identify which students attended specific events.

Table 2. Demographics Table by Participation Condition and Overall

Demographics	**Comparison Group (N=90)**	**CCERS Group (N=423)**	**Total (N=513)**
Gender			
Male	40 (44.4%)	113 (26.7%)	153 (29.8%)
Female	24 (26.7%)	125 (29.6%)	149 (29.2%)
Do not wish to specify	—	24 (5.7%)	24 (4.7%)
No response to demographics	26 (28.9%)	161 (28.1%)	187 (36.4%)
Ethnicity/Race	—		
American Indian or Alaska Native	3 (3.3%)	5 (1.2%)	8 (1.6%)
Asian	7 (7.8%)	37 (8.8%)	44 (8.6%)
Black or African American	10 (11.1%)	32 (7.65)	42 (8.2%)
Hispanic/Latino	15 (16.7%)	74 (17.5%)	89 (17.3%)
White (non-Hispanic or Latino)	26 (28.9%)	75 (17.7%)	101 (19.7%)
Other	3 (3.3%)	13 (3.1%)	16 (3.3%)
Do not wish to specify	—	30 (7.1%)	30 (5.8%)
No response to demographics	26 (28.9%)	157 (37.1%)	183 (35.6%)

After six months, the research team, PI, and BOP staff recognized that participation in the treatment and comparison groups was below expected recruitment numbers, thus collaborating to refine the sampling strategy. Using information gathered from previous phases and literature on school-based interventions (Krajcik, Blumenfeld, Marx & Soloway, 1994), the project staff identified various additional strategies to increase the sample size (e.g., holding community events, holding information sessions for parents, increasing project outreach personnel). In addition, project staff used purposeful and snowball sampling techniques and multiple forms of advertisement (e.g., project website, project social media page, flyers). In addition, key project personnel scheduled monthly meetings to discuss ways to continuously refine and improve recruitment strategies throughout the length of the project.

This report includes responses from participants who provided student assent and parental consent per the IRB requirements. A total of 513 students, with parental consent and student assent, completed the research and evaluation surveys. Table 2 displays the respondent demographics in further detail.

2.3 Data Analysis

Researchers examined the data for patterns of omissions, normality of distribution, and multicollinearity. For data that met all the assumptions, an independent samples t-test was used to examine if there were statistically significant differences in the measured outcome variables between the CCERS (treatment) and comparison groups. For continuous data that did not meet the assumptions of equality of variance, Welch's t-test was used, and for categorical data, Fisher's exact test was used. The research team presented the indices' means and standard deviations for each identified group.

Between 32% and 45% of data needed to be included in the variables of interest (access to technology, career interest, engagement in STEM, school use of technology, technological abilities, self-efficacy) above the typically acceptable 10%. It was decided that rather than conducting an itemized deletion in the entire dataset (i.e., delete any participant who had missing data), which would have reduced the number of participants from 513 to just 11, missing data were removed as models were created, only removing missing data from the variables in each model. Because it was suspected that the data would not be normally distributed, an assessment of the normality of the data was done before outliers were identified. Skewness and kurtosis were within the normal range ($-2 < \text{skew} < 2$, $-7 < \text{kurtosis} < 7$) for all variables. Despite this, none of the histograms appeared to be normally distributed. This was confirmed by a Shapiro-Wilk normality test, which showed that none of the variables used in the analysis were usually distributed. Because of this, non-parametric tests were deemed more appropriate to use than parametric tests for analysis. As a result, outliers and homoscedasticity were not tested for. Specifically, outliers were not removed because the large amount of missing data means further removing data could severely underpin the results of any analysis. Simple correlations between the variables were assessed to examine whether any variables may increase the risk of high inter-correlation. A correlation matrix revealed that no variable had a Pearson's r with an absolute value greater than 0.8, meaning no individual variable posed a risk to multicollinearity.

3. Results

3.1a Findings - Student

Seven hundred sixty-four students opened the survey through the general link and arrived at the landing page in Step 1.

A total of 513 respondents completed all the necessary steps for the surveys (i.e., steps 2 and 3), including providing parental consent and student assent. A total of 513 students, with parental consent and student assent, completed the research and evaluation surveys. Two hundred-one respondents across both treatment and comparison conditions were identified as part of an underrepresented group (URG). The URG Category consists of American Indian or Alaska Native, Black or African American, Hispanic/Latino, and others.

