The Curriculum and Community Enterprise for Restoration Science S.T.E.M. + C Professional Learning Model: Expansion and Enhancement

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Abstract

Professional Development in the field of education has undergone several shifts in focus. Currently, teacher content knowledge and the ability to disseminate this knowledge is the focus in professional learning communities. The importance of creating a thriving STEM workforce in the United States has been promoted for the last decade. Studies have shown that capturing students' interest must occur before they enter high school, ideally in the middle school years (Blotnicky, Franz-Odendaal, French, & Phillip, 2018). Teachers are the conduits for encouraging students to explore STEM-related career options. Student engagement is piqued when there is a strong real-world connection to the content being presented. Students find relevance through actual experience with the concepts and skills incorporated in projects that are community-based. The Curriculum and Community Enterprise for Restoration Science STEM + C Project is the marriage of these two components. The professional development of the New York City middle school teachers involved in the CCERS STEM +C Project furnishes these educators with the tools to stimulate students' interest by tackling a problem in their local community using STEM-related content and computational thinking. The hope is that authenticity of the learning experience will entice all students, especially those under-represented populations in the STEM workforce, to consider this as a viable career pathway. The analysis of this project is intended to highlight the significant inroads made and the value of self-reflection and re-design in strengthening the work as it continues.

Keywords: professional development, STEM, trans-disciplinary, STEM careers, computer science, restoration science, community-based project

1. Introduction

Over two decades ago, Linda Darling-Hammond introduced the phrase, seeds of a "quiet revolution" (Darling-Hammond, 1996) that altered the world of educational reform. Triggered by the development of new learning standards and higher graduation requirements in many states, teacher preparation programs and their ability to increase teacher content knowledge became the focus of education programs across the nation. In response, the National Board for Professional Teaching Standards produced a series of assessments for qualifying and certifying teachers. The art of teaching was now being seen not only the ability to covering the required content, but also the necessity of ensuring that the learner is indeed learning. In other words, teachers must be able to understand their students' and the way in which they learn as acutely as they understand the content that they are teaching.

Prior to this epiphany, reforms in education usually made their appearance in the form of curriculum revamping and new textbook adoptions. A prime example of this was evident in the decade that followed the national dilemma of 1957 – the launching of Sputnik by Russia. Almost immediately, additional funds were targeted for science and technology education through the National Defense Education Act (NDEA, 1958). This began an era of governmental control of education and a shift toward scientists and mathematicians creating curriculum for the schools in lieu of the teachers. The aim was to create curriculum content composed of educational objectives accompanied by assessment tools. "Teacher-proofing" the content, it was felt, would lead to high level science and mathematics content understanding and eliminate the pedagogical input made by individual teachers. Often described as "dumbing down" the curriculum, it was believed that teachers reduced the rigor of the content to make it more palpable for the students and often for themselves as well (Luciano, 2014). A decade later, Jerome Bruner would state, "despite all of the changes that the curriculum reform movement introduced into schools, at bottom, schools appear to have changed little" (Herold, 1974).

And so a few decades later, the quiet revolution began to take shape. Education reformers began to look at the role of the teacher and viewed it as a vital component. This would become the focus of future educational shifts. The goal of tackling the problem at the fundamental level, in the classroom, began to take hold. Research began to show that teaching quality and school leadership are the most important factors in raising student achievement (Mizell, 2010). It was felt that teachers should continually attend training programs and professional development to maintain their effectiveness and expand their knowledge base.

Teacher professional learning is now seen as a necessity in the development of effective teachers. Currently, teacher preparation is undergoing a dramatic shift. Schools of education are partnering with K-12 school systems to create a synergetic environment in which the teacher can focus on content and pedagogy as well as the constructivism theory of teaching. Although this is occurring across all content areas, nowhere is it more evident than in the trans-disciplinary area of STEM (science, technology, engineering and mathematics) education and teacher preparation. The current goal of STEM teacher preparation is to increase the number and quality of STEM teachers to help more students develop the 21st century skills of thinking critically and creatively and working collaboratively (Burrows & Slater, 2015). These educational reforms focus on increasing interest in STEM and STEM teaching (Corlu, Capraro, & Capraro, 2014).

