The Billion Oyster Project and Curriculum and Community Enterprise for Restoration Science Curriculum: ITEST Program Impacts on NYC School Student Scientific Identity

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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 that involves multiple stakeholder collaborations and is led by Pace University. Within Pace, the initiative crosses over three different schools and colleges and across multiple departments. Pace University's NSF project of focus in this article is the Innovative Technology Experiences for Students and Teachers (ITEST) program. The purpose is to increase student motivation and preparation for pursuing STEM careers. This article presents results of programming to increase student scientific identity. Findings revealed that students in the 11th grade had the highest level of scientific identity compared to other high school grades. These findings indicate that 11th grade may be an ideal timeframe for interventions to improve scientific identity. Moreover, project participants had higher levels of engagement in STEM-related activities, were more likely to watch videos made by scientists, and read articles written by scientists than those in the control group.

Keywords: STEM education, scientific identity, engagement, motivation, self-efficacy

1. Introduction, 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 that involves multiple stakeholder collaborations and is led by Pace University. Within Pace, the initiative crosses over three different schools and colleges and across multiple departments. Pace University's NSF project of focus in this article is the Innovative Technology Experiences for Students and Teachers (ITEST) program. The purpose is to increase student motivation and preparation for pursuing STEM careers. This article presents results of programming intended to increase student scientific identity, which is the students view of themselves as capable scientists and critical to motivate students to pursue STEM careers. The ITEST program uses experiential learning with New York City public school teachers and students to improve student learning about ecological projects in and around New York's harbor and includes oyster restoration, which is vitally important for cleaning pollutants in the harbor. Student success in these endeavors was used to help improve student perceptions of themselves as effective scientists and hence build their scientific identity.

The focus of the project continues to be to assist both underrepresented and marginalized populations in New York City.

Providing students with opportunities and resources to pursue STEM fields is one of the major project goals The project team, associated partners and stakeholders, laboratories, scientists, and University faculty work together with New York City public school students to provide teachers and students with necessary guidance, resources, and instruction to provide the framework for student success. Leveling the academic playing field to ensure equity, integrity, and efficacy remain paramount factors for this work. The project strives to provide equity for all students in New York City public schools. Thus, BOP-CCERS has a goal to connect teaching and learning with harbor restoration to drive educational and career options for historically underrepresented students in STEM. The CCERS theory of change is based on the idea that learning is more meaningful and motivating when connected to community issues and conducted through experiential learning. "Doing" science as scientists, through a constructivist framework, drives the conceptual framework of this project along with creating a community of learners who benefit from access to each other's thinking, learning, and discovery. Please see Figure 1.0.

