CCERS STEM + C – Emphasis on the Professional Learning of the Classroom Teachers – Expansion of the Pillar

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

[1]Pace University, USA

*Correspondence: School of Education, Pace University, USA. Tel:1-212-346-1889x11889. E-mail: lbirney@pace.edu

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Abstract

This qualitative study chronicles one of the fundamental pillars of the Curriculum and Community Enterprise for Restoration Science (CCERS). The professional development is focused on curricula that are grounded in the community-based environmental restoration of the waterways of New York Harbor. Centered on the restoration of the native oyster population, hundreds of New York City public school teachers take part in this experience with the intent of increasing their own place-based pedagogical content knowledge and skills. Most of the participants teach in school with populations that are underrepresented in post-secondary STEM majors and STEM related careers. Professional learning activities for teachers and community scientists were offered throughout the 2021 calendar year. Professional Learning Activity Surveys were administered and teachers responded to questions about how they participated in CCERS events, the ways in which CCERS participation has impacted their teaching practice, whether they use CCERS activities for student research, and ways CCERS participation impacts student STEM career interest. An intended outcome is to instill a STEM identity in students identifying as URM and to bring STEM career awareness to these students. More than 72% of the teachers in the professional development sessions agreed that the professional learning activities were effective in providing new STEM content knowledge and best practices for teaching. The majority also reported that the sessions enabled them to increase their students' engagement with STEM and interest in STEM careers.

Keywords: STEM professional development, restoration science, inquiry-based research

1. Introduction

1.1 Introduce the Problem

In 1998, the National Research Council (NRC) established the Committee on Science and Mathematics Teacher Preparation (CSMTP). The initial issue that needed to be addressed was identifying critical issues in existing practices and policies for K-12 teacher preparation in science and mathematics. The committee called for a revamping of teacher professional development, stating that, teacher preparation in science, mathematics and technology education can no longer work in isolation if they are to help improve teacher education (National Research Council, 2001). An emphasis on intentionally integrating instruction and curricula by providing stronger connections among the STEM disciplines began to take hold. This committee and their ensuing document became the forerunner of the Framework for K-12 Science Education on which the Next Generation Science Standards are based.

In the initial report, the members of the CSMTP called for improving teacher quality through an overhaul of how teachers are recruited, prepared, inducted and retained. The belief is that this would cause an increase the numbers of teachers who are teaching in ways that allow their students to understand and appreciate science, mathematics, and technology. It would also bring to light the relevance of these disciplines to virtually every aspect of life in the new millennium. Entering the twenty-second year of the new millennium, it can be seen that improving the quality teacher recruitment and preparation is still a major challenge in STEM education. The lack of curriculum documents to guide the teachers and the confusion surrounding the integration of technology exacerbated the problem (Moore & Smith, 2014a). This is especially true for teachers serving students that are historically underrepresented in STEM coursework and therefore, underrepresented in STEM higher education and the STEM workforce. Despite widespread concerns about and calls for access to high-quality STEM education for all students, there is very little research directly focused on STEM preparation for teachers of traditionally underserved K-12 students (Bell, Gitomer, Savage & Mckenna, 2019).

One key factor for increasing STEM opportunities for the underserved students is the establishment of educational programs that guarantee students graduate from secondary school STEM literate and well-prepared for STEM-related post-secondary educational pathways (Ahmed, 2016a). Another is to advocate for working with students in such a way that they are compelled to take social justice action in their lives and in their communities. This requires designing a learning environment in which students develop critical consciousness and engage in democratic participation within and outside school (Grant & Sleeter, 2012).

The issue is then, how can teachers of STEM be provided with professional development that is designed to meet the needs of all students, with a particular focus on historically underrepresented populations in STEM, (such as women and members of underserved racial and ethnic populations)?

1.2 Why is the Problem Important?

In December, 2018, the Office of Science and Technology Policy in the White House issued a document stating, "All Americans will have life-long access to high quality STEM education and the United States will be a global leader in STEM literacy, innovation and employment." In an increasingly knowledge-based economy, nations need well-educated STEM teachers who can advance the current generation with a capacity to innovate. Integrated teacher education programs prepare future teachers equipped with the knowledge, skills, and beliefs to effectively implement STEM education that increases the innovation capacities of students (Cuadra & Moreno, 2005). Reducing the gap between current instructional practices and the skills needed for STEM education is contingent on the expertise of STEM teachers. Professional development that is specific to STEM content and skills is must be well designed to effect change in teaching practices and provide teachers with the ability to grow professionally and in turn, improve student engagement and achievement.

The challenge faced by STEM teachers is the ability to engage students and develop sustained interest in STEM. This is a particularly demanding task when dealing with racial and ethnic groups who are historically underrepresented in STEM. Developing motivation and self-efficacy in the STEM content is needed to build a STEM identity among marginalized youth. Teachers that possess integrated teaching knowledge understand and teach STEM as an interconnected entity with a strong collaborative connection to life. They have the ability to positively affect their students' achievement, beliefs, and attitudes (Tschannen-Moran & McMaster, 2009). The academic experiences of students before college often influence their career aspirations and how they make choices to reach these goals (Ashford, et. al, 2016).