2. Need for STEM Literacy

STEM education is being recognized as one of the necessities of an educated citizenry as well as a nation at large. Employment opportunities in fields related to STEM include health, manufacturing, environmental science, engineering, technology and a host of others (Peters, 2006). These career opportunities are expected to grow at more than twice the rate of non-STEM related jobs. In the ten year period ending in 2022, an estimated 1 million new jobs in the United States will have been created in the joint fields known as STEM (Vilorio, 2014). Yet, only 23% of post-secondary students major in STEM fields and of those students, only 6% earn a bachelor's degree in a STEM program (National Center for Educational Statistics, 2013).

The two major reasons why an effect in STEM education fails is the fact that there is a lack in the skill level/training of STEM teachers and a lack of curriculum structure in the subject integration of STEM (Blackley & Howell, 2015). STEM education needs to be revamped, starting with the advancement of the professional learning of K-12 STEM teachers. More real-world opportunities are needed in the preparation of those who will instruct future STEM professionals. Teachers are the lynchpin to the effectiveness of any of the educational reforms introduced both nationally and locally. In the areas of STEM education, this fact cannot be overemphasized. Professional development is seen as especially key to the reform efforts, as teachers must change their practice in both scope and style in order to support the range of knowledge that students are expected to learn and the new ways in which students are expected to acquire and assimilate that knowledge (Supovitz, Mayer, & Kahle, 2000). Unlike in other professions, in education, few specific requirements and even fewer opportunities exist for teachers to engage in meaningful professional development (National Research Council, 2000).

3. Overview of the Project

One such project that includes and emphasizes the need for professional development in STEM is called Integrating Environmental Restoration with Computer Science in New York Harbor with New York City Public Schools, henceforth referred to as CCERS STEM + C. The CCERS STEM + C program combines the two components of teacher professional development and real-world application to make a seamless synergetic model for educators both in content and pedagogy. Building on the success of the Curriculum and Community Enterprise for Restoration Science in New York Harbor Billion Oyster Project (BOP + CCERS), CCERS STEM + C will enhance the restoration science-based education and teacher training model with the addition of curriculum for teachers and students in computer science topics and CCERS STEM+C career exploration.

The model begins with the premise that public school curricula, particularly in the STEM fields, is enhanced by explicitly linking teaching and learning to a localized, large-scale environmental restoration endeavor that demands authentic research, data collection, and experimentation. Connecting student learning to place is a way to motivate science learning, empower underrepresented communities, and make greater connections between the school curriculum and students' lived experiences (Calabrese-Barton & Berchini, 2013). New York City encompasses a host of research-worthy environmental issues but one is pertinent to every school, teacher and student – the New York Harbor and its estuaries. The New York Harbor estuary was historically one of the most biologically productive ecosystems on the planet. For more than 250 years, the fisheries of the New York Bay and Hudson River nourished the people and propelled the wealth of the city. No species was more essential—or more abundant—in the building of New York City than the native East Coast oyster, *Crassostrea virginica*. The extent of its presence included more than 200 thousand acres of reef and hundreds of billions of individuals. At this scale, the oyster was inarguably the original ecosystem pioneer of New York Harbor. Its power to attenuate waves, continuously filter impurities, and shelter complex communities of marine life was unmatched and irreplaceable. After four hundred years of continual urbanization coupled with inadequate waste management, the estuary is now severely degraded yet remains deeply resilient.

Scientific oyster restoration, more than any other approach, offers students and scientists the opportunity to play a direct role in restoring the ecological health of the estuary with immediate and measureable improvements to biodiversity and water chemistry. Research indicates that students who are engaged in real-world, hands-on science, are more successful in science and have a deeper understanding and appreciation of the content (Foley & McPhee, 2008). To bridge this need for ecological restoration and education, the "Curriculum and Community Enterprise for Restoration Science" program was established through an NFS funded grant (Award #1440869). Consisting of five pillars, a platform for student engagement in STEM was created (See Figure 1).

