The Future of Education in the United States: Emulating the Billion Oyster Curriculum and Community Environmental Restoration Science (STEM + Computer Science) for Secondary School Success

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Abstract

Recent educational developments on the national and regional scale have called for a radical transformation. New York State is reassessing the qualifications needed for high school students to attain a diploma. The federal government is threatening to abolish the United States Department of Education. For students to be prepared to face the challenges of the global economic landscape, several 21st-century skills will be needed. The Billion Oyster Curriculum and Community Environmental Restoration Science (STEM + Computer Science) offers a multifaceted, content-rich, community problem-based model that provides a pattern for similar community involvement while incorporating the competencies and skills needed to become successful in higher education and employment. Student exposure and confidence in STEM content and computational skills enhance their awareness of this as a possible career choice. A student survey which contains a confidence in technological abilities subscale was administered to all subjects of this study.

Keywords: self-efficacy, career awareness, technological aptitude, environmental restoration

1. Introduction

The New York State Education Department and Board of Regents set a plan to develop revised high school graduation measures and diploma requirements. The purpose is to guarantee educational excellence and equity for all students. In 2023, the Blue Ribbon Commission disclosed its recommendations, focusing on the shared commitment to diversity, equity, and inclusion, the initiative was developed to: (1) create equity in New York State's public education systems, and (2) ensure that all New York students gain the knowledge and skills necessary to succeed in school and after they graduate. Ultimately, the current high school diploma configuration (Local, Regents, or Regents with Advanced designation) will be transitioned to a high school diploma (with refined seals and endorsements) signifying a required proficiency in both the learning standards and the Portrait of a Graduate. The thirty-seven recommendations proposed by the members of the Commission were eventually combined. Although many deal with the details of the one diploma model, two of the recommendations directly focused on the types of competencies and skills needed by successful high school graduates. They are:

1. To include civic responsibility (ethics); cultural competence; financial literacy education; fine and performing arts; science, technology, engineering, and mathematics (STEM) credit(s); and writing, including writing skills for real-world scenarios in diploma credit requirements.

2. To ensure access to career and technical education (CTE), including internships and work-based learning opportunities for all students across New York State.

Table 1. Competencies, Skills, and Content Focus for NYS High School Graduation

Competencies	
	Civic responsibilities (ethics)
	Cultural competencies
	Financial literacy
	Writing skills for real-world scenarios
	Internships and work-based learning
Content	Fine and performing arts
	Science, technology, engineering, and mathematics
	Writing
Skills	Creativity and innovation
	Critical thinking and problem-solving
	Social and emotional skills including collaboration, communication, and self-management
	Digital literacy and information processing
	Basic life and career skills
	Authentic learning experiences (connection classroom learning to the world in which the students live)
	Civic education and civic readiness

On the local level, the New York City Public Schools (NYCPS) mission is to ensure that each student graduates on a pathway to a rewarding career and long-term economic security, equipped to be a positive and productive citizen. To deliver on this mission, it seeks to ensure all students graduate with real-world skills and experience, a head start on life after high school, and a strong plan to put them on this path. All New York City Public High School students will have foundational skills for career readiness, digital fluency, and financial literacy. Armed with a strong postsecondary plan will ensure students are prepared for economically secure and rewarding careers.

1.1 The Problem

The challenge at this crossroads is how to create a curriculum that will encompass the competencies, content, and skills needed to produce successful high school graduates and future members of the workforce. The advancement of 21st-cnetury skills, such as critical thinking, creativity, and teamwork, is a necessity for education in the current century (Zivkovil, 2016). A reevaluation of conventional curricula and pedagogies is necessary, emphasizing personalized instruction and the need for lifelong learning. With an emphasis on 21st-century skills and competencies and de-emphasis on quantitation measures of success through arduous and often unnecessary testing and accountability measures, education's priorities have shifted toward performance expectations and their ability to transition students to successful career-oriented citizens. Cognizant of this change in focus, the successes of the Curriculum and Community Enterprise for Restoration Science STEM+C can be viewed as a potential model to emulate. The project is modeled on the Smart and Connected Communities for Learning (Roschelle, Martin, Ahn & Schank, 2017). Working to solve problems within their community, students can comprehend the connection they have to a complex system involving schools, businesses, and the environment.

The Curriculum and Community Enterprise for Restoration Science STEM + C (hereafter known as CCERS STEM+C) was a National Science Foundation-funded grant conducted throughout the five boroughs of New York City during the years 2014 – 2024. The New York City Public School system, in partnership with Pace University, the Columbia University Lamont-Doherty Earth Observatory, the New York Academy of Sciences, the New York Harbor Foundation, the New York Aquarium, the River Project, and numerous restaurants and business organizations built on the Billion Oyster Project to restore the waterways of New York Harbor. The model of the project hinged upon five interconnected pillars, all of which evolved throughout the tenure of the project. (See Figure 1).

Pillar 1 – Teacher Training Curriculum – professional development was provided to middle and high school educators to develop and implement a new curriculum integrating restoration science through active learning of STEM + C through the use of long-term project-based learning.

Pillar 2 – STEM CCE Student Learning Curriculum – project-based activities provide the students with the opportunity to apply classroom learning to real-world problems. Along with classroom instruction, students visit restoration stations to measure the growth of oysters, identify organisms in the mobile traps, and assess water quality through collecting and recording data. (See Table 2).

Pillar 3 – Digital Platform https://bopuiprod.azurewebsites.net/home – A dynamic multifaceted repository containing collected fieldwork data in a collaborative database, student curriculum units and lessons, individual investigation reports, and projects, and symposia information.