The relatively new field of STEM education (first coined in the 1990's by the National Science Foundation) has necessitated the expansion of professional development for STEM education (Gardner, Glassmayer & Worthy, 2019). Several studies have addressed the issue of STEM professional development opportunities for teachers that work with underserved populations of students. Reducing the gap between current instructional practices and the actual skills needed for STEM education is contingent upon the expertise of STEM teachers to successfully transition from the departmentalized model of teaching to an integrated teaching model (Furner & Kumar, 2007). Research has identified several aspects of STEM teacher professional development that may improve teachers' knowledge of science and engineering principles, as well as affective domains related to pedagogical confidence (Astor-Jack et al., 2007). Additionally, studies have shown that engaging teachers in longer professional development activities and active learning were found to be positively correlated with enhancing knowledge and skills (Goodnough, et. al, 2014).

Through the partnership developed among the New York City Department of Education, Pace University School of Education, The Lamont-Dougherty Center and the New York Academy of Science, a unique set of professional development sessions were created for the high school, middle school and elementary school teacher of New York who serve students in low-income, multi-ethnic communities. The majority of the students identify as being a part of a cohort that is underrepresented in STEM higher education and careers. Areas of concentration include in the offerings are:

- Professional development in informal settings such as the Oyster Research Stations (ORS)
- Professional development that is facilitated by environmental science experts and teachers
- Professional development that focuses on teacher comfort level and self-efficacy

- Professional development that enables teachers to incorporate authentic environmental restoration scienc eand inquiry-based research into their regular school day
- Professional development that focuses on place-based, hands-on, real-world learning embedded in long-term community projects – underrepresented in the STEM pipeline.
- Professional development that can bridge the gap between formal learning and informal learning
- Professional development that provides fellowships at the Pace University School of Education and includes expertise guest speakers from Lamont-Dougherty and The New York Academy of Science

1.3 Primary and Secondary Hypotheses

The primary focus of the CCERS STEM + C project is the restoration of the native oyster in New York Harbor. The outcomes from this project are varied and numerous. The increase of biodiversity and water quality in the harbor, the partnerships and collaborations developed within the educational and industrial communities and the stewardships of the oysters through the ORS and in the classroom are all achievement of the project, but the focus of this paper is the "C" for curriculum in the CCERS STEM + C project. Through the collaboration of classroom educators, faculty at Pace University and expert guest lecturers in the fields of conservation and environmental studies, dynamic and unique curricula have been developed for the project along with STEM specific professional development for the New York City school teachers involved. Effective professional development has the ability to prepare teachers to lead more and better prepared students to stay in the STEM pipeline (Subotnik, Tai, Rickoff, & Almarode, 2010).

The hypotheses stemming from the professional development provided are as follows:

1. The Professional Development provided to the teachers will result in an increase in the teachers' Harbor Restoration and STEM content knowledge, instructional skills and inquiry-based field research practices.
2. The Professional Development provided to the teachers will develop teachers' capacity to develop student awareness and interest in careers in the marine sciences, the environment, and related STEM Fields.

2. Methodology

A partnership was developed between the New York City Department of Education and Pace University School of Education at the onset of the first phase of the Curriculum and Community Enterprise for Science Restoration in 2014. The focus was centered on the New York Harbor Oyster Restoration Curriculum. Professional development for middle school teachers in some of New York City's most disadvantaged communities provided the conduit for restoration science in these classrooms. Research has shown that students in the middle grades are at the critical stage in forming their academic identity and career-professional interests and skill sets. It is here that students develop self-efficacy about their abilities (Britner, & Pajares, 2006). Additional partnerships with the Lamont-Dougherty Center and the New York Academy of Science provided a unique set of professional development sessions and collaboration between the teachers, the education faculty at Pace University and the environmental experts. Units of project-based, extended lessons for the classroom and the field stations, known as Oyster Research Stations, were developed, taught, reviewed and revised in an effort to create meaningful, life-long learning experiences for the teachers and the children in their classrooms. To some extent, STEM education has focused on interdisciplinary, authentic, and contextualized problems (LaForce, et al., 2016). STEM education undergoes a currently evolving effort to integrate science, technology, engineering, and mathematics, based on authentic problems and tasks, taking a holistic approach to real-world problems, and promoting the integration of knowledge and practices from several fields (Moore & Smith, 2014b). Research has found that integrated STEM teaching encourages student-centered pedagogies (Roehrig, Wang, Moore, & Park, 2012) and a more authentic treatment of mathematics and science content. Connecting student learning to place is a way to motivate science learning, rouse underrepresented communities, and galvanize the connection between school curriculum and students' lived experiences (Calabrese-Barton & Berchini, 2013).

Phase two (2018) of the Curriculum and Community Enterprise for Science Restoration built on the successes of phase one and expanded to include elementary school teacher training in restoration science. Understanding the significance of the STEM pipeline and the continuum of the educational trajectory for STEM, the professional development for elementary teachers was seen as a vital component to the project. A six-part professional development series for elementary school teachers provides curriculum and instructional support to engage students in early exploration of aquaculture and marine biology. STEM education in the early grades should be a national priority. This strategic direction can be achieved by facilitating a national agenda to develop kindergarten to college