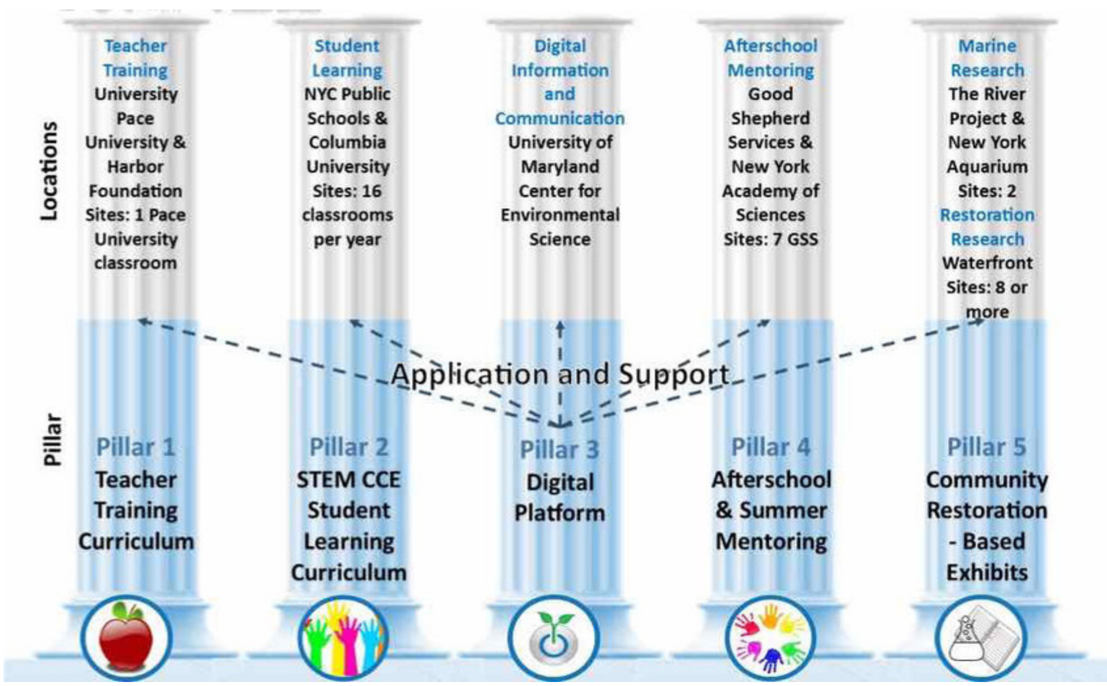

Figure 1. The Five Pillars of STEM Community and Curriculum Enterprise Restoration Science (CCERS STEM+C)

Pillar 1: Professional development (PD) for middle school teachers in underserved areas

Pillar 2: Student engagement with PD-trained teachers in middle school classrooms

Pillar 3: Digital platform for data management and shared learning

Pillar 4: Out-of-school mentoring for middle school student engagement

Pillar 5: Community engagement

4. Professional Development Model in Original Project

The first and arguably, most essential pillar is teacher training or professional development. In line with the current theories on enhancing educational outcomes, teacher content knowledge became the starting point. A professional learning community of New York City teachers was established through the formation of a fellowship program. Teachers were invited to a series of monthly workshops focusing on the training the teachers in the STEM content and the desired pedagogical approach to this project-based citizen science enterprise. The focal points of the workshops were the units and the lesson found in each. Essentially, each of the units highlights a critical component of the restoration of the harbor (See Table 1). The lessons found within contain objectives that align with both the New York State Science Learning Standards, STEM content and project-based, hands-on, real-world applications that pertain to the restoration process in New York Harbor.