CCERS respondents, on average, had higher scores on scientific identity (motivation) and higher levels of preparation, with higher average scores of general engagement than the comparison group. A model was created to test the relationship between condition (i.e., treatment and comparison) and scientific identity though non-significant, on average, CCERS respondents (n=513) expressed a slightly higher scientific identity (M=3.85, SD =0.78) than comparison group respondents (n= 90, M=3.69, SD=0.72).

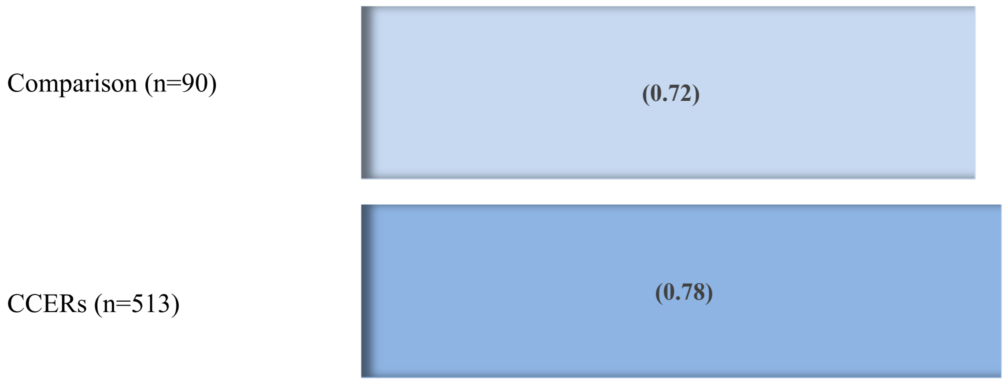

Figure 2. Average Scientific Identity of Respondents from the CCERS and Comparison Groups

On average, underrepresented group (URG) CCERS respondents reported higher levels of scientific identity (motivation) and engagement in scientific activities (preparation) compared to URG students who did not participate in CCERS. On average, though non-significant, URG CCERS respondents (n= 124) expressed a higher sense of scientific identity (M=3.87, SD=0.71) than the URG comparison group respondents (n=31, M=3.64, SD=0.65).

Figure 3. Average Scientific Identity of Respondents from the URG CCERS and URG Comparison Group

3.1b Findings – Teachers

There is evidence that the CCERS program impacts awareness. This is a direct result of Pillar 1: Teacher Training with Computer Science, Data Science, and STEM Career Exploration, as one of the pillar's goals was for teachers to increase student engagement and learning in oyster restoration research and interest in STEM careers. Additionally, teachers predicted that students' awareness of STEM careers would increase due to participating in the BOP activities, as they acted as scientists and collected and worked with computer data. The data support this prediction. Teachers used the experiences from BOP activities to generate student interest in the New York waterfront and oyster restoration research with an average of 5.25 (standard deviation=1.14).

- My experience in BOP exposed me to ways to engage my students in virtual or in-person field site or classroom oyster restoration research, which received an average response of 5.46 (standard deviation=1.13).
- These responses suggest that BOP provided teachers with various ways to engage students and met one of their primary goals: raising awareness of oyster restoration in New York Harbor.

