The Curriculum and Community Enterprise for Restoration Science Making STEM Accessible, Equitable and Environmentally Relevant

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Abstract

Underrepresented and marginalized students have challenges when connecting their personal identities to STEM identities. This has a direct impact on the post-secondary educational and career choices of these students. Some factors which contribute to the disenfranchisement of marginalized students include inequity in academic preparation, students' lack of self-efficacy and self-identity in STEM, students' lack of connection to the STEM curriculum and students' lack of role models and mentors. Although the opportunities in the STEM workforce are abundant and lucrative, students who identify as students of color, female and/or English language learners are poorly represented in the STEM professions. Through the CCERS STEM + C Program, students are asked to expand their STEM identity through near-peer mentoring, encounters with STEM experts and individual STEM Research projects that are focused on the environmental restoration of New York Harbor, its watershed and the native oyster population.

Keywords: diversity, equity, inclusion, ecological restoration, peer-mentoring, STEM identity

1. Introduction

When considering future generations of scientists and healthcare professionals, the Sullivan Commission (2004) declared under-represented minorities to be "missing persons" in those fields. There is a lack of STEM identity among marginalized populations in the United States. Underrepresented students (students of color, students with linguistic challenges, female students) struggle with the connection of their personal identities to STEM identities and see themselves as part of the STEM domain. This has a direct impact on the post-secondary education and career choices of these students. Some factors which contribute to the disenfranchisement of marginalized students include inequity in academic preparation, students' lack of self-efficacy and self-identity in STEM, students' lack of connection to the STEM curriculum, and students' lack of role models and mentors.

There is a need for a more inclusive STEM presence in the United States and this can be accomplished by cultivating a diverse STEM workforce. STEM talent is needed to drive innovation and solve real-world problems and this can only be achieved through the creation of opportunities that support a diverse STEM population. As reported recently, the bulk of the growth in population in the United States has occurred in people who identify as Hispanic, Black, Asian, or more than one race (Moses et al, 2021). As stated by William Frey, a demographer at the Brooking Institution, "This is a pivotal moment for the country. We have people of color who are younger and growing more rapidly. They are helping to propel us into a century where diversity is going to be the signature of democracy" (Frey, 2021). Currently, this growth is occurring in a U.S. context that has historically disenfranchised and marginalized students of color (Ladson-Billings, 2006). In addition, research indicates that greater gender diversity will bring a wide range of viewpoints to bear on scientific problems, facilitating innovation, creative problem solving, and novel discoveries (Lewis et al., 2017).

In the United States, the lack of diversity in pursuing STEM education and continuing onto a STEM career is glaringly apparent. As stated in the U.S. Commission on Civil Rights Report (2018), the United States has continued to create inequitable educational opportunities for culturally and linguistically diverse student populations in the first quarter of the 21st Century. Women, especially women of color, are significantly underrepresented in STEM fields in the United States. Hispanic and African American women each receive less than 5% of STEM bachelor degrees (Ong, Smith & Ko, 2018). Researchers find that women, Blacks, and Hispanics are less likely to be in a science or engineering major at the start of their college experience, and less likely to remain in these majors by its conclusion (Griffith, 2010). Because most STEM workers have a science or engineering college degree, underrepresentation among science and engineering majors could contribute to the underrepresentation of women, Blacks, and Hispanics in STEM employment (U.S. Census Bureau, 2013). The importance of diversity in the STEM domain cannot be understated. It increases the social, economic, and human capital, not only for the individual but also increases our national prosperity and global competitiveness. Available jobs in STEM have increased by 27% in the last decade. Technology companies, engineering firms, and science research facilities need to fill these positions from members of the STEM disciplines. When trying to solve complex problems, progress often results from diverse perspectives. Research indicated that when a challenge is confronted by a group of intelligent people from various backgrounds, the diversity of the problem-solvers matters more than their individual ability (Hong & Page, 2004). Full representation of women and minorities is a necessity, not only for the self-efficacy and upward mobility of the individual but also to create a more successful and inclusive workforce (Covington, Chavis & Perry, 2017).