Pillar 4 – Afterschool and Summer Mentoring – scientists, educators, and peer mentors collaborate in a joint effort to provide afterschool and summer STEM + C curriculum in underserved communities. Out-of-school lessons in afterschool programs, oyster clubs, and summer camps, teach students about oysters, science, and the history of New York Harbor through hands-on experiences.

Pillar 5 – Community Restoration-Based Exhibits – Community exhibits complement and extend the learning of science, restoration efforts, and related history. They are created for the general public as well as the students and aid in educating about oysters and biodiversity in the local environment. Community exhibits simultaneously promote the program and drive students, educators, and the general public together toward the digital platform for more sharing. (See Figure 8).

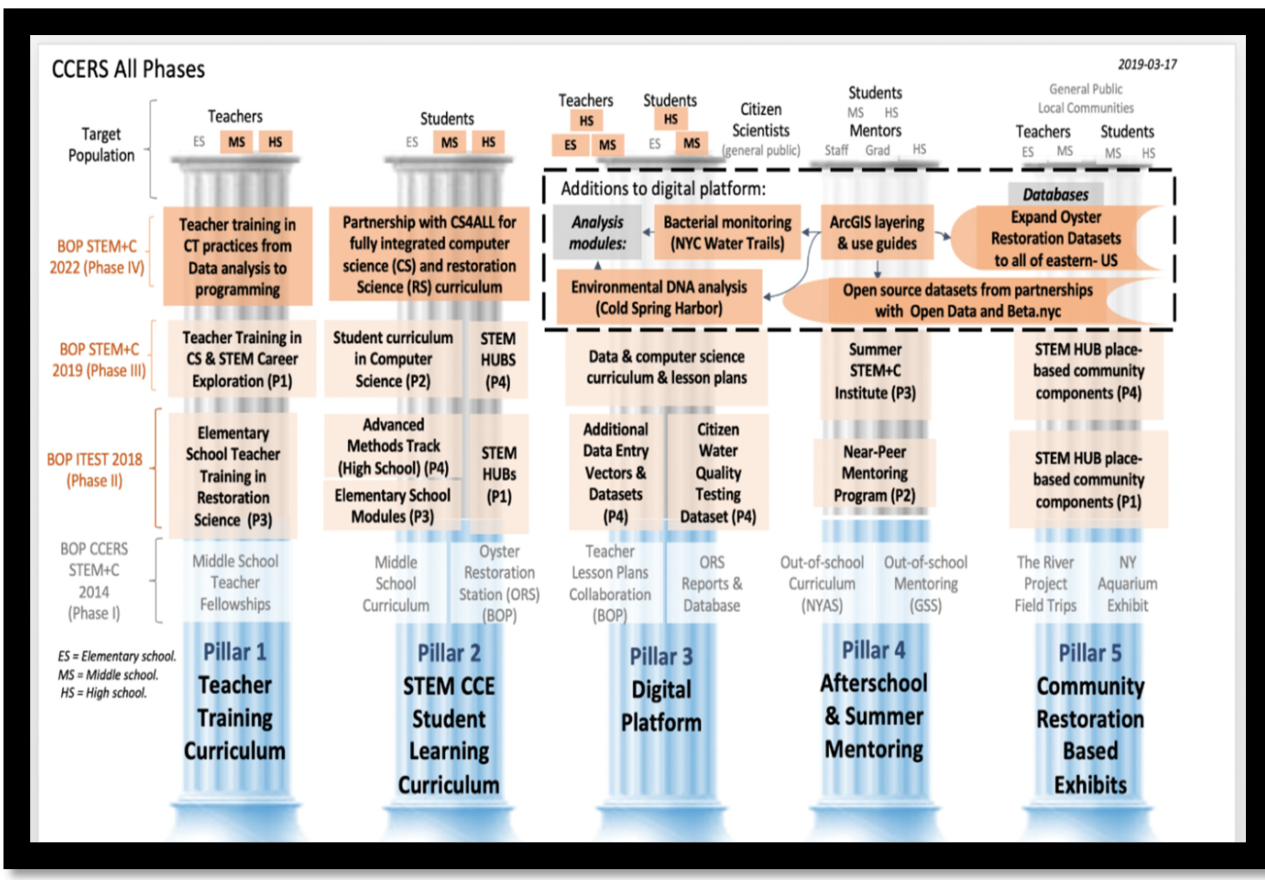

Figure 1. The Five Pillars of the Curriculum and Community Enterprise for Restoration Science + STEM-C

The CCERS STEM + C Project in New York Harbor worked to meaningfully connect teaching and learning to the restoration of New York Harbor and to provide an opportunity for underserved students to gain access to STEM knowledge. The CCERS STEM + C Project began with the premise that learning is more meaningful and motivating when connected to a specific personal local community issue and that science is learned best by doing as an exploratory field. This long-term problem-based learning drives the conceptual framework of this project because it creates a community of learners who benefit from access to each other's thinking, learning, and discovery. Engaging in experiential learning has surfaced as the stimulus for cultivating holistic student achievement while supporting and enriching the community. Students gained a heightened awareness of the practical application of theoretical concepts, to address real-world environmental challenges. This process bridged the gap between theory and practice, significantly enhancing their critical thinking and problem-solving skills (Mohammad, Shamsul, & Mohammad, 2024).

These experiences, guided by teachers and mentors in the program, provided students with the support needed to develop their science self-efficacy, which can shape what type of future career a student pursues. This created enhanced education and career outcomes for K-12 students who have historically also been underrepresented in STEM fields. The term STEM (Science, technology, engineering, and mathematics) education was first coined by the National Science Foundation in 2001. In the over twenty-year interim, the implementation of STEM has proven to be a great challenge for both the educational system and the socioeconomic systems.