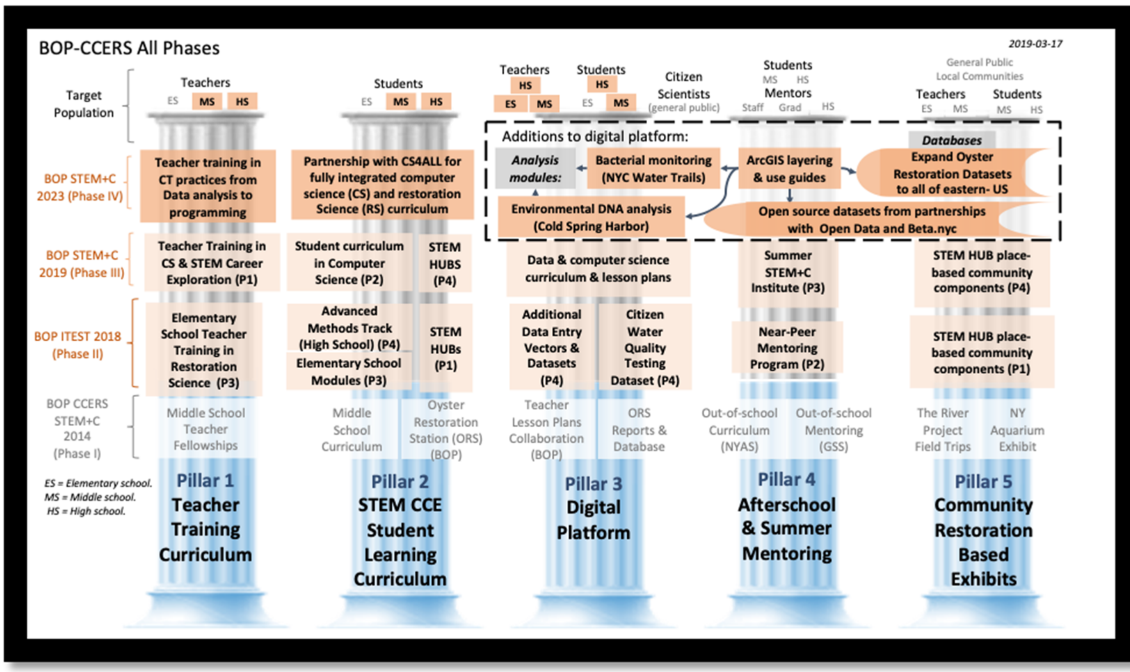

Figure 1. BOP CCERS Pillars

According to the National Research Council (2009), extracurricular activities has potential to positively influence interest in education and can contribute to career choices. STEM identity provides a lens to better understand the mechanism by which these experiences could influence career choice and persistence (Dou et al., 2019). Therefore, a student's development of scientific identity, such as thinking of oneself as a scientist, can improve academic performance, retention, and persistence in STEM and STEM degree completion (Maton et al., 2016; Syed et al., 2011). Chang and others (2014) indicated that underrepresented students with higher academic self-concept were likely to persist in STEM fields. Thus, a strategy to foster scientific identity and increase salience among underrepresented students in STEM is mentoring. For underrepresented students, mentoring can be the changing factor in encouraging STEM career pathways and fostering scientific identity (Summers & Hrabowski, 2006).

2. Theoretical Framework and Literature Review

The researcher on this project have 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 line of research has been based on Bandura's (1986, 1997) self-efficacy and social cognitive theory in which student cognitive and social development occurs through social interactions both through collaborative learning and with the student/teacher interactions. This relationship functions as a guide for student exploration and learning. This also has implications for student self-efficacy. Hands-on experiential learning has been shown to improve self-efficacy (Nava & Park, 2021). The ITEST project is guided by this framework to create a community of learners and develop self-efficacy and is also grounded in Vygotsky's (1987) work on a sociocultural theory of learning that supports collaboration and community-building among the students. Self-efficacy connects with 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 framework for this line of research since 2017 has been additionally supported through engaging students in 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). This directly relates to building the students' sense of their scientific identity, which is the students' view of themselves as capable scientists and critical to motivate students to pursue STEM careers. Hence, the driving force in the ITEST project is to teach science in the manner in which students engage in the scientific process in the way that scientists conduct their own research (Gorghiu & Ancuta Santi, 2016; Tuss, 1996).

Scientific identity has been defined as the way people make "the concept of fitting in within STEM fields, specifically, the way individuals make 'meaning of science experiences and how society structures possible meanings" (Carlone & Johnson, 2007; Hughes et al., 2013). Scientific identity is important for students' sense of self-efficacy and capabilities as student scientists. Students who have a strong sense of science identity are likely to be motivated, engaged and persistent in science. Strong STEM education with capable students who pursue careers in STEM is important for the United States' continued leadership in science and continued economic growth (Rotermund & Burke, 2021). Moreover, there is concern about the quality of STEM learning in the United States. It has been suggested that students are not prepared for the technical demands facing the economy and in the near future (Daggett, 2010). Projects such as ITEST are essential for supporting and developing the next generation of scientists for an increasingly technical future for the country.

Science identity sheds light on how early informal experiences can contribute to fostering interest and through it, identity construction (Dou et al., 2019). Early exposure to science activities and experiences such as science camps, clubs and hands-on experiments positively influences science identity development (Archer et.al. 2012). According to a 2015 study by Carlone and others, out-of-school science experiences and the role these play in how students personally connect with science have shown to be significantly influential. The authors describe a study of diverse youth who after engaging in an outdoor environmental science program found that the activities held the potential for sparking a newly constructed scientific identity. Throughout this experience, students did not have prior interests in the outdoors or science, but through connections made with nature and scientific elements during the program, they grew situational interests and experienced new ways of seeing themselves (Dou et al., 2019). Similarly, enabling science identity construction through informal scientific experiences as opening up "new and different opportunities" for science identity development (Barton & Tan, 2010; Elmesky, 2005).

In a 2007 study focused on strategies to increase diversity in STEM, the utilization of mentoring programs was found to lead to increased grade point averages, increased self-efficacy, and more defined academic goals (Tsui, 2007). Additionally, socioemotional and culturally relevant mentoring are shown to correlate strongly with the development of research skills and independence; both are considered key elements of scientific identity (Haeger & Fresquez, 2016).

