Billion Oyster Project: Linking Public School Teaching and Learning to the Ecological Restoration of New York Harbor Using Innovative Applications of Environmental and Digital Technologies

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Abstract

Research consistently shows that children who have opportunities to actively investigate natural settings and engage in problem-based learning greatly benefit from the experiences. They gain skills, interests, knowledge, aspirations, and motivation to learn more. But how can we provide these rich opportunities in densely populated urban areas where resources and access to natural areas are limited? This project will develop and test a model of curriculum and community enterprise to address that issue within the nation's largest urban school system. Middle school students will study New York harbor and the extensive watershed that empties into it, and they will conduct field research in support of restoring native oyster habitats. The project builds on the existing Billion Oyster Project, and will be implemented by a broad partnership of institutions and community resources, including Pace University, the New York City Department of Education, the Columbia University Lamont-Doherty Earth Observatory, the New York Academy of Sciences, the New York Harbor Foundation, the New York Aquarium, and others. The project targets middle-school students in low-income neighborhoods with high populations of English language learners and students from groups underrepresented in STEM fields and education pathways. The project will directly involve over forty schools, eighty teachers, and 8,640 students over a period of three years. A quasi-experimental, mixed-methods research plan will be used to assess the individual and collective effectiveness of the five project components. Regression analyses will be used to identify effective program aspects and assess the individual effectiveness of participation in various combinations of the five program components. Social network mapping will be used to further assess the overall "curriculum plus community" model.

I. Introduction

The Billion Oyster Project (BOP) is a comprehensive initiative to restore New York Harbor in New York City schools. The premise of BOP is that secondary school students can and should play a direct, authentic role in restoring their local environment, and that the practice of teaching and learning is enhanced - school becomes less isolating and abstract, more meaningful and motivating – as the work and study of keystone species and habit restoration is integrated into curricula and school-based activities. This vision is particularly relevant for high density urban school districts where the student population is largely confined to the traditional classroom, learning takes place in fragmented 45minute blocks, the surrounding natural environment is severely degraded and there exist both social and physical barriers to accessing non-human ecologies. By enabling urban students materially, logistically, and intellectually to participate in restoration and environmental monitoring projects during their regular school day and linking those experiences to a broader curricular focus on place, stewardship, and inquiry, schools fundamentally improve the quality of the education they offer to their students. These improvements will, we strongly believe, translate to demonstrable improvements in long-term academic outcomes.

The aim of this paper is to propose a "restoration-based education" as one in which curriculum and pedagogy are explicitly tied to the work of restoring a local keystone species or habitat type, through a comprehensive and long-term approach. Comprehensive is defined by a layered focus on restoration that takes place at 1) the level of the individual student experience, in his/her classes and regular school day, 2) the level of the school culture and mission, in school wide activities and communications, and 3) the level of the surrounding community, in out-of-school time (OST) and extracurricular activities offered to/by students, teachers, friends, families, and partners of the school.

The implementation of restoration-based education is not a singular unit of study or a one-off project. This would be inauthentic on its face, as the work of restoration ecology (RE) is defined by the timescales of ecological balance, which are interannual to interdecadal. The restoration process, as articulated by Apfelbaum et al (2007), begins with comprehensive assessments of existing conditions: site inventories, and data collection, including historical, social, political and economic analysis of the site(s) and surroundings to augment field data on the physical, chemical and biological setting. Project designs and proposals are informed by rich data and, whenever possible, environmental modeling. Implementation is then an adaptive, iterative process that requires frequent cycles of study and modification. Periodic communication of findings and input from external stakeholders often results in additional RE project proposals and significant shifts in direction. Neither the project content nor even its goals can be considered stable over the lifetime of an RE program.

Long-term outcomes of RE in a heavily impacted biome is not predictable. Therefore, successful restoration is typically not certain. New policies, protections, and, in most cases, human behavior changes are required. Restoration of historical ("natural") ecologies is not possible until (and unless) these changes can restore historical biochemical cycles. Reworking of such ecological "infrastructure" will operate on the joined timescales of societal change (years to decades), interacting with the cycling timescales of the biochemical substrates. In estuarine settings like the lower Hudson Valley, the latter is years (water chemistry) to many decades (sedimentary and pore-water chemistry).