In its final iteration, the CCERS STEM + C Project Model had great success in increasing student understanding and interest in restoration-based STEM+C careers, increasing the development of the BOP-CCERS Digital Platform, and providing support to teachers and students in learning statistical and computational concepts. This was accomplished through (1) scientific STEM professional development for teachers, (2) curriculum units that address computer science and data science, and describe pathways to restoration-based STEM+C careers, (3) a summer STEM Institute for computer science and computing, and (4) the expansion and development of restoration STEM Hubs that support field science experiences. Ultimately, the fundamental endeavor continues to understand how best to engage and retain students from historically underrepresented communities in pursuing the technical skills and knowledge needed to advance careers in the fields of environmental science, computer science, biology, engineering, ecology, urban planning, and design. The focus of each of the curriculum units is the four essentials of 21st-century skills; critical thinking, communication, collaboration, and creativity (Thornhill-Miller et. al, 2023).

Table 2. Sample STEM + C Student Learning Unit

New York Harbor Populations Investigation (Grades 6-8)	
Summary	The student will explore topic libraries and their Oyster Research Station and Oyster Research Tank to do original research about the populations of New York Harbor, focusing on arthropods. They will have a lot of fun while doing it and can bring their research projects to the Billion Oyster Project Student Symposium.
Description	This unit will begin by exploring individual organisms of New York Harbor and work together to create a food web. Then, students will expand on the food web by connecting organisms to the habitats in which they live, while reviewing NYC geography. Next, students will focus on two historically important species of New York Harbor, the American shad fish and the Eastern Oyster. Students will read and analyze historical documents to create their timelines and figure out the causes of the species declines. Students collect small arthropods from their ORS and take them back to the classroom for observation and exploration. Students ask a lot of questions while sorting their organisms, make predictions about what their organisms eat, become stewards of the arthropods, and then work in small groups to create the best tank conditions for their organisms. At the end of the unit, students will propose a large-scale study about a population found in New York Harbor. To inform this process, students will first sort their questions about small estuarine arthropods, and then students will read and discuss 'digests' of four original scientific journal articles on small estuarine arthropods.
Chapter 1	Is the Web a good model of an ecosystem?
Chapter 2	How well have people managed New York Harbor populations up to now?
Chapter 3	What are the populations and ecosystems in our classroom tank?
Chapter 4	What do we need to know about New York Harbor populations?

The CCERS STEM + C project is an excellent model to pattern subsequent educational programs to address the competencies, content, and skills listed in the New York State Blue Ribbon Commission needs for successful high school graduates; For example:

1 Competency – Through the stewardship of the New York Harbor and its wildlife, students gained a sense

of civic responsibility. Working alongside teachers, mentors, and environmental scientists, students had a greater understanding of work-based learning and were involved in related internships.

1. Content – The CCERS STEM + C project's curriculum is based on multi- and interdisciplinary content comprised of science, technology, engineering, mathematics, and computer science. Each of the learning modules contained within the CCERS STEM + C curriculum required students to engage in long-term, problem-based learning.
2. Skills – The long-term studies embedded in the CCERS STEM + C curriculum focus on the student's ability to think critically about a community related, real-world environmental conundrum, collaborate with fellow students, teachers, and mentors and develop a viable solution to the problem. Skills such as communication and information processing and connecting the classroom to real-life situations are ingrained in each component. Students create and analyze real-time data on the oyster populations, water quality, and marine life in New York Harbor through the dynamic digital platform.

1.2 Hypotheses

Research Question 1a: Does participating in CCERS activities increase students' confidence in their technological abilities compared to non-CCERS students?

Research Question 1b: Does participating in CCERS activities increase URG students' confidence in their technological abilities compared to non-CCERS URG students?

Research Question 2a: Does participating in CCERS activities increase students' scientific identity (motivation) and level of engagement compared to non-CCERS students?

Research Question 2b: Does participating in CCERS activities increase URG students' scientific identity (motivation) and level of engagement compared to non-CCERS URG students?

2. Method

2.1 Participants

A student survey which contains confidence in technological abilities subscale was administered to all subjects of the study. The survey was administered to students in the treatment groups and to those in the comparison groups. Each of these groups was subdivided into students and underrepresented students (URG). Underrepresented groups (URG) were identified as those who self-identified as one of the following: a woman, a person with disabilities, or an underrepresented minority (Black, Hispanic, American Indian, or Alaskan Native). The treatment groups were composed of students who participated in the CCERS activities and the comparison groups were composed of students who did not participate in the CCERS activities. A total of 764 students opened the survey through the general link and arrived at the landing page in Step 1. A total of 513 respondents (67%) completed all the necessary steps for the surveys (i.e., steps 2 & 3), including providing parental consent, an important IRB stipulation for responses to be included in the research analyses

2.2 Data Collection

Data was collected via an online survey (through the platform Alchemer, previously known as SurveyGizmo) and collected from August 1, 2020, to September 17, 2022. The survey took the participants an average of 8 minutes to complete. Due to IRB restrictions, only middle school and high school students who provided parental consent were included in the sample. In addition, due to IRB and other restrictions, this report only examines the differences between respondents who participated in CCERS activities (i.e., treatment group) and respondents who did not participate in CCERS activities (i.e., comparison group).