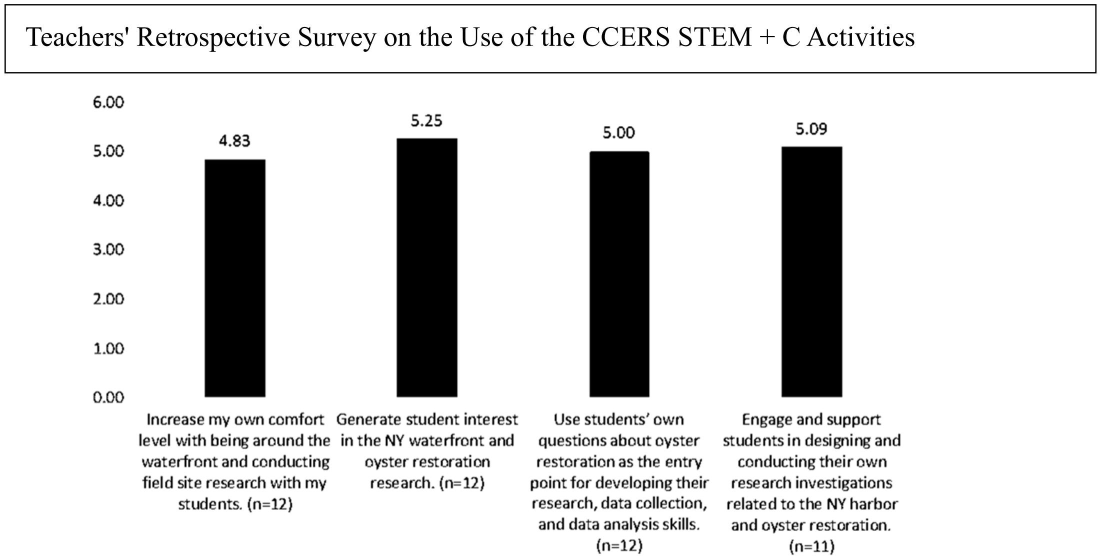

Figure 4. Teacher Survey Results – Use of CCERS STEM + C Activities

Science Symposium

Figure 5. High School CCERS STEM + C Symposium Participant Explaining Aquatic Life Research in New York Harbor

Following the Science Symposium, teachers reported a positive experience for their students. They agreed that participating in the symposium helped students learn about scientific research and STEM careers. They also reported that students could choose the type of project they did, collect field data for their projects, and use data provided by the BOP CCERS STEM + C Digital Platform. There is agreement that students' research projects also taught them about harbor restoration. A panel of reviewers with expertise in environmental restoration spoke with each of the student participants during the symposium. When asked about the sessions with reviewers, one teacher commented, "I think they were awesome. Being able to talk to the reviewers from different backgrounds was helpful for the students. It also helped the students broaden their perspective of STEM careers. I appreciate all the reviewers taking the time to talk to the students and give them feedback. Some are already thinking of what they can do next year."

4. Results

The teachers' retrospective survey strongly suggests that the students were interested in and aware of oyster restoration in New York Harbor. As a result of the professional development experienced by the teachers through the CCERS STEM + C Project, the teachers experienced an increased comfort level in their ability to navigate the waterways and conduct fieldwork. This, in turn, positively influenced the measure of comfort experienced by their students. In addition, due to the CCERS STEM + C professional development, participating teachers envisage greater student interest in the New York waterfront and oyster restoration. These teachers believe this interest would catalyze the students to develop their own data collection, analysis, and authentic research.

In terms of student survey results, all CCERS respondents, on average, had higher scores on scientific identity (motivation) and higher levels of preparation, with higher average scores of general engagement than the comparison group. Students who identify as URM (under-represented minority) and participated in the CCERS STEM + C Project's Oyster Restoration Hub activities and the Science Symposium (informal education activities) expressed a higher sense of scientific identity than the URM comparison group respondents.

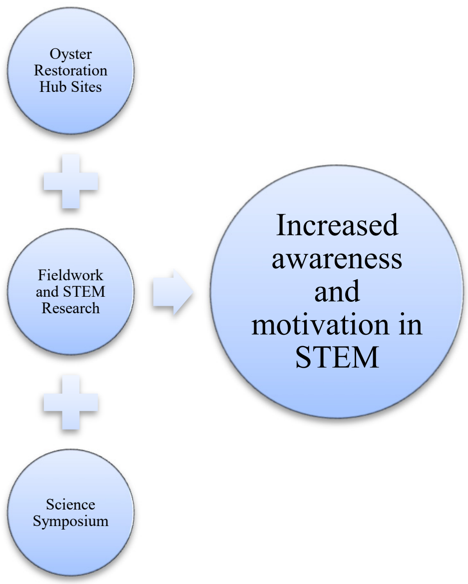

Figure 6. Components of the CCERS STEM + C Project Informal Education Impact

The BOP CCERS STEM + C resources were critical for developing the student's research projects. These included the activities from the curriculum pilot, STEM Hub activities, student-collected data, the Oyster Restoration Stations in the New York Harbor, and the classroom oyster tanks.