A recent quantitative study with underrepresented students found that across intersectional race/ethnicity/gender categories, research self-efficacy was significantly associated with scientific identity and was shaped by research and mentoring experiences (Byars-Winston & Rogers, 2019). Thus, mentoring positively influences scientific identity as mentors can provide a link to career resources and research opportunities, provide emotional support, foster students' confidence and science self-efficacy, and facilitate their valuing of scientific research (Estrada et al., 2018; Byars-Winston et al., 2015). In addition, having positive role models and mentors in science for minority students can significantly impact science identity development and one study in particular associated role model identification with increases in science identity (Merritt et al, 2021).

Research on scientific identity indicates that scientific identity development improves student motivation to learn science along with their persistence in pursuing STEM (Estrada et al., 2011; Smith et al., 2015). Moreover, Vincent-Ruz and Schunn (2018) found that scientific identity is directly related to the choice to pursue STEM careers and in particular, for traditionally underrepresented groups (e.g., students of color, female students).

It has been reported by Syed et al. (2019) that science identity should be considered a fundamental and universal mediator of commitment to a STEM career. Thus, the ITEST project specifically provided experiential opportunities for students to further develop their scientific identity as a way to improve their interest, motivation, and persistence in pursuing STEM. Building these communities and confidence in the application of these skills, makes data science more accessible to them as they consider their academic and career paths. Thus, the goals for CCERS is to create opportunities for students to develop their technological abilities, engage in STEM, identify as scientists, and increase their STEM career options, which remains particularly important.

3. Methodology

The project utilized Bybee's 5E model of learning and teaching (Bybee, 2009) that incorporates the following 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 scientific learning in BOP-CCERS programming that 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.

A sample of 513 students in middle and high school in New York City were sampled in 2022 with 423 participating in the program (treatment group) and 90 who did not participate (control group). It should be noted that the imbalance between experiential and control groups was due to availability of participants and non-participants. This represents a limitation for the study and it is recommended that this be explored deeper in the subsequent iteration of the project. Thee demographic profile for the groups can be found below in Table 1. We dedicate considerable space to this information because a major goal for the project is to support diverse students in STEM. It is important to have this information in context of the study. We provide location data to demonstrate the school districts and systems in which students had arrived to New York City schools.

Participants were surveyed to determine their own sense of scientific identity after the ITEST project with both the treatment and control groups. This survey was part of a larger study focused on other measurement variables such as STEM career interest and preparation for STEM careers. It was determined with agreement on the statements below on a 5-point Likert scale ranging from "Strongly disagree (1)" to "Strongly agree (5)." Lower scores represent lower levels of scientific identity and higher scores represent higher levels of scientific identity. The survey instrument took 8 minutes to complete and was conducted online. Bootstrapping was applied to address non-normal distribution and used to detect small effect sizes and allows for replication of analysis. Statistical analysis was conducted using linear modeling and chi-square analysis.

The survey instrument on scientific identity had five items, among a larger survey of variables related to previous studies in this area (Birney et al., 2021a, 2021b, 2022), and was focus on areas in which project experts identified as important for measuring student scientific identity (see items below).

Statements for scientific identity:

- I can make good observations during a science activity
- I can ask good questions about what is happening during a science activity
- I feel confident about my ability to explain how to do scientific activities to others
- I think I could be a good scientist
- I am interested in learning about science

Data collection was designed and conducted by the NSF grant-funded evaluation firm, The Mark, which serves as a consultant for the ITEST project and is supported by the NSF. Additionally, Gaylen Moore Program Evaluation Services served as a consultant for the project.