2.2.1 Process for Engaging with the Online Survey

Clicking on the survey link would start the respondent on a 6-step process:

- Step one: A landing page, which provides the introduction to the survey and includes screening questions to ensure that the students met participation requirements (e.g., middle or high school students)
- Step two: Obtain parental consent for their child to participate in the research
- Step three: Obtain student assent, where the student provides their consent to participate in the research study

- Step four: An evaluation survey, that captured which activities the respondents engaged in and included questions developed by the evaluation team to collect feedback on the activities
- Step five: A research survey, which included questions specific to the research study
- Step six: Reward page, where the respondent received a certificate for completing the survey

A total of 764 students opened the survey through the general link and arrived at the landing page in Step 1. A total of 513 respondents completed all the necessary steps for the surveys (i.e., steps 2&3), including providing parental consent, and an important IRB stipulation for responses to be included in the research analyses. Student demographic breakdowns are as follows: 29% of students identified as female, with 27% identifying with a URM, (Note 1) and 17% identified as first-generation American. The respondent demographics can be seen in Table 3.

Table 3. Demographics of Survey Participants

Demog Gender	**Comparison N=90**	**CCERS N=423**	**Total (N=513)**
Male	40 (44.4%)	113 (26.7%)	153 (29.8%)
Female	24 (26.7%)	125 (29.6%)	149 (29.2%)
Do not wish to specify	-	24 (5.7%)	24 (4.7%)
No response	26 (28.9%)	161 (28.1%)	187 (36.4%)
Ethnicity/Race			
American Indian or Alaska Native	3 (3.3%)	5 (1.2%)	8 (1.6%)
Asian	7 (7.8%)	37 (8.8%)	44 (8.6%)
Black or African American	10 (11.1%)	32 (7.6%)	42 (8.2%)
Hispanic/Latino	15 (16.7%)	74 (17.5%)	89 (17.3%)
White (non-Hispanic or Latino)	26 (28.9%)	75 (17.7%)	101 (19.7%)
Other	3 (3.3%)	13 (3.1%)	16 (3.3%)
Do not wish to specify	-	30 (7.1%)	30 (5.8%)
No response	26 (28.9%)	157 (37.1%)	183 (35.6%)
First Generation			
Yes	17 (18.9%)	70 (16.6%)	87 (16.9%)
No	32 (35.6%)	165 (39.0%)	198 (38.5%)
No response	41 (45.6%)	188 (44.4%)	229 (44.6%)

2.3 Data Analysis

In Research Question 1, the sample was divided into the CCERS respondents who participated in CCERS activities (treatment) and a group who did not participate in CCERS activities (comparison). Total student respondents numbered 513 across both conditions, with 423 respondents in the CCERS treatment group and 90 in the comparison group. For Research Question 2, the sample included only respondents who identified as members of an underrepresented group (URG). A total of 201 respondents across both conditions identified as part of a URG, with 140 URG respondents in the CCERS treatment group and 61 URG respondents in the comparison group.

2.3.1 Creation of Variables

For each of the research questions, indices were created by averaging items on the survey's subscales. Where appropriate, Cronbach's alpha was calculated to ensure internal consistency.

2.3.2 Career Interest

Career interest was a self-reported measure of participant's agreement with the following statements:

- Scientists make a meaningful difference in the world
- A career in science would enable me to work with others in meaningful ways
- I am interested in jobs related to science
- I am interested in pursuing a career in science, technology, or engineering.

The response options were "strongly disagree," "disagree," "maybe," "agree," and "strongly agree," which were coded as 1-5, respectively. This variable will be used to assess participant's career interests, with lower scores representing less career interest and higher scores representing more career interest.

2.3.3 Engagement

Engagement in STEM is the sum of a series of yes/no questions regarding whether participants engaged in a variety of behaviors. Engagement behaviors here included:

• Volunteering/interning in a STEM field

• Receiving direct guidance on projects from a scientist

• Watching videos made by scientists

• Attending any talks where a scientist spoke

• Reading articles written by scientists

• Listening to podcasts by scientists

Additionally, "yes" was coded as 1, and "no" was coded as 2 for this variable's responses, higher scores meant fewer engagement behaviors. Because this was out-of-sync with other variables, engage was reverse-coded to make higher scores reflective of higher engagement behaviors.

2.3.4 Technological Abilities

The self-reported technological ability is a measure of the participant's agreement with the following statements:

• I use technology in a way that enhances my everyday life

• I have the technical skills I need to use technology

• I can learn new programs (apps) independently

• I have the technical skills I need to use technology

The response options were "strongly disagree," "disagree," "maybe," "agree," and "strongly agree," which were coded as 1-5, respectively. This variable was used to assess participant's technological abilities, with lower scores representing their lower perceived ability in technology and higher scores representing higher perceived ability in their technological abilities. Because this scale had several desperate questions, Cronbach's alpha was calculated to examine its internal consistency. The alpha value is equal to 0.79, above 0.7 which is considered to be acceptable, meaning the scale is internally consistent despite the questions being varied.

2.3.5 Science Self-Efficacy

Science self-efficacy was a self-reported measure of participant's agreement with the following statements:

• I can make good observations during a science activity

• I can ask good questions about what is happening during a science activity

• I feel confident about my ability to explain how to do scientific activities to others

• I think I could be a good scientist, and I am interested in learning about science.

The response options were "strongly disagree," "disagree," "maybe," "agree," and "strongly agree," which were coded as 1-5, respectively. This variable will be used to assess participant's science self-efficacy, with lower scores representing less science self-efficacy and higher scores representing more science self-efficacy.

2.3.6 Condition

The condition was the experimental variable. The control group was "dummy" coded as 0 and the treatment group was "dummy" coded as 1 for later analysis. Due to the unequal distribution of missing data for the treatment and control group, the condition variable won't be added to models unless it is directly being tested.