Table 1. Sample CCERS+STEM Units and Lessons

Unit Title	Lesson Title	Lesson Title	Lesson Title
New York's Urban Ecosystem	Watersheds Where does the rain go?	Permeability	Ocean Acidification & pH
Nitrogen Cycle Investigation	A New York City Water Cycle	Get to know a few nitrogen molecules	Neighborhood Nitrogen Mapping
NY Harbor Populations Investigation	Food & Habitat Webs	Decline of Shad in the Hudson River Estuary	Oyster Decline in NY Harbor
Oysters & Organisms	Oyster Anatomy	Can you out-filter an Oyster?	Density and Oysters
Steward-shed Investigation	Build a Model of your Steward-shed	Run-off based on Maps	Pollution and run-off through pipes
Water Quality	Dissolved Oxygen & Oysters	Fecal Coliform and Numerical Extrapolation	Precision & Accuracy

Teachers in the learning community were tasked with presenting lessons from the curriculum in their classrooms. They then returned to the small learning community of teachers and the lessons were presented to the teachers as micro-lessons (15-20 minute presentations). A study by Remesh (2013) found that microteaching may help to reduce anxiety levels and enhance skills in problem solving, critical thinking, questioning, and reflective thinking for students. In a study (Shernoff, Sinha, Bressler, & Ginsburg, 2017), teachers repeatedly expressed the need to see examples of other teachers implementing integrated STEM lessons. By observing sample lessons, teachers see how curricula, instructional approach, and their interactions play out. The cohort of teachers then analyzed the presentation in terms of content, accessibility by middle school students and the ability to replicate the lesson. The ultimate goal was to ensure mastery of the content found in the lesson as it pertained to the New York State Science Standards (NYSED, 1996) as well as its significance to the restoration project. Input from the cohort retooled sand refined each of the lessons for future presentations in the in the participating schools and classrooms. This portion of the project was very powerful in terms of teacher self-efficacy and empowerment. The microteaching modules allowed for teachers to gain insight as to how the curriculum was being implemented into other teachers' classrooms. It permitted for teachers' exposure to the various teaching methods and resources being used to assist underrepresented students and students where English is a second language (Birney, Kong, Evans, Danker, & Grieser, 2017).

5. Successes and Challenges

Although there were many successes with the original model, challenges had to be overcome to ensure the goals of the project were accomplished. One of the major challenges was the limitation of shared time to develop worthwhile and meaningful tasks related to the New York Harbor Restoration. Teaching in this way requires expert application of knowledge and constant adaptation to diverse context and students (Grossman, Pupkin Dean, Kavanaugh, & Hermann, 2019) Although the original cohort of teachers met monthly for the first two years of the grant, many felt that more time would have further enhanced both the content and the pedagogical approach to the lessons.

A second challenge not only to the CCERS STEM + C Project but for New York City schools in general is the teacher retention rate. "A staggering 41% of city teachers hired during the 2012-2013 school year left the system during their first five years of teaching" (Algar, 2019). Predictably, the exodus is felt to the highest degree in high poverty communities, consisting of the most vulnerable populations of students. The CCERS STEM + C project is focused on the underrepresented populations of students from these critical areas and so teacher retention and the program's success go hand in hand. Attrition of teachers in this small learning community has been an ongoing challenge. Supports such as on-going training and materials for the classroom are provided as well as sessions with experts in the fields of aquaculture and scientific research to entice the cohort of CCERS STEM + C teachers. Additionally, the fact that the project involves community and parent engagement as well as its alignment to the most recently developed standards, adds to its enticement for school administrators, so even if there is teacher attrition, the trend is for administrators to have more than one teacher involved in the professional development.

A third major challenge was 2016 adoption of the New York State Science Learning Standards P-12. Adapted from the Next Generation Science Standards (National Research Council, 2013), the new Science Learning Standards were adopted to meet the changing expectations for scientific achievement. To ensure that students' abstract reasoning, computational skills and collaborative learning are attained for success in the 21st century, knowledge-based economy. A shift in terminology to performance expectation will allow for students to exhibit mastery in the three dimensions of learning standards (Science and Engineering Practices, Disciplinary Core Ideas & Crosscutting Concepts). Students are now required to function at the intersection of content, practice and connection through evidence based modeling, explanation and generative dialogue.