5. Discussion

Informal educational settings such as the natural environment, zoos, aquariums, parks, botanical gardens, museums, and out-of-school programs can provide various opportunities to engage children in STEM learning and scientific discovery (Bell, Lewenstein, Shouse & Feder, 2009). These settings provide the opportunity for all types of learners to engage with ideas that allow for the inclusion of their prior experiences and knowledge. Research has determined an achievement gap in students from low socio-economic backgrounds and in students who are dual language learners. Research suggests that learning in informal settings like those above decreases the achievement gap by building self-esteem, increasing scientific reasoning, and a more significant commitment to science learning (Alexandre, Xu, Washington-Nortey & Chen, 2022b).

The results of the CCERS STEM + C project suggest that students who participated in the informal education activities of the project developed an increased awareness of environmental restoration in their community and, in turn, had a higher degree of motivation and interest in the preservation of New York Harbor and its inhabitants. The informal education experiences incorporated in this project allow the students to experience the excitement of learning about the natural phenomena around them by allowing them to think independently and develop their own science identity. The partnership between the educational, business, and local communities fosters a nurturing environment. The collaboration of the teachers, scientists, and peer mentors creates a synergy that enhances the informal learning experience and inspires participating students to resolve scientific problems rooted in their community.

Informal education is aligned to the 2030 Agenda for Sustainability proposed through the United Nations. The "exchanging plastics for learning resources" is a project in Nigeria that supports this agenda (Almeida & Morais, 2024). Study collect plastic refuse for recycling and the funds attained are used to support the informal education program. A similar study conducted in more than 20 schools in the Petrópolis region in Brazil garnered comparable results (Calvente, Kharrazi, Kudo & Savaget, 2018). Students from these low- and middle-income regions face environmental challenges analogous to those of the CCERS STEM + C participants. Informal environmental education activities were developed to focus on sustainable food practices, gardening techniques, and environmental ethical conundrums. The study found that participants' understanding of local environmental challenges was enhanced, and the students were more aware of their agency and voice. Research (Werquin, 2010) indicates that approximately 50% of education in developing countries can be attributed to informal settings.

6. Conclusion

Partnerships between local communities, science-rich educational institutions, and local businesses show great promise for structuring environmental science learning that pertains to the local environment. Programs such as the CCERS STEM + C afford out-of-school time unique opportunities that expand the STEM learning events and personalize the experience by utilizing community resources and focusing on community needs. This enables students to connect with the issues and become motivated to further their involvement in and education of matters directly impacting their lives.

The data from this study suggests several opportunities for programs similar to the CCERS STEM + C Program. One approach would be to target students with a low interest in STEM careers, showing them that the material they learn can be translated to different STEM careers. More significant efforts can be made to increase access to scientific mentorship and connect students with volunteer opportunities, which can further increase interest and engagement in STEM. Career interest is associated with increased awareness of STEM and increased STEM engagement; therefore, increasing access to mentorship and volunteer opportunities is a concrete intervention schools can implement that may directly benefit students. CCERS can also ensure that students know about their STEM career opportunities. This may promote more learning among those who already see themselves as competent in science and promote further growth in this area.

The question remains: Do interest and motivation provide the catalyst for future success in STEM pathways from education to career? The following steps for research could include a specific focus on out-of-school learning activities related to environmental restoration. Comparing the influence of informal activities such as the science symposium and the HUB restoration activities to the related classroom lessons could indicate each component's interest and motivational impact. Finally, examining the number of students applying to college and seeing how many are pursuing a STEM career path could significantly bolster the findings of future evaluations, as it would give strong and concrete evidence of the program's long-term impacts. Learning about environmental community issues that are impacted by scientific contributions can lead to a life-long passion and commitment that involves students in ways that pique their enjoyment and appreciation of science, technology, and personal, real-world experiences. It is at this intersection that significant, independent growth occurs.

Finally, as the CCERS STEM + C Project nears its completion, the significance of this project and its impact on the environmental, educational, and industrial communities of the City of New York cannot be understated. Future projects aimed at increasing awareness of and responsibility for the local environment can look to this project as a blueprint for environmental restoration success on many levels (See Appendix C). It is suggested that future research focus on the evolution of the BOP CCERS STEM + C Project (Billion Oyster Project- Curriculum and Community Environmental Restoration Science- Science, Technology, Engineering, and Mathematics-Computer Science Project) to understand the nuanced additions to the project at each step of revision. Adapting to the needs of the stakeholders in the community is paramount for the success of this project and others that come after it.