2.4 Summary of Analysis

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

Please note that sample size may vary in different sections because not every respondent answered every question (or a "N/A" option was chosen).

3. Results

3.1 Addressing the Original Research Questions

Research Question 1a: Does participating in CCERS activities increase students' confidence in their technological abilities compared to non-CCERS students?

Respondents answered four questions on a Likert scale with ratings from 1=strongly disagree to 5=strongly agree regarding their confidence in their technological abilities. Cronbach's alpha was run to examine internal validity (.84), and then items were averaged to compute an index, with higher average scores representing higher confidence in their technological abilities. On average, the CCERS group expressed a higher confidence in their technological abilities (n= 115, M=3.70, SD=0.76) than the non-CCERS group (n=85, M=3.60, SD=.85). See Figure 2.

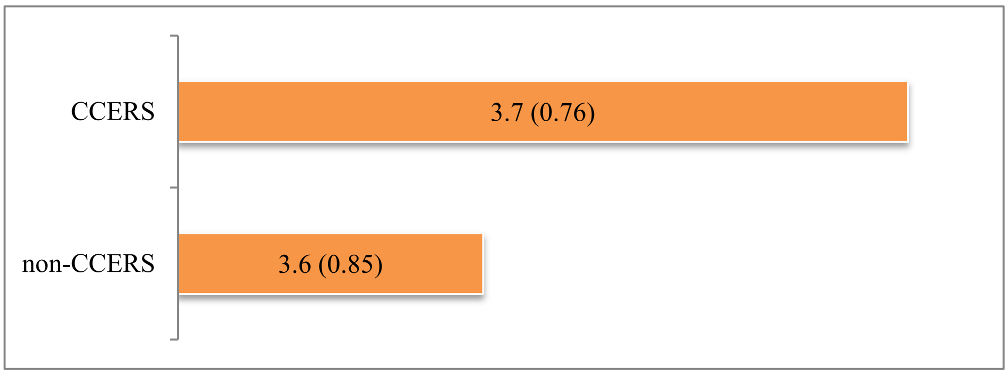

Figure 2. Average Score of Respondents' Confidence in Their Technological Abilities by Condition

Research Question 1b: Does participating in CCERS activities increase URG students' confidence in their technological abilities compared to non-CCERS URG students?

To assess how CCERS participation impacts URG respondents' confidence in their technological abilities, researchers examined respondents' responses to four questions. URG CCERS respondents, on average, had higher levels of confidence in their technological abilities than non-CCERS URG respondents.

3.1.1 URG Confidence in Technological Abilities

Respondents answered four questions on a Likert scale with ratings from 1=strongly disagree to 5=strongly agree regarding their confidence in their technological abilities. Cronbach's alpha was run to examine internal validity (.84), and then items were averaged to compute an index, with higher average scores representing higher confidence in their technological abilities. On average, the CCERS URG group expressed a higher confidence in their technological abilities (n= 86, =3.70, SD=0.76) than the URG non-CCERS respondents (n=61, M=3.60, SD=.85). See Figure 3.

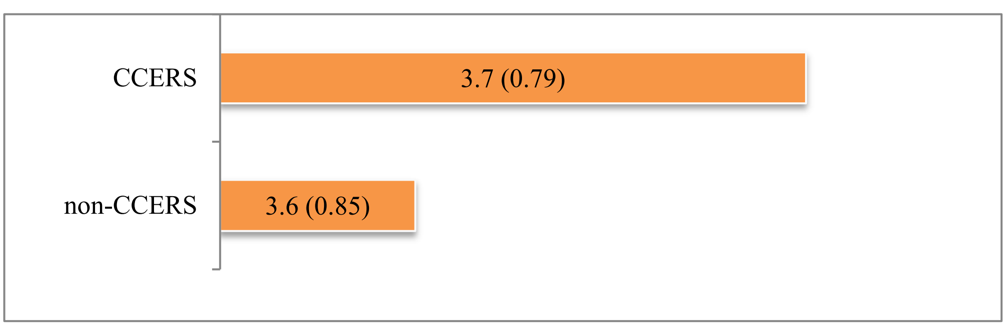

Figure 3. Average Score of URG Respondents' Confidence in Their Technological Abilities by Condition

Research Question 2a: Does participating in CCERS activities increase students' scientific identity (motivation) and level of engagement compared to non-CCERS students?

CCERS respondents, on average, had higher scores on scientific identity (motivation) and higher levels of preparation, with higher average scores of general engagement than the comparison group. A model was created to test the relationship between condition (i.e., treatment and comparison) and scientific identity though non-significant, on average, CCERS respondents (n=513) expressed a slightly higher scientific identity (M=3.85, SD =0.78) than comparison group respondents (n= 90, M=3.69, SD=0.72). See Figure 4.

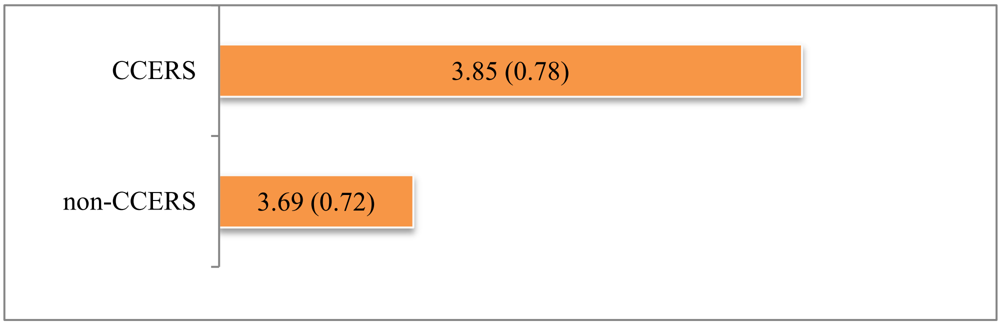

Figure 4. The Average Score of CCERS Respondents' Scientific Identity and General Engagement by Condition

Research Question 2b: Does participating in CCERS activities increase URG students' scientific identity (motivation) and level of engagement compared to non-CCERS URG students?