STEM education and developing a strategy to describe national STEM content guidelines that would define the vital knowledge and skills needed at each grade level (Ahmed, 2016b). Teachers indicate that in order to be effective, they are in need of professional development that incorporate and connect different STEM disciplines and technology integration (Shernoff, Sinha, Bressler & Ginsburg, 2017b). In addition, Phase three (2018) coincided with Phase two and while continuing to implement the original professional development to the middle participating school teachers, additional training in computer science, data science and STEM career exploration was provided. Evaluation of the original professional development indicated that students required more support in computer literacy and help in developing STEM self-efficacy and their own STEM identities. To complete the continuum of STEM education for students in grades K-12, phase three also included an advanced methods training program for high school teachers. Focusing on professional development for educators in the secondary schools in New York City, the program is aimed at engaging high school students in advanced methods in scientific restoration and environmental monitoring. The long-term nature of the protocols introduce the older students to independent field research through real-world investigations which culminate in research projects and papers presented at the Annual Science Symposium held on Governors' Island. These protocols include genetics (barcoding and E-DNA), bacterial monitoring (enterococcus) and water chemistry (including micro-plastics) and are conducted by laboratory and university personnel that have partnered with the project. STEM education builds upon curriculum integration theories in two perspectives. One perspective is that STEM education enables teachers to integrate correlated subjects without ignoring the unique characteristics, depth and rigor of their main discipline (National Research Council, 2011). Research indicates that active learning in the fields of STEM increases student performance and efficacy (Freeman, et al., 2014). Conducting meaningful research in the secondary school allows students to develop the skills, confidence and experience necessary for academic success in higher education (Irizarry & Brown, 2014).

2.1 Professional Development Activities

The Billion Oyster Project (BOP-CCERS) offered professional learning activities for teachers and community scientists throughout the 2021 calendar year. Using programs modified during the previous year due to the ongoing COVID-19 pandemic and creating new workshops, BOP-CCERS facilitated a combination of remote and in-person professional learning sessions, as changing COVID-19 conditions allowed. At the conclusion of each event, teachers responded to a professional learning activity survey designed to assess the effectiveness of the session in providing Harbor Restoration and STEM content knowledge, instructional skills and inquiry-based field research practices and in preparing them to develop and support students' scientific investigation skills and career awareness. Respondents rated the items on a scale of 1 (Strongly Disagree) to 6 (Strongly Agree).

Professional Development activities for the project were conducted from February to December 2021. The sessions included: oyster research station basic training, Introduction to the oyster research tank, the inquiry for anywhere series, symposium prep sessions, advanced lab training and geographic information systems (GIS) training. Evaluators reviewed the professional learning activity survey results from these sessions related to teacher engagement and learning and their perceptions of students' engagement and learning. As a result of these educators taking what they learned in the professional development activities, over 5,400 students could engage in the CCERS STEM + C content.

2.2 Description of Professional Development Activities

Session 1— A Social Ecological System at Paerdegat Basin

A 3-day professional development series was conducted where teachers participated in classroom and field activities to prepare for the use of STEM Hubs(Note 1). Participants used digital tools, participated in hands-on outdoor field science and monitoring. They also interviewed local stakeholders to explore Paerdegat's history, ecology, chemistry, hydrology, and relation to present-day society.

Session 2 – Oyster Research Station Basic Training

Teachers were tasked with monitoring the Oyster Research Stations and organism identification in preparation for work at STEM Hubs. This was an entry-level training and teachers learned how to track oyster growth and identify organisms living among the oysters. The program is designed as a "hands-on" in monitoring and restoring the New York Harbor Estuary. An oyster measurement protocol, including basic equipment, supplies, live oysters, and a permitted waterfront site for safely conducting field science expeditions were addressed.

Session 3 – Advanced Protocol Training

Teachers participated in a day-long professional development session on Governors Island and were trained on water monitoring with a variety of protocols in preparation for work at STEM Hubs. The teachers had to have completed two expeditions to an oyster research station with their students and successfully collect and upload. This is offered on the completion of two expeditions to an ORS and the successful collection and uploads oyster measurement data on the digital platform before attending this session.

Session 4 – Culture your own Algae Professional Development

The teachers participant in a day-long professional development session learning about algae farming and how other forms of aquaculture provide sustainable sources of food, fuel, and jobs, rebuilding marine habitats and ecosystems along the way. This professional development is related to aquaculture career-technology education program in high school.

Session 5 – Annual Research Symposium Professional Development

The teachers are provided with professional development sessions engaging them in authentic restoration science. This enables the teachers to prepare their students for participation in the Annual Research Symposium. Held annual in June, it is a celebration and scientific meeting for students of all ages and adults who study oysters and/or New York City's waters to present their research to fellow researchers and visiting scientists. Opportunities for conducting original research has become a powerful tool for enhancing and maintaining interest in STEM disciplines and leads to better prepared students who stay in the STEM pipeline (Hossain &Robinson, 2012).

Session 6–Professional Learning – Classroom Oyster Tanks

During this professional development session, teachers setup oyster tanks, monitored live oysters and completed other tank study and maintenance protocols. Additionally, teachers experimented with different materials for and types of filters for their oyster tanks. The oyster tank study also included learning about and experimenting with the nitrogen cycle within the tanks; food and habitat webs; investigating the history of oyster and fish decline in New York Harbor, and getting hands-on with some of the smallest visible oyster reef associated organisms.

2.3 Protocol

A professional learning activity survey was administered to the participants in the professional development series. The 98 responses to the survey represented educators in a range of roles, but the overwhelming majority were classroom teachers. As a result of these educators taking what they learned from BOP-CCERS activities back to their classrooms and other contexts, 5,400 students or more could engage with the Curriculum and Community Enterprise for Restoration Science content.