The Curriculum and Community Enterprise for Restoration Science STEM + C Project is a National Science Foundation-funded project that is working to tackle these issues, starting with students in the New York City Department of Education. This is the largest school system in the United States and is comprised of 1,094,138 students. Ethnically, the students identify as 40.8% Hispanic, 24.7% Black, 16.5% Asian, and 14.8% White. Included in this ethnic delineation are 13.3% English Language Learners and 20.8% students with disabilities. A staggering 73.0% of all of the students in the New York City Department of Education are economically disadvantaged (New York City Department of Education, 2021). The Curriculum and Community Enterprise for Restoration Science STEM + C Project, henceforth known as the CCERS STEM + C project, has been able to address these challenges by introducing a real-world, community-based, hands-on environmental conundrum. At its essence, the CCERS STEM + C Project is an environmental science restoration design aimed at restoring a billion oysters in New York Harbor by the year 2035. New York Harbor was once the “oyster capital of the world” (Kurlansky, 2006) but through environmental degradation and overharvesting, its waterways became so polluted that by 1927 the oyster beds were closed due to toxicity (Nigro, 2011). Several environmental groups had attempted to revivify the harbor and its watershed through restorative efforts and public awareness campaigns. However, a more unified and consolidated attempt has been established through the CCERS STEM + C Project. Through the formation of a vast, multifarious organization of partnerships with educational districts, university leaders, researchers, community groups, and restaurateurs, sustainable environmentally restorative efforts are seeing marked improvements in the quality of the water and the abundance and diversity of the aquatic populations.

The CCERS STEM + C project considers the STEM journey from the elementary level through post-secondary education and employment. The project includes formal and informal (fieldwork) education, in-school, after-school, and summer learning experiences; and support through the integration and collaboration of near-peer mentors and highly and specifically trained teachers and experts in the STEM disciplines. Students are encouraged to pursue their STEM goals through career exploration which includes stewardship and meaningful, thought-provoking research in environmental restoration.

The objective of the study is to determine whether the marginalized students in the program

a) Develop a deeper STEM identity; can identify as a STEM student and/or pursue employment in a STEM Career

b) Develop a greater affinity for their community through their stewardship of the NYC harbor and the restoration project

c) Develop the content knowledge and skills needed to pursue STEM in higher education and employment opportunities

2. Method

2.1 Background

Initially instituted in 2014, the Billion Oyster Project and the Curriculum and Community Enterprise for Restoration Science Project formed an expansive place-based environmental education effort conducted in the schools in New York City (Birney & McNamara, 2017). The project is anchored by five supporting pillars: (1) the Teacher Education Curriculum, (2) the Student Learning Curriculum, (3) the Digital Platform, (4) After-school STEM

Programs, and (5) Public Exhibitions. Each pillar is driven by the work of a variety of community partners, creating synergy throughout the web of activities and experiences. Preliminary research on successful STEM schools indicates that cultivating partnerships with industry, higher education, nonprofits, museums, and research centers is important for engaging students in STEM learning through internships, mentorships, interdisciplinary project-based learning, and early college experiences (Means et al., 2017).

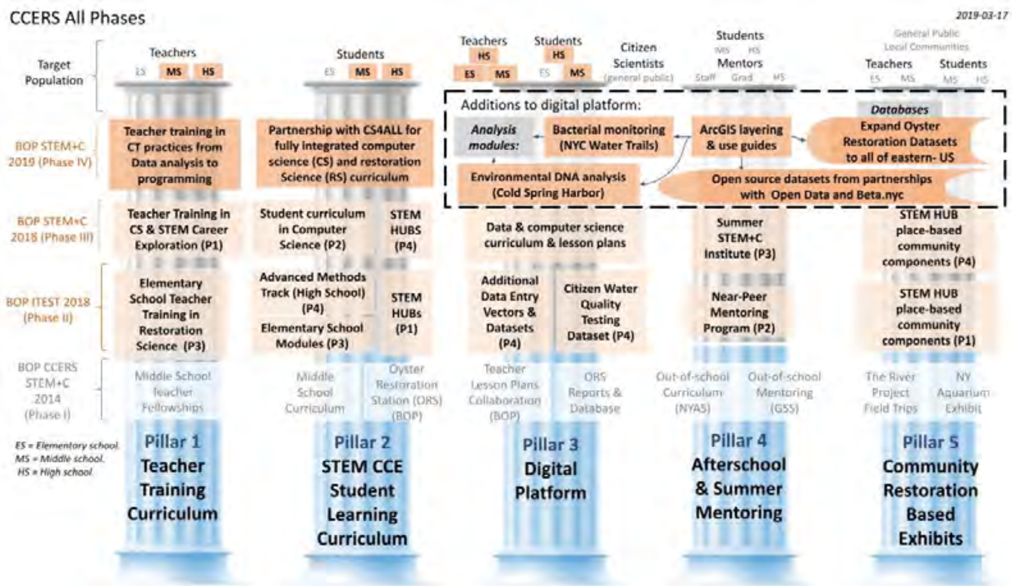

Figure 1. The Five Pillars of the Curriculum and Community Enterprise for Restoration Science + STEM-C