On average, underrepresented group (URG) CCERS respondents reported higher levels of scientific identity (motivation) and engagement in scientific activities (preparation) compared to URG students who did not participate in CCERS. On average, though non-significant, URG CCERS respondents (n= 124) expressed a higher sense of scientific identity (M=3.87, SD=0.71) than the URG comparison group respondents (n=31, M=3.64, SD=0.65). See Figure 5.

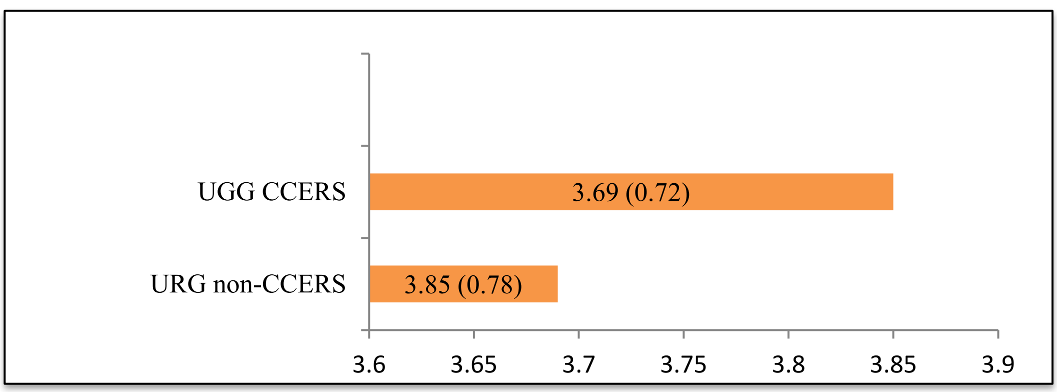

Figure 5. The Average Score of URG CCERS Respondents' Scientific Identity and General Engagement by Condition

The mediation model shows that CCERS participation may have given students more access to technology, in part, by improving students' technological ability. This model is even generalized to URM students, showing how the program can equitably distribute benefits so that all students can prosper. What this means is that CCERS may have provided students with more resources, as well as the means to utilize them. In the future, this is important, as solely providing students with computers, smartphones, and tablets may not alone improve outcomes. Students must also be given training to increase their technological ability so they can use these tools effectively.

3.1.2 Increased Technological Ability and Science Self-Efficacy

The second research question for this paper was whether improved technological ability explains the project's influence on students' science self-efficacy. Because participation in CCERS did not have a direct effect on science self-efficacy, the mediation analysis could not be conducted. However, separate analyses revealed that CCERS students had greater technological ability than non-CCERS students, (Note 2) and students with higher technological ability were more likely to have higher science self-efficacy. (Note 3) This paints an image of a student who participated in CCERS: improved technological ability may have helped them do things that made them feel more like a scientist, which made them feel more confident about STEM activities and careers (i.e., their a measure of science self-efficacy).

This relationship holds for URM students, except that the strength of the relationship between CCERS participation, technological ability, and science self-efficacy was stronger.(Note 4) This suggests that by changing the way students engage with technology, CCERS was able to have an indirect impact on students' perceptions of their ability to solve problems and engage in STEM, including URM students.

3.1.3 Impact on Career Interest

Subsequent analysis revealed that science self-efficacy predicts interest in STEM careers, controlling for other variables such as engagement in STEM, general self-efficacy, and access to technology. As shown in the diagram below, CCERS may indirectly affect students' interest in STEM careers by bolstering their ability to use technology, which may enhance their confidence in STEM. On the other hand, knowledge about oysters and the BOP system and having access to technology were not significant predictors of STEM career interest when considering the other variables. This is consistent with literature as it may be more important to make students feel like they can take on problems and see themselves as a scientist (León, Núñez & Liew, 2015).

3.2 Moderation Analysis

An exploratory moderation analysis was performed to identify areas for improvement and intervention for future iterations of the program. There was a strong association between science self-efficacy and technological ability that warranted further investigation. (Note 5) It was found that awareness of STEM careers moderated the relationship between science self-efficacy and technological ability. This means that a higher awareness of STEM careers makes the relationship between science self-efficacy and technological ability stronger, while less awareness of STEM careers can lead to their relationship being weaker (shown in the diagram below).

Figure 6. Factors Contributing to Students' Increased Technological Ability

3.3 Implications

Results show support for the study's hypotheses. Students who participated in CCERS activities showed a higher level of confidence in their scientific observations, inquiries, and communication compared to students who did not participate in the CCERS activities. The fact that CCERS students' scores were higher than non-CCERS scores in technological ability can be attributed to the CCERS STEM + C project's influence on self-efficacy. Also, the program's influence on technological ability and science self-efficacy is related to students' career interests. The results of these analyses seem to hold for URM students when there is enough data to perform the analysis, meaning the results may be equitably distributed throughout the student population. Limitations of the study include the size of the comparison group and the limited number of completed surveys.