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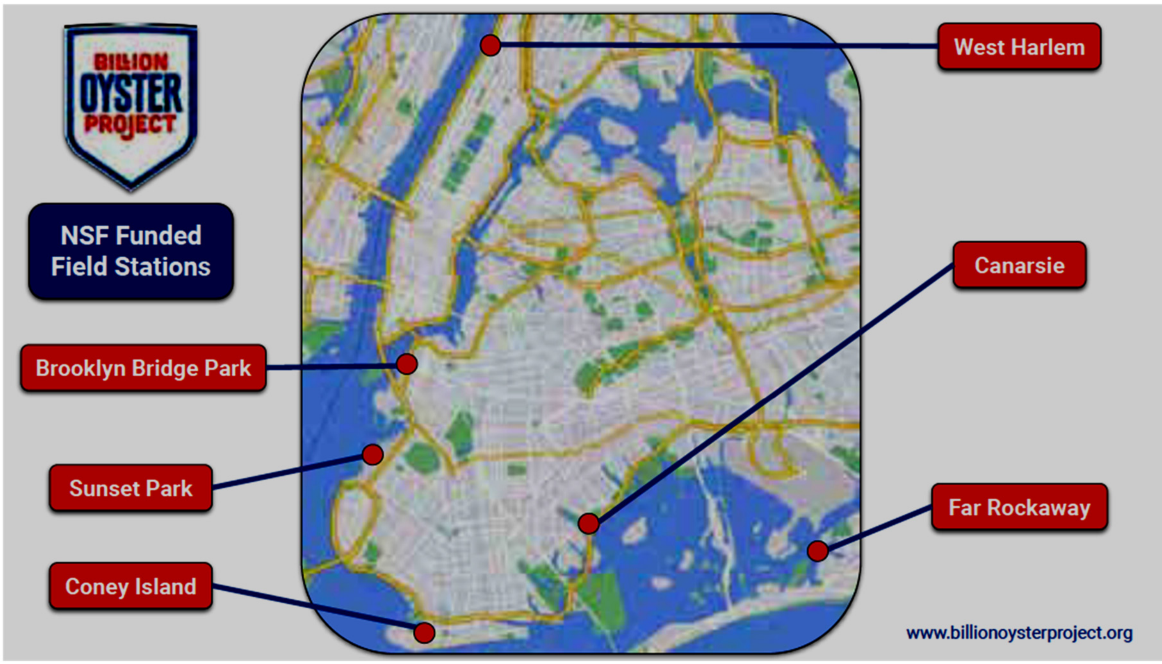
Appendix A – STEM Hub Oyster Restoration Stations with affiliated schools and Community-based Organizations