Uncertainty, long time frames and iterative adaptation pose a difficult, if exciting, challenge to secondary school teachers. Teachers must become comfortable in a setting in which even they do not know what the outcome of a semester's work is likely to be. They have to relinquish a degree of control that comes with knowing the answer. In a school system increasingly reliant on detailed learning plans and tracking outcomes against objectives, they must redefine what science learning is when the end product is not entirely known at the outset. The concession is that both teachers and their students will be engaged in authentic scientific learning, in which the scientific process will be central to the curriculum … a learning goal that is nearly impossible to achieve in the traditional classroom context. Teachers must have a significant voice in research, policy and classroom practices (CochranSmith and Lytle, 2009).

Lastly, this paper highlights how the Billion Oyster Project harnesses the power of emerging digital technology in support of restoration-based education in New York City and beyond. Our experience implementing the prototype of BOP at New York Harbor School and other public schools across New York City over the past two years, has demonstrated the potential in leveraging web-based software, environmental sensors, and the emerging "internet of things" to support and enhance restoration-based education and RE projects. Given the ubiquity of digital technology across global society and the education sector's increasing focus on STEM-C (Science, Technology, Engineering, Mathematics - and Computing) as career readiness, we have endeavored to yolk digital technology to restoration-based education in ways that enhance the student teacher experience, build discreet STEM-C skills in students, and improve the scientific outcomes of the RE project itself.

This contribution outlines the Billion Oyster Project's pending creation a robust digital platform consisting of four main functional components: 1) environmental data collection, recording, and uploading using both live/streaming and manual inputs; 2) tools for monitoring, comparing, and analyzing real-time and longitudinal data; 3) curriculum and educational resources archive for teachers and students; and 4) internal communication, networking, media, and gamification. The overall design and functionality of the BOP platform has been derived from extensive discussions with participating students and teachers, as well as our public and private sector development partners. We look at how these initial designs align with the current state-of-the-art in online environmental monitoring citizen science platforms. Currently, the beta version of the BOP digital platform is under construction at the University of Maryland's Center for Environmental Science Integration and Application Network Group with database programming provided by engineers at View Into the Blue Camera Systems.

II. The Background And Motivation

The Billion Oyster Project (BOP) is a long-term initiative to restore one billion live oysters to the New York Harbor over a 20 year period, and in the process, educate thousands of young people in New York

City about the ecology and economy of their local marine environment. This project is driven by public and private partnerships that engage public school students, restaurants and the general public throughout all aspects of its implementation. BOP is both a green jobs training program for NYC youth and a habitat-restoration project with benefits for the entire region. Since its inception in 2009, the project has spawned, reared or planted more than 7 million oysters in NYC waters, helped restore 1.25 acres of shoreline and submerged bottom, and in so doing involved more than 4,600 NYC public school students in the hands-on science and technology of restoration.

BOP began at the Urban Assembly New York Harbor School (Harbor School), a New York City public high school founded in 2003 in Bushwick, Brooklyn and now located on Governors Island in the New York Harbor. The original inspiration and vision for the project arose out of conversations between Harbor School's founder, Murray Fisher and Pete Malinowksi, the aquaculture instructor. Mr. Fisher, a lifelong environmentalist and board member of the Waterkeeper Alliance, founded Harbor School as a stewardship academy with the intent to train a new generation of urban natural resource managers, conservationists, Marine environment professionals in a city that had largely severed its connections with the water. Specifically, he wanted to ensure that students from the city's most economically disadvantaged communities had the opportunity to access the city's most abundant and oft forgotten natural resource; to study, work, play and pursue careers on and around the water.

Mr. Malinowski, a second-generation oyster farmer from Fishers Island, New York, joined the faculty of the New York Harbor School with the intent to create a career technical education curriculum based around shellfish aquaculture. Growing up on a large-scale commercial oyster hatchery separated by less than 100 miles of water from New York City, he wondered if the same techniques and technologies could be used to grow oysters for restoration, not consumption, and if that highly technical work could be carried out by trained high school students. Both educatorenvironmentalists shared the vision for experiential place-based learning, embracing the HudsonRaritan Estuary and the greater watershed as classroom, laboratory, and motivating force for learning. This vision required that students be intellectually empowered and technically equipped to study the Harbor; that they advocate for its wellbeing and enhancement; and that they play active roles in the rebuilding of maritime culture, careers, and ecology.