Education is one of the most important and difficult endeavors a society can pursue (Faure, 1972). As students develop their science self-efficacy and gain interest in STEM careers, they may be more likely to pick a STEM major in college (Estrada et al., 2018). As CCERS promotes technological ability in students, it seems that the increase in technological ability helps build science self-efficacy. Technology helps to improve students' science learning, increasing their sense of competency (Reid-Griffin & Carter, 2008). This may improve students' learning overall, as incorporating new information technologies may lead to more efficient and effective education (Lòpez-Pèrez et al., 2013). It's also possible that tools given to students to solve problems can help build their sense of competency. Given competency is a key to motivation (Wijayanto & Riani, 2021), this may be one way the CCERS program gets students to become interested in STEM careers.

Lastly, the moderation model showing awareness of stem careers moderates the relationship between science self-efficacy and technological ability and sheds light on a way to improve the project model. Consistent with self-determination theory, it may be that students know the purpose of their pursuits and translate ideas into action (Ng, Liu, & Wang, 2016). Specifically, if students know they can make a career out of their skills, this awareness may act as a catalyst in motivating them to improve their technological abilities. Challenges to the future of STEM education include improving digital literacy and ensuring equitable access for all students. Forward-thinking strategies include interdisciplinary instruction like project-based learning, which is a vital component for engaging students in STEM education (Mayes, & Rittschof, 2021).

4. Discussion

The national secondary educational system is at a juncture that has rarely been seen in the history of our country. At the national level, the Trump administration is working to abolish the federal Department of Education (Minsky, 2025). At the state level, the New York State Department of Education is transitioning from validating high school students' aptitude through the Regents examinations (initiated in November 1865) to a required proficiency in high school experiences that foster content mastery and an aptitude in 21st-century skills. Similar to the work done by the Committee of Ten (United States Bureau of Education, 1893), the work done to reform the secondary education system will be both challenging and transformative. As historical and social developments occur throughout history, educational demands metamorphosed to meet the demands of the times by helping students develop the skills to contribute to their communities and ultimately, the world.

For comparison, an international policy and practice scan explored the assessment, career planning, and apprenticeship models in Canada (Alberta, British Columbia, and Ontario); England; Germany; and Switzerland. This scan revealed a common theme of apprenticeships and work-based learning. Students in these countries were well prepared with work-based skills, social-emotional learning (SEL), and transition skills. Students were treated as adults and their learning reflected real-life experiences. Relationships among community-based organizations, businesses, and the education department are a normal part of the way they do business and lead to lower unemployment, higher gross domestic product (GDP), and higher youth engagement (NYS Blue Ribbon Commission on Graduation Measures, 2023).

The goal of education is to prepare students for the rigors of 21st-century employment. This includes focusing on STEM reasoning abilities needed to address real-world environmental conundrums. Central to this goal is the emphasis on content knowledge in STEM areas and interdisciplinary processes, including critical thinking and problem-solving (Mayes & Rittschof, 2021). As with any successful endeavor - academic or professional, interest and motivation are keys at the onset. Coupled with these is increased confidence in the individual's ability for success. Students who are motivated to learn are likely to engage in the deep-processing of information that they acquire (Urhahne &Wijnia, 2023). Activities that are motivated by student interest do not need external enticements to be enacted and sustained. Interest is a form of intrinsic motivation that is characterized by the three components of affect, knowledge, and value (Renninger & Hidi, 2022).

The CCERS STEM + C Project model has statistically proven that long-term, community-based projects increase student interest in STEM content and real-world community issues. Employing the four-phase framework of interest development (Renninger & Hidi, 2022), it can be seen that through rooting the students in the restoration of New York Harbor and its inhabitants, especially the Eastern oyster, interest in the situation is aroused and leads to individual interest that increasingly becomes well-developed through exposure to the problem(see figure 7). This interest crosses age, gender, and ethnicity and can be a pragmatic tool in developing content-rich curricular courses of study. Content in the CCERS STEM + C Project was multi-disciplinary because of the expanse of the project. Science, mathematics, history, geography, engineering, computation, communication, and technology were taught in an interactive and dynamic environment. The project engaged the students both in the classroom and in the field which helped connect students to their environment and had the potential to advance this work to high educational and employment opportunities. (See Figure 7).

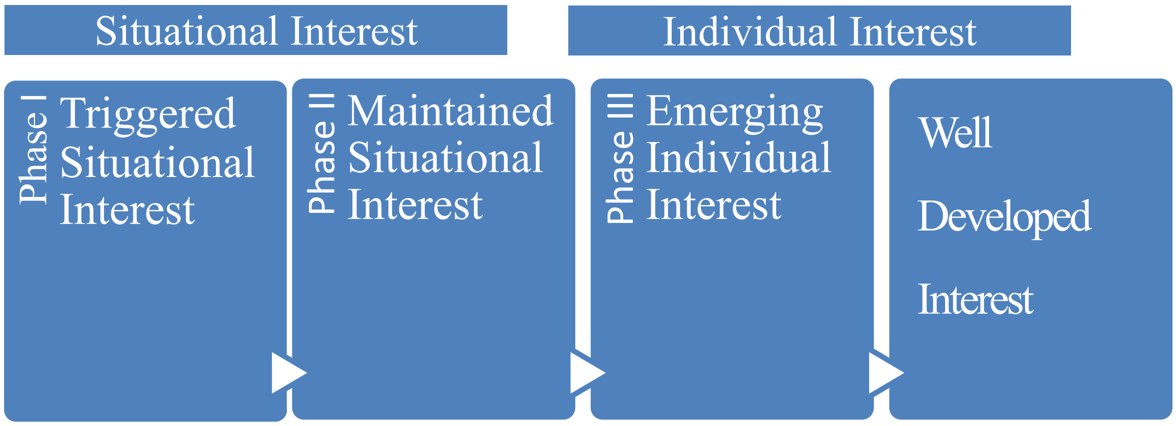

Figure 7. The four-phase Model of Interest Development (Hidi & Renninger, 2011)

The CCERS STEM + C Project contained a component that was vital in developing students' critical thinking, collaboration, and communication skills. The Digital Platform was a dynamic web-based portal that encompassed the field databases created by the student teams in the project as well as the K 12 curriculum units and classroom resources and the results of the authentic research-based projects created by the students. Independent projects cultivate experiences that surpass traditional classroom limitations, encouraging students to explore their fervor and engage in collaborative, real-world projects that have societal significance (Marley, Siani, & Sims, 2022).