Table 1. Demographic Information

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%)	150 (29.2%)
Do not wish to specify	-	24 (5.7%)	24 (4.7%)
No response	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 (7.6%)	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%)	17 (3.3%)
Do not wish to specify	-	30 (7.1%)	30 (5.8%)
No response	26 (28.9%)	157 (37.1%)	183 (35.6%)
First Generation Student			
Yes	17 (18.9%)	70 (16.6%)	87 (16.9%)
No	32 (35.6%)	165 (39.0%)	198 (38.5%)
No response	41 (45.6%)	188 (44.4%)	229 (44.6%)
Grade			
6^{th} grade	5 (5.6%)	-	5 (1.0%)
7^{th} grade	-	1 (0.2%)	1 (0.2%)
8^{th} grade	1 (1.1%)	1 (0.2%)	2 (0.4%)
9^{th} grade	37 (41.1%)	35 (8.3%)	73 (14.2%)
10^{th} grade	5 (5.6%)	107 (25.3%)	112 (21.8%)
11^{th} grade	6 (6.7%)	39 (9.2%)	45 (8.8%)
12^{th} grade	10 (11.1%)	53 (12.5%)	63 (12.3%)
No response	26 (28.9%)	187 (44.2%)	213 (41.4%)
City			
Bronx, NY	-	27 (6.4%)	27 (5.3%)
Brooklyn, NY	-	244 (57.7%)	244 (47.5%)
Great Neck, NY	-	2 (0.5%)	2 (0.4%)
New York, NY	-	81 (19.2%)	81 (15.8%)
Queens, NY	-	17 (4%)	17 (3.3%)
River Forest, NY	-	2 (0.5%)	2 (0.4%)
Staten Island, NY	-	10 (2.4%)	10 (2.0%)
Vestal, NY	-	2 (0.5%)	2 (0.4%)
Hoboken, NJ	-	3 (0.7%)	3 (0.6%)
Las Vegas, NV	-	1 (0.2%)	1 (0.2%)
Philadelphia, PA	-	3 (0.7%)	3 (0.6%)
N/A	90 (100%)	31 (7.3%)	122 (23.7%)

4. Results

The evaluation firm for the project, The Mark, used a linear model that was created with the variable "scientific identity" as the dependent variable. Condition, engagement, and grade level as predictor variables. Their simple slope analysis revealed that students in 11^{th} grade who were in the treatment condition had the highest reported scientific identity ($M = 3.28$) when compared to any other grade across the treatment condition (9^{th} grade $M = 3.02$, 10^{th} grade $M = 3.07$, and 12^{th} grade $M = 3.08$). It should be noted that the scores reflected the Likert scale data in aggregate with higher scores indicated stronger levels of scientific identity (i.e., 5-point Likert scale ranging from "Strongly disagree (1)" to "Strongly agree (5)."), and this was used to measure strength of student scientific identity.

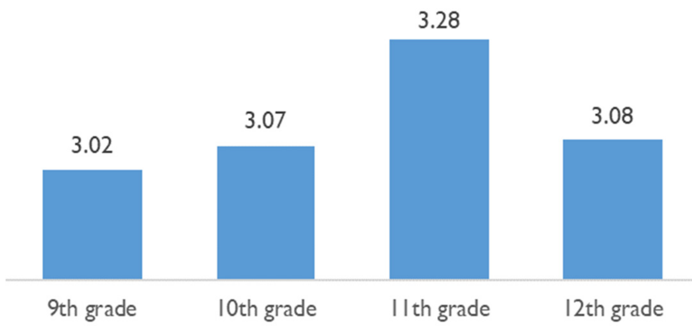

Figure 1. Scientific Identity by Grade Level

The Mark USA Inc. Used a linear model to test the relationship between condition and engagement. Their analysis revealed there was a significant difference between the BOP-CCERS treatment group's level of general engagement compared to the control group. It was found that the BOP-CCERS group engaged in more STEM-related activities (n = 185, M = 3.05, SD = 1.61) than the comparison group (n = 39, M = 2.29, SD = 1.87). Note that the sample sizes are smaller than the total sample size for the study since some participants did not complete every item in the survey instrument.

Figure 2. Engagement (blue = control group and green = treatment group with M (SD)

To examine which specific engagement activity differed between groups, The Mark conducted multiple chi-square tests. Results indicated that participants in the treatment group were more significantly likely to receive direct guidance on projects from a scientist than the control group [χ (1) = 11.3, p-value < .001]. Additionally, students in the treatment group were more likely to watch videos made by scientists [χ (1) = 9.9, p-value = .002] and read articles written by scientists [χ (1) = 22.6, p-value < .001] compared to the control group. No other differences were significant, though across all variables, students in the treatment group engaged more in STEM activities than the comparison group, but not at a significant level.