To meet this task, Phase 2 of the CCERS project was expanded into the CCERS STEM+C Project to include teacher training in Computer Science, Data Science and STEM Career Exploration.

6. Enhanced Professional Development in Phase 2

While continuing to implement and improve existing BOP-CCERS teacher training on New York Harbor ecology and restoration, Pillar I: Teacher Professional Development, placed more emphasis on teacher data literacy and the addition of computational tools now available for use in the classroom. Pillar III: The BOP-CCERS Digital Platform which contains both the units/lessons and the scientific data collected at the Oyster Restoration Stations is more accessible by virtue of a more extensive incorporation in the teacher professional development workshops. Although mathematics and science teachers have extensive content knowledge in their disciplines, they often lack the skills of data literacy and have limited experience teaching these skills. The lack of data analysis and interpretation within the units and lessons corroborates these findings. Through the training of teacher in the professional development sessions and their involvement in the design and execution of the lessons, a synergetic model will be created. Curriculum development can be challenging, therefore the involvement of all stakeholders, especially individuals who are directly involved in student instruction, are a vital piece in successful curriculum development and revision (Johnson, 2001).

In conjunction with a focus of the teachers' content and pedagogical knowledge, the enhanced professional development that is found in Phase 2 of the CCERS STEM +C Project presents itself as the perfect opportunity to introduce these computational competences. Currently, the New York City Department of Education's Division of Computer Science has launched the Computer Science for All (CS4All) initiative, with the goal that all NYC public school students receive a high-quality Computer Science (CS) education at each school level (elementary, middle, and high school) by 2025. In alignment with that goal, and the recent introduction of the P-12 New York State Science Learning Standards (see Section V), the teacher training component CCERS STEM + C will combine the most relevant concepts and practices of the K-12 Computer Science Framework (Computer Science Teachers Association, 2016), with an emphasis on those areas where computer science integrates seamlessly with the NYSED Science Learning Standards content, specifically the Core Concepts of Data and Analysis, and the following Core Practices:

- **Define Real Life problems and Community Issues**

S1. Ask questions and define problems (from NGSS) (Oyster Restoration in New York Harbor)

M1. Make sense of problems and persevere in solving them (from Common Core Math standards)

CS3. Recognizing and Defining Computational Problems (Data Analysis and Measurements in the Field)

- **Use computational thinking to resolve Environmental Restoration Issues**

S5. Use mathematics and computational thinking (Coding)

CS3. Recognizing and Defining Computational Problems

CS4. Developing and Using Abstractions

CS5. Creating Computational Artifacts

- **Communicate with data in terms of Citizen Science and Problem Based Learning**

S4. Analyze and interpret data (from the Field Oyster Restoration Stations, ORS).

CS7. Communicating About Computing (Presentations at Symposia and Local Community Events)

This pillar enriches the original BOP-CCERS's Teacher Training by scaffolding the fundamental concepts and pedagogy of statistical variation and distribution based on the data literacy of the cohort of teachers. Through the use of the BOP-CCERS's Digital Platform database (http://platform.bop.nyc) and the Jamaica Bay Data Analysis and Visualization Tool, teachers will contribute to the design and function of BOP-CCERS's open-source Digital Platform. Teachers are more prone to select a curriculum with which they are familiar and which provides easy access and embedded professional development and supplies (Eidietis & Jewkes, 2011). Teacher's opinions and ideas should be incorporated into the curriculum for development – it is important for successful and meaningful curriculum development. Teachers being the implementers are part of the last stage of the curriculum development process (Alsubaie, 2016).