New York City public school students in middle schools located in underserved communities were chosen to study the New York Harbor and its impact on the community within the harbor and surrounding it. Although each of the boroughs of New York is situated in the harbor, students rarely saw this as an environmental issue that directly affected their community. The initial educational goal was for these students to understand the historical, environmental, and geological factors of their waterways and the aquatic life within, especially focusing on the oyster. Motivation to restore the population of the native oyster and develop stewardship for their environment is embedded in the project. Students experience higher levels of engagement and take a deeper approach to learn when they can apply what they are studying to address a real-world problem (Lombardi, 2007). This is done through the combination of classroom lessons and field investigations that allow for problem-based learning and individual science research. One of the ways to ensure that this authentic and connected learning can take place is by leveraging strong community partnerships to provide real-world learning to students in middle and high schools (Gross, et al., 2015).

Since 2018, the project has expanded to focus on practices that increase student motivations and capacities to pursue careers in fields of science, technology, engineering, or mathematics (STEM). These expansions include an after-school STEM mentoring program and a near-peer mentoring program, community-based restoration science hubs, and advanced methods of laboratory analysis in restoration science. In addition, a STEM symposium is held annually to showcase the individual science restoration research projects many of the students submit and present. All are designed to heighten motivation in STEM disciplines for students in low-income neighborhoods comprised of high populations of English language learners and students that are underrepresented in STEM fields and education pathways and to bring to light a possible pipeline to future career paths. Creating a most diverse STEM workforce is a major enhanced focus of the project. The project directly involves 97 schools, over 250 teachers, and approximately 11,000 K-12 students.

2.2 Subjects

Currently, the CCERS STEM + C Project has enlisted 250 teachers, working mostly in Title I schools, and their 11,000 New York City public school high-needs students. The majority of the students identify as underrepresented populations in the STEM fields. These schools are located throughout the five boroughs of New York City

(Manhattan, the Bronx, Queens, Brooklyn, and Staten Island).

Initially, the teachers are invited to summer professional development sessions at Pace University that focus on the content and skills the teachers will need to share with their students. Through a series of professional development workshops, the faculty and STEM-specific expert guest lecturers introduce the CCERS STEM + C curriculum which focuses on the environmental restoration of New York Harbor with an emphasis on the Eastern Oyster (*Crassostrea virginica*) population. An inquiry-driven STEM curriculum that enables students-as-scientists to conduct authentic field observations and data collection, articulate research questions based on fieldwork, design experiments and research methodology, analyze and assess results, and publish and disseminate findings will enhance student understanding of and interest in STEM career fields, as compared to those who are not able to experience inquiry-driven field science, based curricula and pedagogy. The epistemology of teacher professional development undergoes a paradigm shift to include a culturally responsive learning environment. Culturally responsive teaching practices focus on the assets that students bring from their communities and their cultures (Cooke-Nieves & Trowbridge, 2020).

The primary factor affecting a student's ability to experience inquiry driven field science curriculum is their teachers' level of training and technical background in both the pedagogical methods and curricular content. Secondary factors include logistical and economic barriers such as scheduling, transportation, procurement/use of supplies and equipment, student safety and field class management, and overall costs. Scientific inquiry prepares students to think and act like real scientists, ask questions, hypothesize, and conduct investigations using standard science practices. Teachers must possess a high level of knowledge and engagement for the inquiry-based approach. They often feel unprepared because they are lacking authentic scientific research and inquiry experiences themselves (Nadelson, Seifert, Moll & Coats, 2012).