STEM Hub - Oyster Restoration Site	Schools	Community-Based Organizations
Bush Terminal Park (Sunset Park)	Brooklyn Environmental Exploration School (BEES)	Back to the Lab
	PS 506 The School of Journalism and Technology	Center for Family Life
	The Cultural Arts Academy at Spring Creek Charter	New York City Parks Department
	Sunset Park High School	Sunset Spark
	Brooklyn Urban Garden Charter School (BUGS)	
Canarsie	PS 12. Dr. Jacqueline Peek-Davis Elementary School	Community Board 18
	All City Leadership Secondary School	Public Agenda
	Cultural Academy for Arts and Science	New York City Parks Department
	IS 211. John Wilson	Paerdegat Basin Ecology Park
	I.S. 68 Isaac Bildersee	Canarsie Community Development, Inc
	Kurt Hahn Expeditionary Learning School	Fresh Creek Civic Association
	Mott Hall IV	Millenium Development
	PS 115 Daniel Mucatel School	Science and Resiliency Institute of Jamaica Bay
	PS 276 Louis Marshall	Sebago Canoe Club
	The Science and Medicine Middle School	
	Hebrew Language Academy	
	PS 207 Elizabeth G. Leary	
	Avenues Middle School	
Bayswater (Far Rockaway)	PS 104 The Bays Water	New York State Parks Department
	M.S. 53 Brian Piccolo	Jamaica Bay-Rockaway Parks Conservatory
	Rockaway Collegiate High School	RISE Rockaway
	Academy of Medical Technology	Science & Resilience Institute of Jamaica Bay
	Waterside Children's Studio School	St. John's Residence for Boys
		Eastern Queens Alliance
Brooklyn Bridge Park	Brooklyn Friends School	Fire Lotus Temple
	P.S. 58	Brooklyn Bridge Park Conservancy
	Guidepost Montessori Brooklyn Heights School	Adapt Network
	PS 261	Sailing Collective
	PS 38	
	MS 447	
	Uncommon Collegiate Charter H.S.	
	McKinley S.S.A	
	Berkeley Carroll School	
	PS 369	
	A Fantis School	
	Maxwell H.S. for Career Technical Education	
	Packer Collegiate School	
Coney Island Creek	Edward R. Murrow	City Parks Foundation- Coastal Classroom
	IS 281- Joseph B Cavallaro	Community Board 13
	IS 98- Bay Academy	Coney Island Beautification Project
	JHS 234 Arthur W. Cunningham	Coney Island History Project
	John Dewey High School	Friends of Kaiser Park
	Kingsborough College	New York Aquarium
	Liberation Diploma Plus High School (Alternative school)	New York State Marine Education Association
	PS 90 Magnet School for Environmental Studies	New York City Parks Department
	PS 188 (Michael E. Berdy)	Partnerships for Parks
	PS 329	SWIM Coalition
	PS/IS 288 Shirley Tanyhill School	Waterfront Alliance
	Rachel Carson High School	STEM from Dance
West Harlem	East River Elementary	Good Shepherd Services
		The Felix Organization
		Baylander Steal Beach

Appendix B

Map of the NSF Funded Field Stations (Oyster Restoration Stations) and location



Appendix C - Significant Achievements attained through the BOP CCERS STEM + C Program

- New York Harbor has four developed reefs in NYC, covering 12 acres on our Harbor's floor. Central installations included the addition of 22 million oysters to our existing 1-acre reef in Head of Bay, located at the eastern end of Jamaica Bay.
- Our nine active field stations (Far Rockaway, Brooklyn Bridge Park, Sunset Park, Coney Island Creek, Governors' Island, Canarsie, Great Kills, Soundview, Williamsburg) hosted 83 events with 1,952 participants — comprised of partners, teachers, students, community-based organizations, and Billion Oyster Project Ambassadors. (Watch live coverage via dive-cam at Soundview in the Bronx: https://www.instagram.com/billionoyster/reel/C0Vc-7tstpf/)
- An expanded student engagement in oyster restoration and STEM curriculum, introducing 3,299 students from 73 schools — 81% of which are public and charter — to waterfront classwork and fieldwork.
- In 2024, we expect to install 84 million oysters in New York City waters, with the bulk distributed across our sites at Soundview, Head of Bay, and SUNY Maritime. With the help of the National Fish & Wildlife Foundation's Long Island Sound Futures Fund, we will be working toward the future restoration of 10 acres of reef upstream in Queens and The Bronx.
- The shell collection program collected 322,000 pounds of shell from 75 NYC restaurants in 2023.
- The annual Billion Oyster Project Student Symposium culminates a year of learning for NYC students — offering them an opportunity to share their findings from harbor-inspired research. 2023's event, hosted on Governors Island, showcased the work of 352 students across 120 projects.
- In response to Superstorm Sandy's devastation in the northeast region of the United States, construction has begun on the Living Breakwaters, a 2,400 linear foot structure located off the southern shore of Staten Island, New York. The coastal green infrastructure comprises a floating oyster nursery and shell collection supplied by the Billion Oyster Project. In addition, the Living Breakwaters Project includes educational,

stewardship, and workforce training activities and materials developed by the BOP CCERS STEM + C Project.
- On September 19, 2023, Prince William visited the Billion Oyster Project. He waded out to pull several oysters out of a cage installed by the organization at Brooklyn Bridge Park. After collecting a bucketful of oysters, he returned to shore and examined them with students afterward.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.