Finally, CCERS STEM + C teacher training curriculum will be supplemented by adding more sessions on STEM career exploration. Findings from the prior BOP-CCERS implementation point to the need for greater attentiveness in supporting students' long-term educational and professional trajectories, increasing both interest in and access to STEM careers and professional role models and mentors. Research suggests that improving the pool of STEM teachers, instructional methods and/or curricular materials are better pathways to increasing interest in STEM majors and careers by women and minority students (Darolia, Koedel, Martorell, Wilson, & Perez-Arce, 2016). With this in mind, the design of the professional development will encompass a fortified focus on increasing study self-confidence and efficacy in the area of STEM through integrated, community based scientific research and restoration of the New York Harbor. Teachers will learn to focus on the self-esteem and self-worth of the students in their classes by preparing and presenting lessons that are rich in interest and content but palpable for all middle school learners. The computational component will act as a lens for engagement and will create an opportunity for problem-solving and design thinking. Showing an interest and confidence in mathematics and science in middle school is a strong indicator that students will pursue STEM degrees (Hinojosa, Rapaport, Jaciw, LiCalsi, & Zacamy, 2016). Decisive changes must be made in the delivery of STEM content to all middle school students but especially those that feel disenfranchised. Female and minority students must become more engaged in the STEM disciplines at an early age to safeguard a diverse STEM workforce.

7. Conclusion

The overarching mission of the Curriculum and Community Enterprise for Restoration Science (CCERS), more extensively called the Billion Oyster Project (BOP), is to restore the New York Harbor and its waterways through the introduction of a billion oysters by the year 2025. A community of educators, students, citizen scientists, businesses and local organizations has been enlisted to play a direct role in the ecological restoration and stewardship of the harbor. The foundational partnership is composed of personnel from Pace University School of Education, New York Harbor Foundation, New York City Department of, Columbia University's Lamont-Doherty Earth Observatory, New York Academy of Sciences, the University of Maryland's Center for Environmental Science, Good Shepherd Services, New York Aquarium-WCS, and The River Project. Possibly the most significant of these partners is the New York City Department of Education. More than any other partner, the NYC Department of Education has played a critical role in helping to establish the project and in supporting its long term objective of engaging every student in the city in the restoration and stewardship of New York Harbor (Billion Oyster Project, 2016).

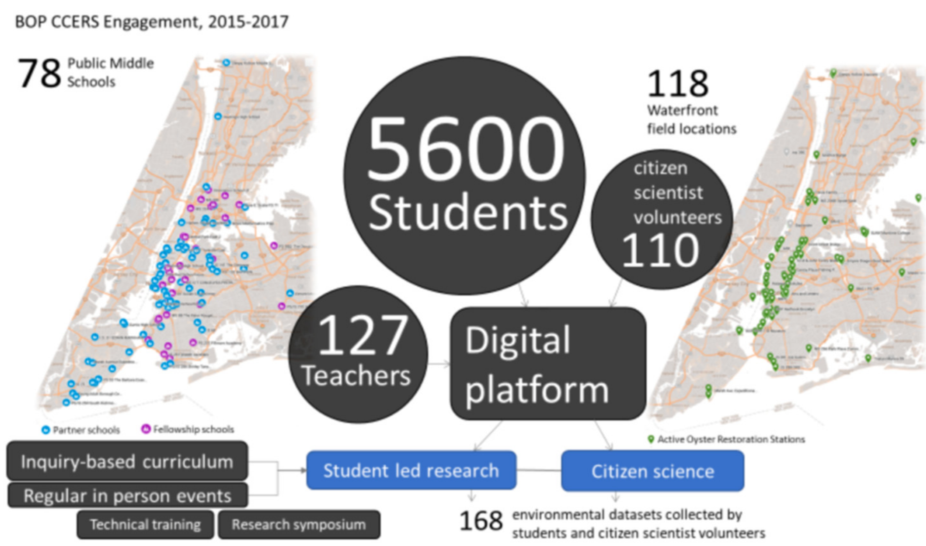

Figure 2. The Billion Oyster Project – Curriculum and Community Enterprise for Restoration Science 2015 – 2017 Engagement