2.4 Subjects

- Forty-five respondents (46 percent) were high school teachers. This was the most frequent answer for educator role.
- Twenty-five respondents (26 percent) were middle school teachers
- Twenty-three respondents (23 percent) identified as elementary teachers

Those in other roles described their roles as: Paraprofessional, College Professor, Parent of Student, Laboratory Specialist, Special Education, Science Department Chairperson, Marine Biology Society moderator, ENL Teacher, After School Teacher, Program Administrator, Environmental Educator

3. Results

3.1 Professional Development Participants

The participating teachers were asked to complete the *Professional Learning Activities Survey* at the conclusion of the professional development sessions. The Professional Learning Activity Survey is used to detect to what extent the types of learning experiences have transformed teachers' perceptions in their own knowledge and skills and their perceptions of this effect on the students in their classes. Similar learning activities surveys have been utilized in educational research (Caruana, Woodrow & Pérez, 2010). In the sessions observed, evaluators looked for four practices which created opportunities for participants to be actively and directly involved in the session. These items relate to: providing opportunities for participants to use the skills and content in the session; encouraging participants to express their ideas and work together with session participants to build on their session ideas; and allocating time for individual and group interactions to reflect on the learning. These items are listed in Table 1.

Table 1. Professional Development Participants

ITEM	% of Sessions Item Observed
Includes opportunities for participants to apply content and/or practice skills during training (excludes webinars)	100%
Includes opportunities for participants to express personal perspectives	85%
Facilitates opportunities for participants to interact w/each other related to training content	92%
Includes opportunities for participants to reflect on learning	77%
Average of Participants' Action Observed	85%
OVERALL AVERAGE OF DESIRED PRACTICES	89%

The data collected from observations of a sample of BOP-CCERS CCERS professional learning activities contribute to answering Evaluation Question 2 and achieving one of the project's major goals: preparing teachers to develop student engagement and learning in Oyster Restoration Research. The majority of practices identified as characteristics of high-quality facilitation were observed in an average of 89 percent of sessions. Where applicable, an integral element of the design and implementation of the BOP-CCERS-CCERS activities was the interactive component.

Providing opportunities for participants to play an active role in oyster research restoration is important to achieving high-quality professional learning sessions, as these practices can be carried over to the classroom. Teachers report in their participant survey that these qualities are what make BOP-CCERS CCERS sessions successful for them. Responses also reflect that teachers plan to attend more Billion Oyster Project professional learning sessions in the future.

3.2 Teacher Retrospective Survey

A second teacher survey, the *Teacher Retrospective Survey*, was administered in June 2021 to participants of all BOP-CCERS activities from September 2020 to June 2021. This survey was designed to give teachers the opportunity to look back on the entirety of their BOP-CCERS experiences at the end of the 2020-21 school year to assess the value and impact of the project activities in supporting them and their students over the year in oyster restoration research and developing STEM career awareness.

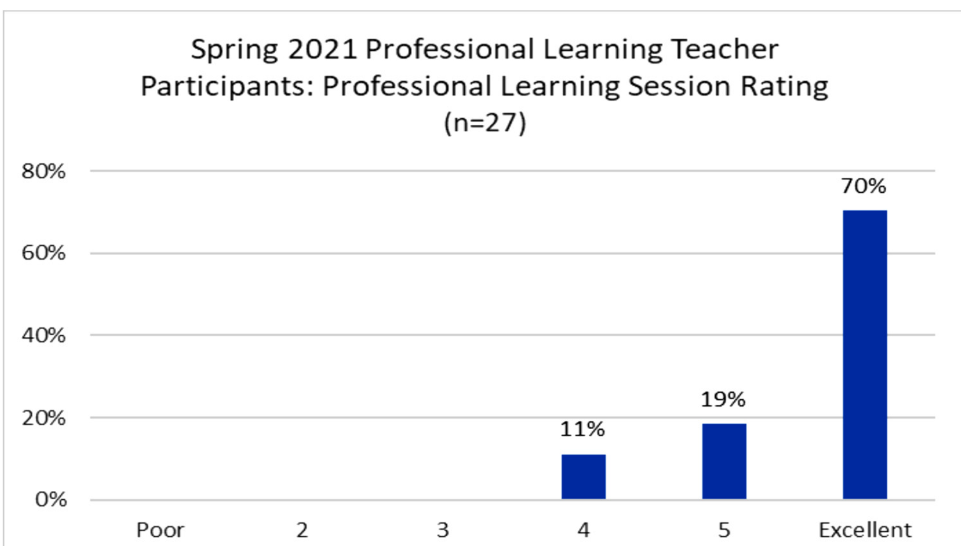

Figure 1. Spring 2021 Professional Learning Session Rating

Teachers that participated in the 2020-21 Retrospective Survey attended a range of Curriculum and Community Restoration Science Enterprise activities during the school year. Participants reported positive experiences both in professional learning sessions and in using BOP-CCERS lessons and activities in their classrooms. All respondents used their participation as a way to teach students about harbor restoration and some used it as an entry to students' own scientific research. The majority of respondents thought that BOP-CCERS activities facilitated teachers' abilities to develop students' interest in STEM careers, although outcomes varied by grade level and teacher experience. All around teachers reported a positive and impactful experience with Billion Oyster Project. Encouraging more BOP-CCERS professional learning participants in preparing and guiding students in generating their own Symposium projects, however, is an area that needs improvement.