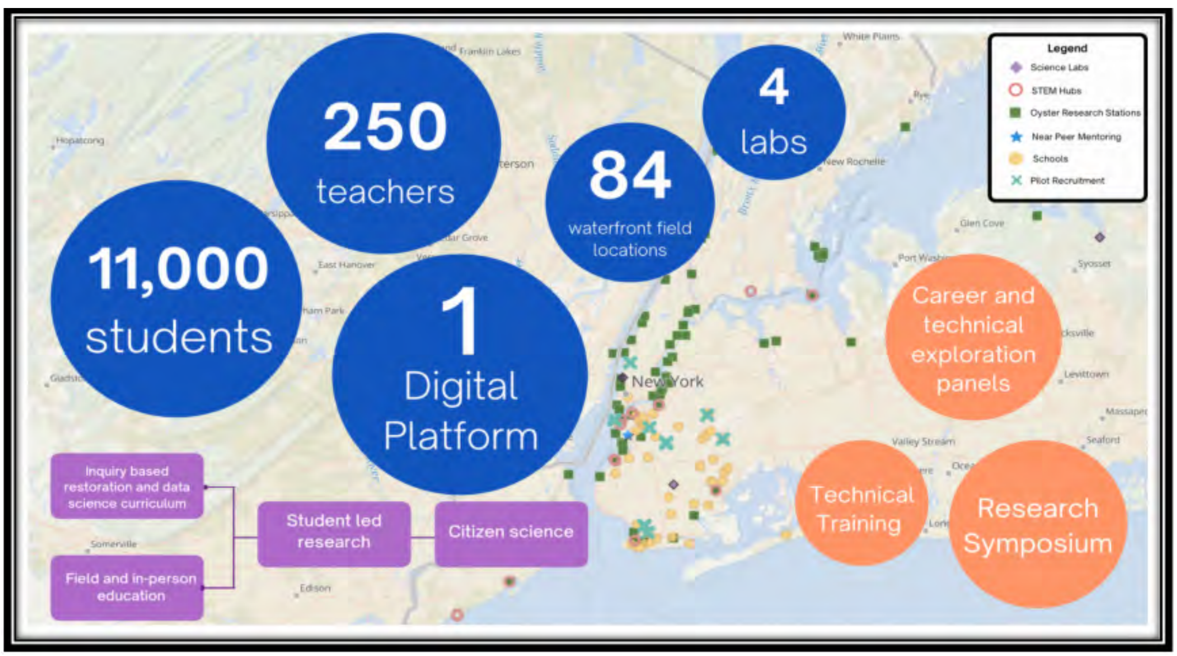

Figure 2. BOP CCERS Community Impact Factors 2021 Summary

2.3 Cultivating STEM Identity

A decade ago, New York City, along with many large metropolitan cities such as San Francisco, Washington, D.C., Los Angeles, and Houston became a majority-minority city (Frey, 2011). School districts within these cities have been grappling with a changing dynamic in the classroom by addressing cultural, ethnic, and gender identity in teacher professional development and the curriculum. In the content areas of STEM, where there is ever-increasing employment growth the CCERS STEM + C project in New York City is preparing a space for a more inclusive, less restrictive STEM environment and in so doing, is fostering underrepresented students' interest, motivation, and sense of self-efficacy in STEM fields. Research suggests that gender and ethnicity can impact feelings of acceptance, with students from underrepresented groups reporting more uncertainty about whether they belong in their academic fields than students from well-represented demographic groups (Zaniewski & Reinholz, 2016).

To inculcate inclusiveness in STEM education and employment opportunities, the following elements have been presented to the participating students:

a) Near-Peer mentoring – Students who exhibit a consummate understanding, motivation, or aptitude in the CCERS STEM + C project are tapped to be formally mentored by a STEM professional. These students are a smaller sub-set of the marginalized students in the program. Research has shown that students' positive self-efficacy and identity development can be impacted by the experiences of others in their field who are "like themselves" through any number of shared characteristics (Bowers, Rosch & Collier, 2016). Students are accepting of non-outlier individuals as role models when these individuals are relatable and possess the qualities they value in a role model. This suggests that it is possible to create larger and diverse pools of role models for underrepresented minorities in STEM who represent a wide range of examples of feasible paths to success. Such a pool could influence student positive self-efficacy and positive self-identity development and potentially increase intrinsic motivation to pursue and persist in STEM (Aish, Asare & Miskioglu, 2018). Educators can help build interest in STEM and encourage underrepresented students to pursue STEM careers by asking about their mentorship preferences and then connecting students with mentors accordingly (Kricorian, Seu, Lopez, Ureta, & Equils, 2020).

b) STEM Research – Students are further encouraged to formulate their STEM identity by developing their research and writing skills through the lens of a STEM-specific research project. Teamed with STEM mentors from the New York Academy of Science and other formal and informal institutions of STEM-related work, students confer with their mentors as they delve into a STEM-related challenge CCERS STEM + C Project. Topics vary from the resurgence of aquatic life in New York Harbor to possible solutions to combined sewer overflow, with students becoming the experts on the various topics. Journal appropriate articles are created and presented at the annual STEM Symposium held on Governor's Island each June. Trans-disciplinary capstone projects blend science, English language arts, social studies, engineering, and mathematics, and are designed to transcend in-school and out-of-school environments. Students' projects are structured to more closely resemble the tasks and uncertainties inherent in real life and make schoolwork more relevant to the students' lives and more transparently linked to the skills needed to succeed in the working world (Vega, 2012).