The New York Harbor School was established in Bushwick, Brooklyn, New York, one of the poorest, most marginalized neighborhoods in New York City. It was designated as a Title I School with 90% or more of its student body receiving free or subsidized lunch. As such, Mr. Fisher and the founding principal, Nate Dudley set about creating a curriculum that would explicitly foster economic opportunity and career training alongside, and indeed as a result of, the stewardship-based and maritime experiential education. These two motivating forces, the desire for authentic environmental education in New York City public schools and the need for authentic economic opportunity in New York City's most marginalized neighborhoods, became the drivers of the Harbor School curricula and subsequently the BOP.

In the school's proleptical stage, unable to "bring the water to the school," Harbor School teachers developed innovative practices in order to "bring the school to the water." Founding teachers, Ms. Ann Fraoli and Mr. Roy Arrezo created the 9th grade core course known as "Introduction to New York Harbor", and simply "Field Class." The course teaches marine science, environmental policy, and Harbor-related humanities through 18 two-week cycles in which all 125 ninth grade students visit 18 unique field sites around New York Harbor and conduct lab activities and hands-on learning experiences, including one cycle devoted entirely to oyster restoration. Each site includes a workshop delivered by the host organization, a full day of follow-up study and final assessment back in the classroom. The unique lesson plans, field resources, and procedures of this course were developed in partnership with educational organizations, businesses, waterfront park sites, and government agencies, many of whom continue to serve today as partners or advisors for the larger BOP initiative.

When the Harbor School moved to Governors Island in September 2010, it gained the facilities needed to transition toward becoming a state-approved Career and Technical Education (CTE) high school. It established six unique programs - Aquaculture, Marine Biology Research, Ocean Engineering, Marine Systems Technology, Vessel Operations, and Professional Diving - each of which now has a full three-year curriculum leading to a professional examination and state certificate. The CTE instructors have developed their programs' curriculum in collaboration with a core team of professional advisors from their respective sectors of science and industry. Reflective teaching practices such as these encourage teacher autonomy, teacher proprietorship, establishes community and galvanizes ingenuity (Loughran and Russel, 2002).

In addition to professional training and career readiness, the unifying focus for all six CTE programs aims to be environmental restoration. In this regard, each program contributes specific facilities and efforts to the project of oyster reef restoration; from oyster breeding to reef building to long term monitoring, project design, modifications, and policy proposals. For example, aquaculture students spawn and rear all of the oysters used in the project. Marine Biology Research students develop and implement the protocols for monitoring oyster gardens and reefs for biodiversity and water chemistry. Marine Systems Technology students build and maintain vessels, engines, and other structures used for exploring and restoring the harbor. Ocean Engineering students study and monitor the submerged environment using electronic sensors and Remotely Operated Vehicles (ROVs) or underwater robots. Professional Diving (SCUBA) students carry out the physical work of underwater monitoring, installation, reef building, and maintenance. Vessel Operations students navigate and drive the boats required for all of these activities and more. In this way Harbor School CTE programs provide what is arguably the best venue in New York City for high school students to participate directly in value added marine STEM projects during their regular school day. Additionally, teachers have created their own unique learning community permitting them to work on a sustained basis with their colleagues, develop a shared mission, and create a feeling of connection to both the students eliminating a sensation of isolation which often permeates teachers under traditional circumstances (Horn and Little, 2010).

Interestingly, as opposed to the vocational schools of the post-WWII era, CTE programs of today do not track students away from college. Rather, they offer an additional curricular layer. Most CTE students do not intend to seek employment in the fields for which they are achieving certification; they nonetheless often report that their CTE projects were a favorite part of their high school experience. For innovative programming such as BOP, the CTE curricula offer an appropriate structure for flexible project- and place-based learning. However, even at the Harbor School, there is an underlying tension between field based programming and the demands of regular academic teaching and preparation for the New York State Regents exams, required for even the most basic high school diploma. It is not clear how these tensions will play out in participating BOP schools that do not offer a CTE component or extensive electives.

III. The BOP beyond the New York Harbor School

It was envisioned early on that the BOP could ultimately engage a much wider audience than Harbor School's 450 students and 40 staff by exporting oyster gardens and related marine STEM curriculum to dozens of partner (middle) schools around the city. Ultimately, this would help expand the reach of restoration science and also create much needed recruitment pathways for Harbor School to attract high-motivation, high-need students to its semi-isolated location on Governors Island. The BOP would also engage local NYC restaurants to serve as shell recycling partners and hundreds of public volunteers to help with the labor-intensive tasks of reef building and marine monitoring. Ultimately BOP would become a city wide initiative for restoring the Harbor and reconnecting people to the water.