- All teachers rated their sessions positively to some degree. (Figure 1)
- Seventy percent of teachers rated their session as 'Excellent,' suggesting that BOP is meeting their goal of providing high-quality professional learning opportunities to teachers
- The average rating for all the sessions was 5.50.
- Two session categories had the highest average rating at 6.00:
    1. Symposium Prep
    2. Introduction to Oyster Tank Training

The session category with the lowest average rating was the Inquiry Science series with an average rating of 5.00 (standard deviation=0.89)

Overall, the data collected from a survey of teachers following their participation in the professional learning activities, provides evidence that these sessions were successful and met the project's goals to provide and support and resources for the teachers to engage students in oyster restoration research and learning to think for themselves as environmental stewards. Some sessions were more successful than others for helping teachers build student awareness and motivate interest in STEM careers.

Analysis of the year-end *Retrospective Teacher Survey* data shows:

3.2.1 Teacher Engagement and Learning

Teachers also responded positively to the impact of BOP-CCERS in their understanding of oyster restoration research, with average responses between 5 (Agree) and 6 (Strongly Agree).

• The statement, "*My experience in BOP-CCERS has increased my awareness of what is happening with oyster restoration in the New York Harbor"* received an average response of 5.77 (standard deviation=0.44).

• The statement, "*My experience in BOP-CCERS had exposed me to ways to engage my students in virtual or in-person field site or classroom oyster restoration research* received an average response of 5.46 (standard deviation=1.13).

These responses suggest that the BOP-CCERS project provided teachers with a range of ways to involve students and contributed to meeting one of the goals to develop student engagement in oyster restoration in the New York Harbor.

3.2.2 Teachers' Application of Professional Learning Activities

Teachers responded to a series of statements about how they will engage with students based on what they learned from the professional learning session they attended. These statements were rated on a scale of 1 (Strongly Disagree) to 6 (Strongly Agree). Note: for these statements, respondents also had the option "Not addressed in this session." Differences in n-values reflect those who selected "Not addressed."

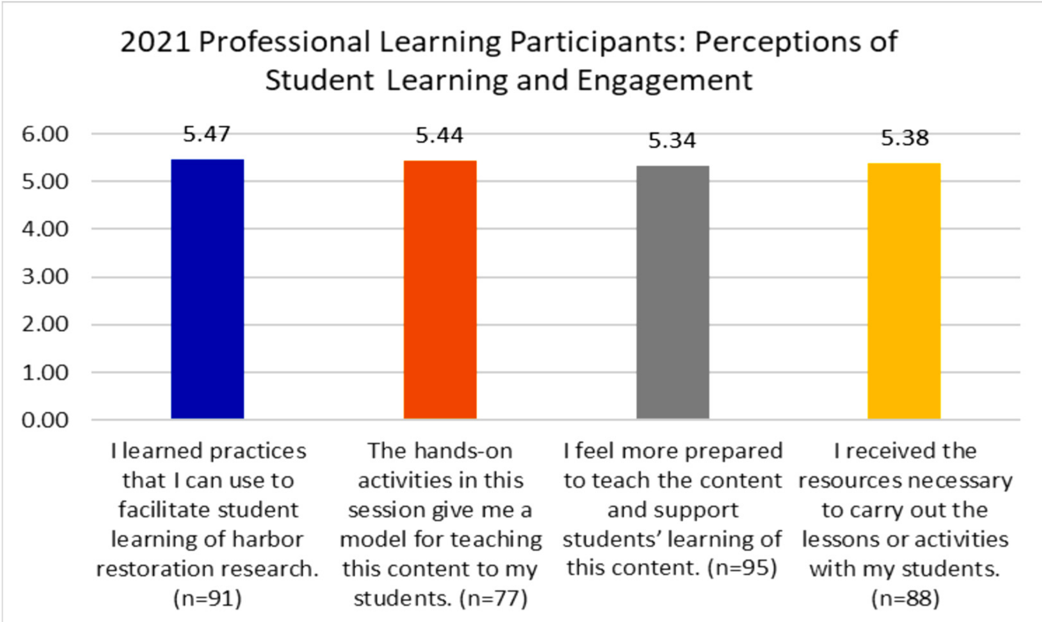

Figure 2. Perception of Student Learning and Engagement

• Average responses to all statements were positive, with average responses between 5 (Agree) and 6 (Strongly Agree) to all. (Figure 2).

• The statement with the highest average response was *I learned practices that I can use to facilitate student learning of harbor restoration research* with an average response of 5.47 (standard deviation=0.90).

A separate set of statements focused on using BOP-CCERS experiences to conduct research with students. Responses to these statements had an average response close to 5 (Agree).

• The statement with the highest average response was, "*I used the experiences from BOP-CCERS activities to generate student interest in the New York waterfront and oyster restoration research"* with an average of 5.25 (standard deviation=1.14).