c) STEM Professionals – STEM experts meet with the students and share their expertise in the critical skills of expertise problem-solving, research development, and collaboration. Students learn to work and learn side-by-side with top professionals in the STEM fields. The barriers are diminished and the students begin to realize the opportunities that are available by pursuing STEM education and careers. Citizen Science aims to integrate scientists and non-scientists into the research process and therefore offers the opportunity to represent a broader public in scientific knowledge production (Wünsche & Schimmler, 2019). Research supports the potential benefits of internships or apprenticeships and community service for academic achievement and student engagement when these experiences are closely connected with curricular objectives (Bell, Blair, Crawford & Lederman, 2003)

d) STEM-trained teachers - Teachers receive professional development in all relevant harbor restoration content areas. These include New York Geography, Marine Biogeochemistry, and Environmental Justice. Through a series of summer and after-school sessions, the NYC public school teachers learn from the CCERS STEM + C staff and various guest lecturers to engage in the development of the student curriculum. By planning the CCERS STEM + C curriculum for use in the classroom and the field at the oyster stations, the teachers not only develop an understanding of the nuances of New York Harbor but also increase their knowledge of best instructional practices. Greater investment is needed for the training and recruitment of teachers, in addition to new pedagogical approaches to support quality education (Shostya, 2021).

e) STEM Inclusive atmosphere – Creating a space where students, in particular, marginalized students who have difficulty relating to their STEM identity, are encouraged to become an integral part of the STEM ethos. By involving all aspects of the students' lives (school, stewardship, and community) in the CCERS STEM + C Project, the students are immersed in the STEM environmental restoration movement and view the challenge more holistically. Research indicates that the academic climate that individual students experience is a manifestation of the college culture and one factor that influences student performance, engagement, and persistence outside of what would be predicted by socioeconomic or academic preparation indicators (Chang, Eagan, Lin & Hurtado, 2011). Science identification is important for minority students because it confers a sense of belonging in science that might otherwise be negatively targeted due to their marginalized group status (Chen, et al., 2020).

f) STEM Self-efficacy – The culmination of these factors, which have been developed for the CCERS STEM + C

Project, manifest themselves in the overall self-efficacy of the student and increasing comfort with his/her STEM identity. This, above most other factors, is the indicator for persistence and success in the STEM fields. Motivation, in particular intrinsic motivation, has proven to be a big influence on persistence in STEM (Simon, Aulla, Dedic, Hubbard & Hall, 2015). A sense of belonging is defined as the subjective feeling of fitting in and being included as a valued and legitimate member in a particular setting, such as a STEM learning environment (Walton & Cohen, 2007). Self-efficacy and identity both play a role in motivation and have been shown to have a big influence on minority students (Zeldin, Britner & Pajares, 2007).

3. Results

The objectives of the program can be seen in the results of the external evaluation and the anecdotal responses from some of the participants who represent the marginalized populations targeted by this project.

a) Objective: Develop a deeper STEM identity; can identify as a STEM student and/or pursue employment in a STEM Career

The majority of the teachers reported that the professional development sessions enabled them to increase their students' engagement with STEM and interest in STEM Careers. One of the participating teachers commented, "By being able to act in a role that is similar to the role of scientists, my students saw the possibility of becoming scientists". These findings suggest that participating in CCERS does increase students' knowledge about STEM careers and improves their perception of their scientific skills compared to those with less involvement (Moore, 2021). Another stated, "As a woman in STEM, it's easy to get discouraged, especially when you're typically the only girl in the room…but I remind myself that I have communities and resources to support me. STEM is a way to find new and better solutions to the problem found in our community".

b) Objective: Develop a greater affinity for their community though their stewardship of the NYC harbor and the restoration project.