As the educational landscape undergoes what seems to be a radical revamping, models such as the CCERS STEM + C Project can be explored and analyzed to determine the direction of the emerging curriculum and its impact on student's academic attainment and preparedness for the potential career paths in emerging fields during the 21st century. Scholarship on this and other real-world, multifaceted educational models will elucidate and enhance creative directions for the future of secondary education.

One of the fundamental measures of the success of a project is its ability to endure. Even though the National Science Foundation funding for the BOP CCERS STEM + C Project has ended, its impact can be felt throughout the city of New York. Over forty-five Oyster Research Station Sites have been established along New York City's 520 miles of shoreline, most of them monitored by teams of community scientists. Each station contains up to 200 live oysters and is small enough to pull up by hand, functioning as a community data-gathering hub about that specific location of the Harbor. Each station eventually evolves into its ecosystem. These research stations create habitats and invite all other biodiversity in our Harbor to join them and become oyster reef ecosystems. This is a nature-based solution for shoreline resilience. Wave energy is diffused and sand and sediment settle and accumulate to reinforce the shoreline and prevent erosion. The unique design of the oyster reefs allows water to flow through the reef while decreasing the impact of the wave action. The shoreline and surrounding area will have more resilience and hopefully prevent damage from storms such as Superstorm Sandy in 2012. Additionally, several of the New York City public schools that participated in the program have permanently embedded the curriculum and fieldwork into the school syllabus to help meet STEM and computer science goals. On the high school level, Advanced Placement Environmental Science courses adopted the BOP CCERS STEM + C Project as its main content and required fieldwork.

A further example of the enduring nature of the project is a 50-square-foot art installation in Times Square that is running from February 4–March 4, 2025. Love Ever After was created by Swedish architect Pernilla Ohrstedt in collaboration with the Billion Oyster Project. It is a 3D metal heart made of oyster cages that highlight the importance of oysters in New York City. The sculpture is intended to raise awareness of the city's history with oysters and how they can help improve water quality and create storm barriers. Once the exhibit has ended, the oyster cages from the sculpture will be placed around the city's shoreline as oyster research stations in New York Harbor. Volunteers will continue to monitor these cages as well as existing cages as part of the Billion Oyster Project's mission to restore one billion oysters to New York Harbor by 2035 (See Figure 7).

Figure 7. A Three-Dimensional Exhibit Showcasing the Cages of the Oyster Research Stations (ORS)

5. Conclusion

The world of education is explicitly concerned with the need to develop and assess 21st-century skills, because it represents the first link in the chain of skills acquisition, preparing the human resources of tomorrow. Traditional educational approaches cannot meet the needs of our emergent societies if they do not teach, promote, and assess in line with the new learner characteristics and contexts of the 21st-century. The rapid development and integration of new technologies will also aid and change the contexts, resources, and implementation of education. The decisions and actions made by students can be informed and enhanced through education. Education will help to determine impact society and the environment (Abo-Khalil, 2024). Interdisciplinary pedagogical approaches are essential for effectively integrating sustainability into teaching and learning processes (Caputo, Ligorio, & Pizzi, 2021).

To create a curriculum that successfully integrates community-based environmental sustainability with the needed 21st-century content and skills deemed necessary for future education, educational stakeholders and industry partners must collaborate closely, crafting a coherent strategy and action plan. Such collaborative efforts are vital for advancing student preparation and success in academia and the workforce. Projects such as the CCERS STEM + C project combine social, environmental, and economic conundrums with the content and skills needed to engage in practical applications for their future careers. Models that parallel the Billion Oyster Curriculum and Community Environmental Restoration (STEM + Computer Science) curriculum should be developed with an emphasis on the environmental issues of the given regions. This approach, along with a robust network of local partners, will help to establish a rigorous course of study that will promote ecological stewardship through cutting-edge educational programs and advanced technology.

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Notes

Note 1. Underrepresented minorities include those identifying as American Indian or Alaska Native, Black or African American, and Hispanic/Latino.

Note 2. The standardized coefficient, a measure of the strength of a relationship, for CCERS participation and technological ability was 0.28. This means that there is a small, but significant, difference between students who participated in the CCERS curriculum and those who didn't.

Note 3. The standardized coefficient for technological ability and science self-efficacy was 0.61. This means that a change in one measurement is associated with a large change in the other.

Note 4. In students who identified with a URM, the standardized coefficient for CCERS participation and technological ability was 0.40. This means that among URM students there is a moderate difference in technological ability between students who participated in CCERS curriculum and those that didn't. The standardized coefficient for technological ability and science self-efficacy among this student population was 0.63. This means that a change in one measurement is associated with a large change in the other.

Note 5. The standardized coefficient for technological ability and science self-efficacy was 0.61. This means that a change in one measurement is associated with a large change in the other.

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Data sharing statement

No additional data are available.