3.2.3 Teachers' Perceptions of Student Career Awareness

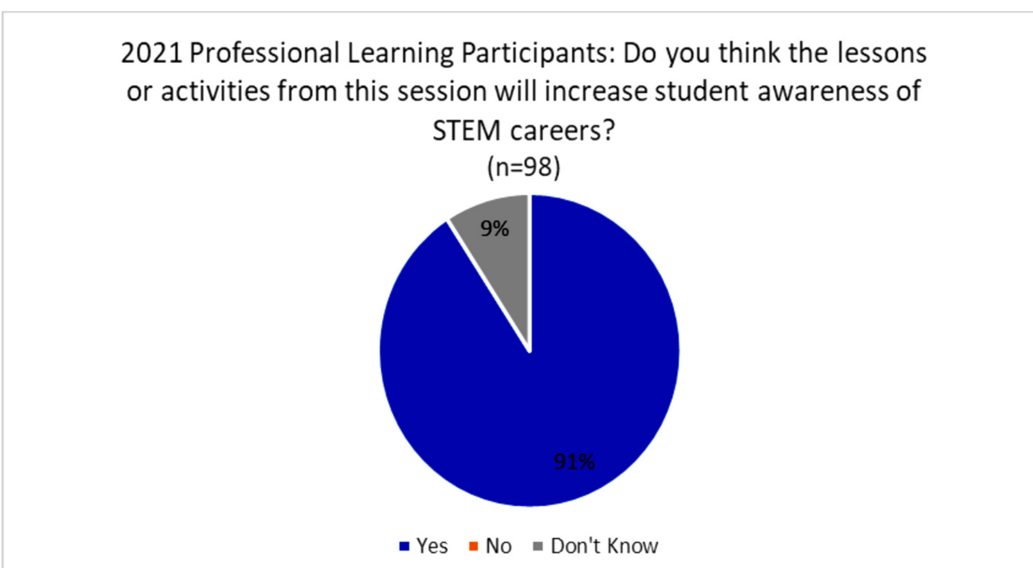

Figure 3. Possible Increase of Student Awareness of STEM Careers

- Ninety-one percent of teachers think that lessons or activities from BOP-CCERS professional learning sessions will increase student awareness of STEM careers. (Figure3).
- Nine percent "do not know" if student awareness of STEM careers would increase.
- No respondents thought that BOP-CCERS would definitely not increase student awareness of STEM careers.

The high percentage of teachers thinking that BOP-CCERS activities and lessons will increase student awareness of STEM careers also suggests that teachers are getting the outcomes for themselves that they are seeking from BOP-CCERS professional learning sessions, and reinforces BOP-CCERS's role in providing this content.

3.2.4 Teachers' Perceptions of Student STEM Career Knowledge and Interest

A key objective of BOP-CCERS activities is for teachers to raise student awareness and interest in a range of marine-related STEM careers and build interest in those careers.

• Eighty-five percent of respondents reported they attended activities where they learned how to develop students' awareness of STEM careers.

• The average response to the statement, "BOP-CCERS *activities modeled practices and instructional activities that I can use to motivate students to follow careers in STEM fields"* was positive at 5.33 (standard deviation=0.65).

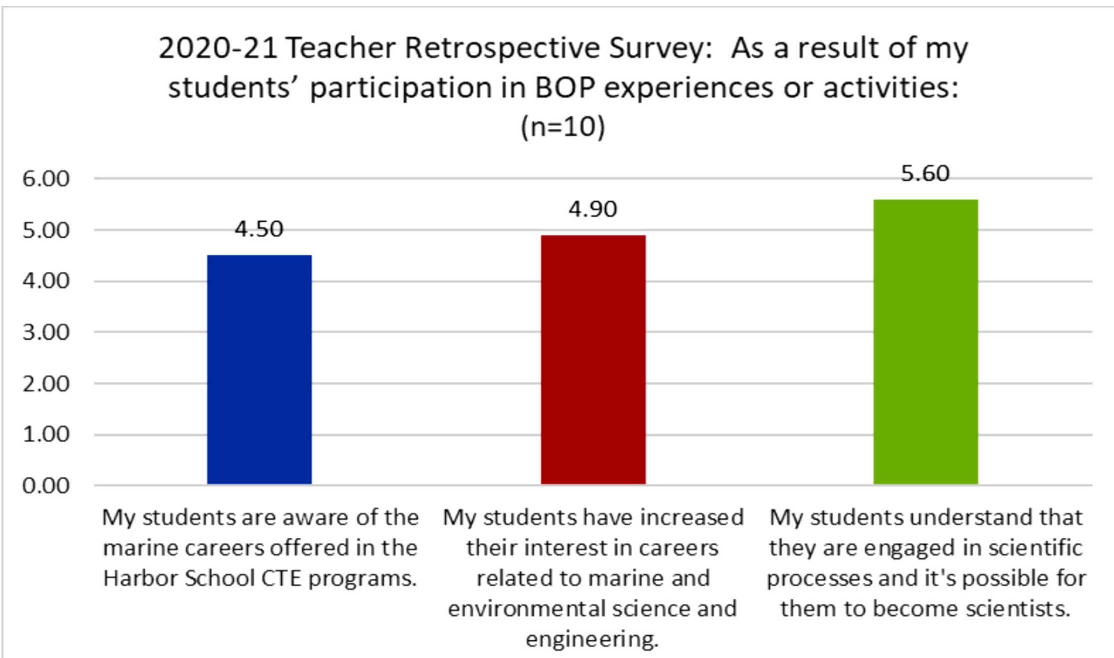

Figure 4. Teachers' Perception of the Impact of Activities on Students' Career Awareness

• Responses to STEM career awareness and interest were mixed, but still positive overall. (Figure 4)

• The highest average response was to the statement *As a result of my students' participation in BOP-CCERS experiences or activities, my students understand that they are engaged in scientific processes and it is possible for them to become scientists* with an average of 5.60 (standard deviation=0.70).