The majority of teachers whose students participated in the 6th Annual Student Research Symposium stated that their students' direct participation in the Oyster Research Stations and classroom tanks provided the main impetus for the development of their symposium research projects. The STEM Hubs are CCERS' greatest strength. Evidence of this strength is the depth and breadth of student participants who presented projects at the Annual Symposium. They demonstrated awareness of the environment and a sense of ownership of their environment and a call to action that was addressed in many of the research projects (Moore, 2021). When students were asked about STEM identity, responses included "being able to be a part of the STEM field and expand the demographics" and "having a STEM identity will allow me to use my knowledge to help serve my community". Another participant stated, "To me, STEM identity means feeling a sense of belonging within a STEM field/community. It is a feeling of being drawn to and interested in the STEM world".

c) Objective: Develop the content knowledge and skills needed to pursue STEM in higher education and employment opportunities.

The external evaluator has found that overall the project's implementation has measurably contributed to achieving its major goals of increasing student engagement with real-world STEM learning and increased student interest in STEM careers. Research results indicate that students with moderate to high levels of engagement with the project have higher motivation, interest, and engagement in STEM knowledge and career pathways as compared to a low-engagement comparison group, as measured by survey instruments and analysis. This finding is expected given the higher degree of exposure and opportunities gained by these students through their completion of the project's core curriculum, field science activities, and their direct contact with scientists and learning from mentors. In comparison to the low-engagement control group, participating students had a higher self-rating on STEM identity, intent to pursue STEM careers, and engagement In STEM activities.

4. Discussion

The Curriculum and Community Enterprise STEM + C Project primarily expands the quantity and quality of STEM teaching in the New York City public school system. It provides meaningful ways to support underrepresented students in STEM through a highly engaging curriculum and activities that are anchored in real-world restoration ecology and marine environmental science. Thousands of students from low-income communities and demographics which are historically underrepresented in the STEM community have the opportunity to work alongside environmental scientists and STEM professionals, restoring the native oyster population in New York Harbor. The inclusion of these disenfranchised populations of students enables the nurturing of intellectual STEM talent that can drive innovation and solve real-world problems. Peer mentors from underrepresented groups promote STEM talent diversity as a means of inclusion in STEM education and career pathways.

Although the project has had many successes in its original iteration and through the evolving modifications that have been made to strengthen the program, additional work is needed to ensure continued success. The findings from the project's target demographic, the subset of historically underrepresented and minority (URM) students had on average higher levels of interest in STEM and scientific identity as compared to non-URM respondents evaluated pre and post-participation. However, underrepresented minority participants reported on average a significantly lower expectation of academic success in STEM compared to non-URM students after experiencing the same level of project participation. This finding indicates that improving underrepresented minority students' persistence in STEM requires additional measures of support or intervention to increase self-efficacy, motivation, and awareness/access in terms of STEM content and opportunities. An additional negative impact on the project has been the pandemic caused by COVID-19. The efficacy of portions of the project, in particular, direct in-person contact with the students (near-peer tutoring and mentorship) has been diluted through the inability of consistent person-to-person contact. Further research is needed when the program can be fully implemented in its intended format.

Similar studies that have focused on diversity in the STEM disciplines and the need to sustain these students in STEM through their educational trajectory and onto a career in STEM have focused on similar research strategies. At the university level, an active learning project was introduced to increase the students' sense of belonging to the STEM community. Through a long-term focus on diversity in the STEM fields, students demonstrated a shift in their self-identities and how these intersect with their scientific identities (Singer, Montgomery & Schmoll, 2020).

In a study exploring the effectiveness of project-based learning on student self-efficacy and career aspirations in STEM (Beier et al, 2019), a specific ad open-ended authentic project was presented to the students. Students were tasked with conducting a goal-directed investigation requiring inquiry, problem-solving and knowledge building. The findings of this study indicate higher levels of career aspirations in STEM disciplines and greater STEM skill efficacy. These findings also suggest that these results are regardless of race or gender.

The implications suggest that long-term real-world investigations in STEM benefit all students and have the ability to unify a student's self-identity and STEM identity. Combining this with environmental investigations of personal concern raises both the level of interest and the tenacity with which the students meet the challenge. A suggestion for further study would be to conduct more of these investigations on the primary and secondary level of education. The two studies cited above were both done at the university level. Research supported by the National Science Foundation (Honey, Bass, Strutchens & Rodriguez, 2020) concludes that young children benefit from learning STEM subjects, which include Science, Technology, Engineering, and Mathematics, because they become the building blocks for future learning.

Environmental restoration is a universal problem that can be tackled by improving the capacity of ecosystems through education and stewardship. The CCERS STEM + C Project has had great success in the largest school system in the United States combined with one of the largest natural harbors in the world. The model is seen as a replicable one. Because of the breadth of partnerships and the inclusion of all of the various components of the project, many and varied iterations are possible in other settings.

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