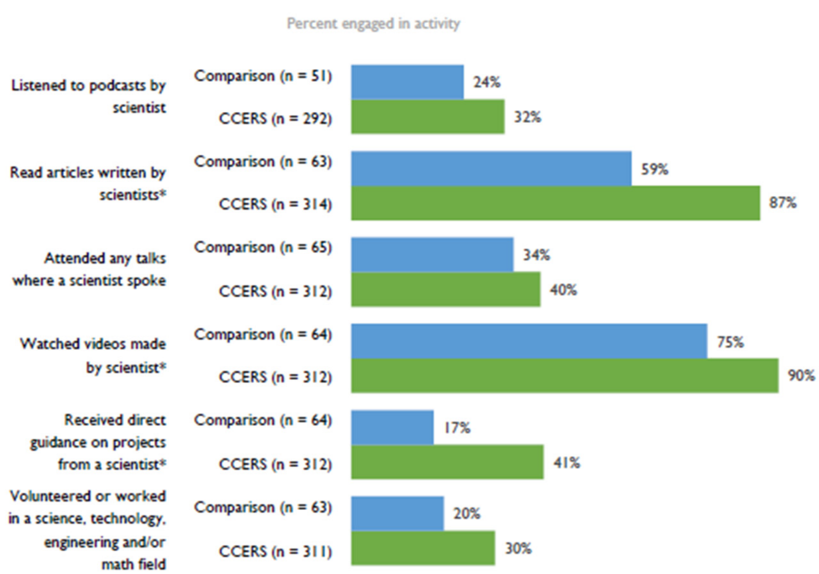

Figure 3. Percent Engaged in Each Activity

5. Discussion

The results of this study indicated that the 11th grade could be the optional time for intervention as related to scientific identity and self-efficacy. This is a grade in which students are considering their college and career choices and thinking about direction for college major. It is possible that given senior year's close timeframe to college, activities such as the ITEST project might be somewhat too late. Moreover, it is possible that 9th and 10th grade could be too early and too far from career and college. This aspect should be further investigated in future studies in this project and others. It was not surprising that members of the treatment group were more likely to engage in STEM-related activities than those in the control group.

Significant results were found using chi-square between the treatment and control groups on direct guidance on projects by scientists. This came as no surprise given the interactions the treatment group had with actual scientists during the project. This provides evidence of the durational impact on having exposure to actual scientists, and future research should determine how long lasting this duration could be. Additionally, not surprising was the significant difference found between the treatment and control groups on the likelihood of watching videos made by scientists. Again, participants in the treatment group were exposed to such videos, and hence, it became more likely that they would continue to watch videos made by scientists. Further research should explore how long lasting this impact is.

More disappointingly, no significant differences were found between the treatment and control groups for listening to podcasts by scientists, reading articles by scientists, attending talks by scientists, and volunteering or working in a STEM field. Future iterations of the project should place additional emphasis on these important activities. Assisting students in finding their own voices and including them in "training" podcasts, allowing students to work alongside scientists and faculty more frequently, internships and externships for students and job shadowing all assist in providing students with a unique and engaging experience that would promote growth in STEM fields.

Given the recent research on scientific identity and the relationship it has with improvement of student motivation to learn science along with their persistence in pursuing STEM (Estrada et al., 2011; Smith et al., 2015), the results found in this study were promising. In particular, the improvement in scientific identity found in this study has the potential to directly influence students to pursue STEM fields, and in particular, for students from traditionally underrepresented groups such as, students of color and female students (Vincent-Ruz & Schunn, 2018). This is in line with the literature by which the students in this present study were exposed to science activities and experiences to provide real-world science experiences. Archer and others (2012) investigated this through science camps, clubs and hands-on experiments. Moreover, Carlone and others (2015) found that out-of-school science experiences help students personally connect with science and had positive benefits. The present study found this to be true with the experiences provided to the program participants. Finally, Byars-Winston and Rogers (2019) found that mentoring contributed to scientific identity. The present study confirmed this through the extensive mentoring embedded in our program.

6. Conclusion and Implications

The purpose of the ITEST project is 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 are promising, there are ways in which the project could be further improved. Langreo (2012) indicated that female student interest in STEM had significantly declined in high school years from 17% to 12%. Additional focus on supporting female student identity should be implemented and evaluated to determine which aspects of the project can best help develop female scientific identity, engagement, and self-efficacy.

As stated earlier, additional emphasis on the various learning opportunities from actual scientists should be further enhanced in future iterations of the project (e.g., listening to podcasts by scientists, reading articles by scientists, attending talks by scientists, and volunteering or working in a STEM field). In addition, greater emphasis on mentorship opportunities with scientists can be additionally explored. Given the significant results found for the 11th grade students and their scientific identity in the project, it is possible that 11th grade should be the focus grade for future projects.

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