Currently there are over 127 teachers in the professional development component of the project. They have helped to create 15 separate units containing over 75 lessons and through mini-lesson presentations in their small learning community as well as whole class presentations to their students, have placed focus on the ecological environment that encompasses New York City. Over 5,000 students have been taught though the field tested and evidence-based lessons focused on the New York Harbor and Oyster Restoration. The authentic, problem-based trans-disciplinary lessons focus on all areas of STEM, requiring students to develop hands-on, real world applications to local environmental issues. Findings from the project suggest that treatment classrooms had higher levels of knowledge in STEM topics than students in the comparison classrooms. (Birney, McNamara, Sanders, Luintel, & Penman, 2018).

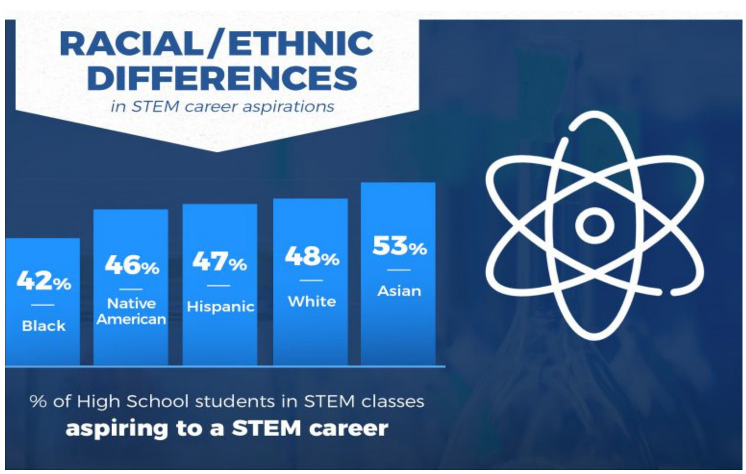

Figure 3. STEM Career Aspiration by Racial/Ethnics Differences

2017 Student Research Foundation – Data form the 2016-2017 school year

As with any dynamic model, the design phase is always being tested and evaluated. In this next phase of the project, the inclusion of STEM career and educational opportunities as well as enhanced computer science experiences have been added because research indicates that these are educational areas that need bolstering, especially in the middle school students. Exposure to STEM careers can elevate student interest in pursuing careers involving science, technology, engineering and mathematics (Blotnicky, Franz-Odendaal, French, & Phillip, 2018). Emphasis must be placed on the inclusiveness of underrepresented populations in the STEM fields.

It is essential that participating teachers receive the professional development necessary to disseminate these options to their students, especially those underrepresented in the STEM fields. Professional development of educators is important as it is likely that instructors are not fully aware of what they can do to positively impact students' science identities (Martin-Hansen, 2018). The Curriculum and Community Enterprise in Restoration Science-Science, Technology, Engineering and Mathematics + Computer Project (CCERS STEM + C) is focused on extending the project in this direction.

Finally, the focus on any educational system must be on the teacher and improving the preparation and professional development model to augment their ability to reach all students. No area of pedagogy is more critical than that of the STEM disciplines. The clamor for more STEM prepared students will continue to increase as the STEM field continues to evolve and grow. Communicating findings in STEM and innovation can only be done through information technology and digital media. Creating opportunities for students, especially marginalized and underrepresented students, to engage in interdisciplinary approaches in solving authentic environmental challenges in their own communities plants the seeds of enticement and makes the career option accessible. The CCERS STEM + C project continues to redesign portions of the project as proposed in research-based evaluations. The teacher professional development model has been strengthened by providing teachers with the knowledge to guide their students toward STEM career pathways. The additional of computer science and computational tools, including large data sets found on the digital platform, bolsters the computational thinking skills needed by students to explain real-world phenomena found in their own community and design possible solutions. The advances that have been added to the CCERS STEM + C Project will not only create a conduit for a future STEM workforce but will have a greater impact on the ecological restoration of New York Harbor.

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