These initial conversations revolved around two key notions. 1) The Eastern Oyster, (Crassostrea virginica) is the original ecosystem engineer of New York Harbor. New York City is the terminus of a regional watershed that encompasses more than 17,000 square miles, four states, and approximately 20 million people. When the water of the combined Hudson, Raritan, and the Bronx River watershed arrives in New York Harbor it meets the Atlantic Ocean and forms one of the largest and most well protected natural harbors in the world. The 300-square mile estuary that surrounds and comprises New York City was, at the time of European arrival, also one of the most biologically productive and resilient ecosystems on the planet. For more than 250 years the vast fisheries of the Upper New York Bay and Hudson River both nourished the people and propelled the wealth of the city. Arguably no species was more essential—or more abundant—in the building New York City than the native East Coast oyster, Crassostrea virginica. The historical extent of the New York Bay oyster included more than 200 square miles of reef and hundreds of billions, if not trillions of individuals. At this scale the oyster was inarguably the original ecosystem engineer of New York Harbor. Its power to attenuate waves, continuously filter impurities, and shelter complex communities of marine life is unmatched and irreplaceable. New York Harbor was once one of the most productive and bio-diverse places on Earth. Oyster reefs, as the dominant habitat type, were the engines of this productivity and diversity. By filtering the water, providing habitat, stabilizing the benthos and protecting vulnerable shorelines, oyster reefs created the abundance of natural life that fed New Yorkers for centuries. Two centuries of continuous overharvesting followed by industrial pollution, dredging, and ongoing sewage overflows have decimated the Harbor and its native oyster reefs. The last NYC oyster bed was officially closed in 1923 due to bacterial contamination. Today there are exceedingly few naturally occurring populations of oysters left in NYC waters and the few that remain are sporadic and diffuse. That being said, BOP exists to jumpstart the natural process of restoration. To restore oysters is to restore New York Harbor.

2) Large-scale oyster restoration is a complex scientific undertaking requiring collaboration between multiple STEM disciplines. The Billion Oyster Project requires Harbor School's CTE programs to work together to design, implement, and monitor all aspects of the project together. BOP also creates strong tie-in points for academic teachers to craft their own curriculum around environmental policy, restoration,

history, and related topics. The potential for oyster restoration to become a motivating tool and unifying platform for other, non-CTE, non-New York Harbor School teachers remains an open question. While BOP/restoration-as-curriculum is undoubtedly a compelling concept - we hear this over and over again from teachers and administrators wanting to get involved - the everyday demands of classroom teaching, standardized testing and performance evaluations impose constraints that make it difficult to implement a very much out-of-the-box field based curriculum.

Despite these constraints, currently approximately 25 New York City Department of Education (NYCDOE) middle schools, eight OST program providers, and six environmental education program providers have implemented some component of the BOP/Oyster Restoration curriculum and community enterprise over the past two years. The current BOP middle school curriculum is a compilation of dozens of lesson plans, afterschool activities, technical procedures and a 110-page manual that have been developed and tailored by Harbor School faculty, Harbor Foundation staff, and our partners collaboratively over the past ten years. The in-class and supporting curriculum is based around the hands-on project of "oyster gardening." As with the larger BOP, the two main goals of oyster gardening are: 1) Restoration: to help rebuild native oyster populations of NY Harbor by installing small, protected breeding colonies of "spat-on-shell" oysters in strategic locations throughout the Harbor; and 2) Education: to engage students, teachers, schools, and community groups in environmental monitoring, science, and stewardship around their local marine environment and waterfront. Practically speaking, an oyster garden is a small wire mesh enclosure attached to a dock, pier, or bulkhead containing a set number of oysters. BOP oyster gardens are 2'x1'x1' enclosures made of 14-gauge nylon coated wire mesh. The top of the cage has a hinged door that closes with a heavyduty bungee. The cage is attached to the dock with 1/2" marine poly line and 3/8" nylon coated steel cable.