• The lowest average response was to the statement, "*As a result of my students' participation in BOP-CCERS experiences or activities, my students are aware of the marine careers offered in the Harbor School CTE programs"* with an average of 4.50 (standard deviation = 1.43).

3.2.5 Teacher Engagement and Learning

Teachers responded to a series of statements about what they learned from the professional learning session they attended. These statements were rated on a scale of 1 (Strongly Disagree) to 6 (Strongly Agree). Note: for these statements, respondents also had the option of "Not addressed in this session." Differences in n-values reflect those who selected "Not addressed."

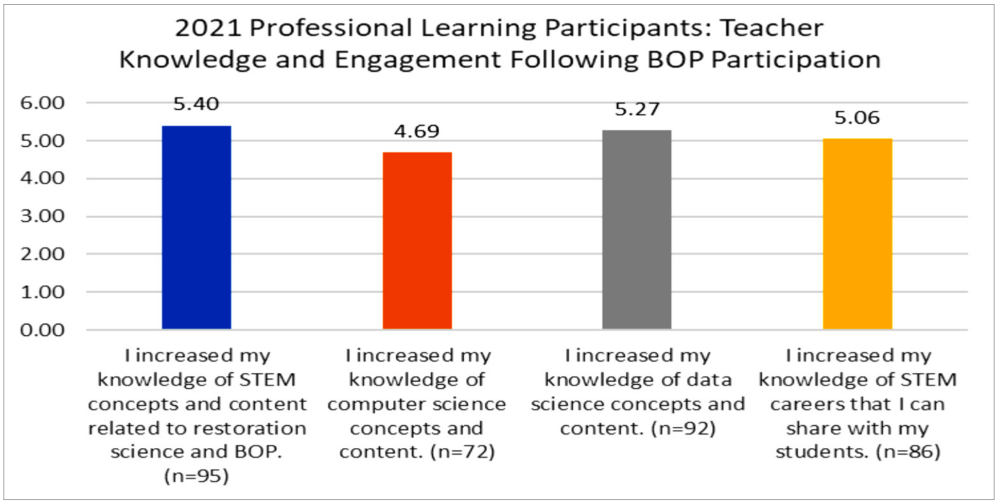

Figure 5. Teacher Knowledge and Engagement Following Participation

- Average responses to statements about what teachers learned in their professional learning were positive with averages about 4 (Somewhat Agree). (Figure 5)
- The highest average was to the statement *I increased my knowledge of STEM concepts and content related to restoration science and BOP-CCERS* with an average response of 5.40 (standard deviation=0.96).
- The lowest average response was to the statement *I increased my knowledge of computer science concepts and content* with an average of 4.69 (standard deviation=1.54). This outcome is not surprising as computer science is not the primary focus of professional learning sessions offered.

Overall high averages in both teacher learning and student engagement suggests that BOP-CCERS met its goals in Year 4 in offering high quality professional learning sessions to educators that would prepare them to engage students in oyster restoration research activities.

3.2.6 Overall Rating of Professional Learning

Teachers had the opportunity to sum up their professional learning experience in Year 4 by rating each of the BOP-CCERS professional learning sessions they attended on a scale of 1 (Poor) to 6 (Excellent).

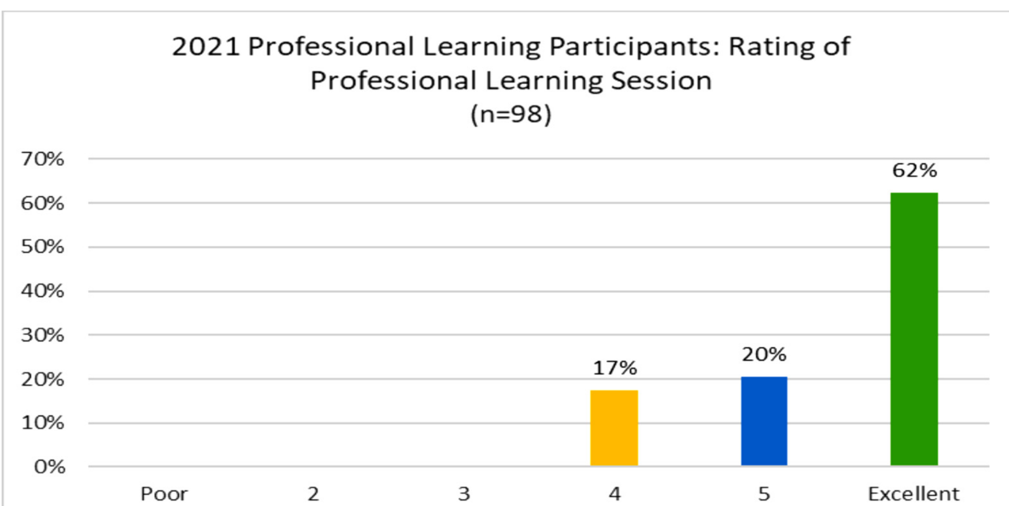

Figure 6. Rating of the Professional Learning Sessions

• Sixty-two percent of teachers rated their session as Excellent (Figure 6)

• No one rated the session as Poor.

• When asked for feedback to improve the professional learning sessions, feedback was in the following categories: interest in more in-person/hands-on sessions; additional resources for classroom use; more information on Billion Oyster Project as an organization and basics about oysters; and resources for adapting lessons to different students' needs.

Teacher outcomes from Billion Oyster Project professional learning sessions are positive. Overall, BOP-CCERS succeeds in providing high quality professional learning that teachers can use to engage students in harbor restoration, STEM careers and environmental stewardship. Providing opportunities for teacher participants to have an active role is important for high-quality professional learning sessions as these practices can carry over to the classroom. Teachers report in their participant survey that these qualities are what make the sessions successful for them.

4. Discussion

4.1 Addressing the Original Hypotheses

Results of this study supported the original hypothesis – participating teachers clearly acknowledge that the professional development provided contributed to their Harbor Restoration and STEM content knowledge, instructional skills and inquiry-based research practices. Data collected through the Retrospective Teacher Survey indicated that the impact of the BOP-CCERS professional development increased their understanding of oyster restoration.

The secondary hypothesis, the capacity to develop participating teachers' capacity to develop student awareness and interest in careers in the marine sciences, the environment and related STEM fields is supported by the findings in this study. Referring to figures 2 and3, teachers feel that as a result of the STEM professional development opportunities, their capacity to develop students' awareness and interest in careers related to STEM fields has been realized. The statement, "BOP-CCERS *activities modeled practices and instructional activities that I can use to motivate students to follow careers in STEM fields"* was positive at 5.33. The project can expand its impact by being more explicit in using the workshop activities to teach teachers how to raise student awareness of themselves as doing scientific work and to link students' research to the pursuit of a STEM career. The qualitative results provide evidence in support of the positive impact the professional development had on teachers' classroom practices. As in similar studies (Gardner, Glassmayer & Worthy, 2019; Nadelson, et al., 2013), participating teachers significantly increased their self-efficacy with STEM content as a direct result of the STEM professional development provided.

4.2 Limitations of the Study

The primary limitation to the generalization of these results is sample size. There are 250 participating teachers in the BOP-CCERS program, yet only 93 classroom teachers answered the teachers' surveys (*Professional Learning Activity Survey; Retrospective Teacher Survey Findings*) used to collect this data. When the population is 250 participants, a sample of 152 participants would be needed for a confidence level of 95% or a margin of error of 5% with (p=0.5). One contributing factor was the overtaxing felt from the effects of virtual teaching for the entire school year due to COVID-19. Plans to increase teacher survey response included inviting teachers to visit the BOP-CCERS headquarters and oyster nursery at Governors Island, and schedule opportunities for teachers to meet in person at BOP-CCERS social events, such as the Mingle event.

Teachers are tasked with accommodating the accelerated emergence of new knowledge and sophisticated technologies, preparing for trans-disciplinary careers, and merging traditional disciplines to better meet the needs of citizens in the 21st century (Nadelson & Seifert, 2017). Arguably, this is never more apparent as with the New York City Department of Education public school teachers. Teaching students STEM content in an integrated setting more closely mirrors the integrated STEM issues with which they will engage as productive citizens in the 21st Century. Since STEM teachers are often educated as science, mathematics, or technology teachers, they rarely have an opportunity to experience truly multidisciplinary and interdisciplinary STEM education, collaborate with peers who have different STEM backgrounds or use technology to engage in STEM education (Milner-Bolotin, 2018). Moreover, the research on educating STEM teachers, as opposed to science, mathematics and technology teachers is also in its infancy. It can be seen that the epistemology of STEM professional development is experiencing a paradigm shift such that the following components are becoming crucial and intrinsic:

- Multidisciplinary/trans-disciplinary approach to the STEM content and skills

- Application and synthesis of multiple STEM platforms
- Culturally relevant and community based
- Extended real-world problem based with advocacy for social action
- Focus on life-long enduring environmental and/or social challenges

A primary implication of these findings is that teachers must receive STEM professional development that is presented holistically. Being able to view STEM education as an intricate web of content areas surrounding the nucleus of a complex environmental challenge will enable teachers to communicate this concept to their students. A secondary implication is teachers' ability to be explicit in explaining to students how STEM is interwoven in the various facets of life. Students' realization of the presence and impact of STEM in nearly every facet of their lives increases students' desire to persist in learning STEM content. Students' perceptions of STEM and self-efficacy are the best predictors for students' intentions to persist in STEM. An individual's career-related pursuits are dependent upon the individual's belief in their ability and the individual's perceptions of the career (Brown, Concannon, Marx, Donaldson & Black, 2016).

In summation, the findings of this study indicate that this is a successful STEM professional development model. By incorporating a teacher learning environment that is focused on the multidisciplinary approach to STEM content and skills and consolidating these with a grassroots environmental conundrum, teachers and in turn, their students, have a vested interest in the process and the outcome. In turn, this involvement can deepen both understanding and self-efficacy in STEM education and possible career exploration. This may be a constructive method for expanding teacher development within the confines of limited resources and time. Another implication is the importance of university researchers and environmental content experts. They are exceptionally situated to educate K-12 teachers on expectations and impacts related STEM principles and practices.

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Note

Note 1. STEM Hubs are active scientific oyster restoration sites that are capable of hosting school and community groups to conduct long-term ecological research. They are located in New York Harbor at Coney Island, Brooklyn Bridge, Bush Terminal Park, and Canarsie.