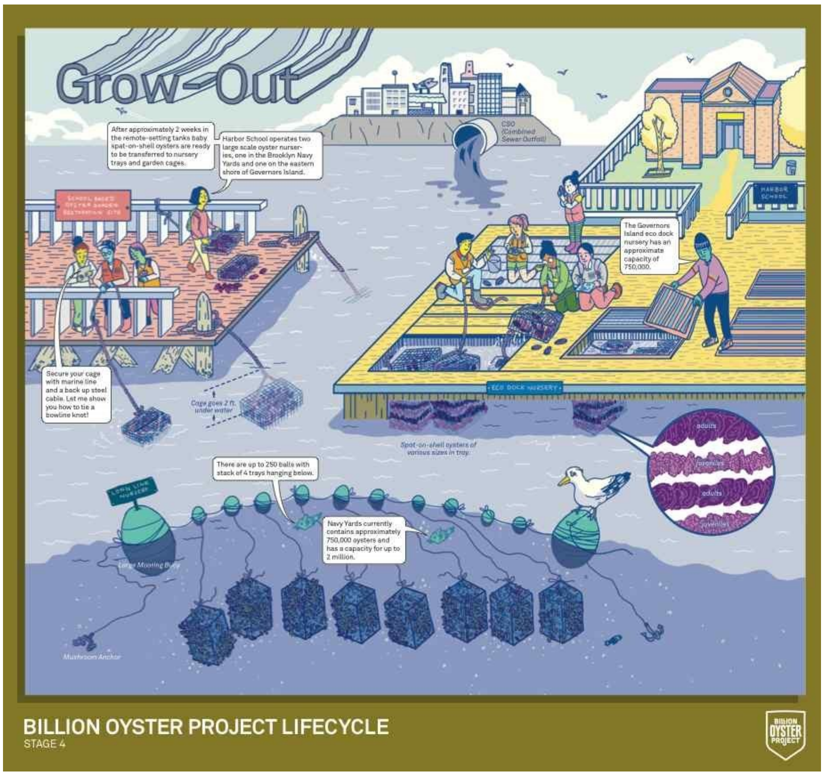

Figure 1 - Oyster Gardening Diagram (BOP Stage Four)

The oyster cage is stocked with "spat-on-shell" oysters: usually 150, 300 or 500 depending on age and size. Unlike commercially grown (individual) oysters, spat-on-shell are clusters of multiple oysters growing on a single recycled shell - meant to mimic the way oysters grow in the wild. All "spat-onshell for gardens" are produced by Harbor School's hatchery on Governors Island. Oyster cages remain in place for a minimum of TWO YEARS with the same oysters, to allow time for maturation and at least one season of spawning. After two years, gardened oysters are transplanted to on-bottom reef sites and the cages are restocked or removed depending on local data and results.

IV. Constraints

New York City schools, the nation's largest and most urbanized system, have unique institutional and physical challenges to teaching and learning outside of the classroom. One of the most fundamental of these is access to the natural world. Most of the City's surface is paved or lying under concrete. Most neighborhoods, and especially those that are predominantly poor, have little greenspace that is accessible by foot and the majority of middle schools have no field or adjacent natural surfaces. Where there are patches of green, teachers must contend with pollution, permissions from private or public entities, and competition for use of limited facilities. For the average New York City public school teacher enabling students to learn or carry out inquiry research in the natural world—be it in forests, fields, waterways, or manmade parks—is thus a logistical and physical challenge too difficult to overcome on his/her own.

Nonetheless, research consistently demonstrates that children who are provided formal learning opportunities in natural settings led by effectively trained educators develop improved cognitive functioning across all learning domains (Miller, 2007). Such formal learning in the natural world occurs more readily and consistently in the nation's affluent and non-urban school systems, which is a systematic problem with implications that reach beyond the school setting to affect college and career outcomes. The model and methodology described herein represents a practical approach to begin correcting this systematic inequity within and between our nation's school systems. Teacher perspective is critical and pertinent for student success. Promoting teacher inquiry and student inquiry promotes effective learning (Bray, Smith and Yorks, 2000).

The additional constraints of a regular eight-period schedule, school based administrative hurdles, and Chancellor's Regulations governing field trips usually outweigh any potential benefits for individual teachers organizing a trip to the natural environment. This situation significantly reduces the ability of teachers and students to conduct project-based and applied science learning "in the field." Absent organizational and logistical barriers, teachers would still need a meaningful and enriching curriculum to provide the motivation and the management systems for students to effectively learn in the field. The BOP curriculum and community model is premised on the belief that authentic environmental problem solving—in the form of species and habitat restoration—is the motivator, and that teachers also need to be equipped with fully developed curriculum, training resources, and administrative support if they are to successfully carry out restoration- based STEM-C teaching and learning across multiple community/field based settings. This integrated methodology, if implemented effectively, will generate significant increases in student and teacher engagement with authentic scientific principles and content. Students learn by investigating and participating in inquiry as opposed to simply learning about inquiry (Leonard and Penick, 2009).

V. The Digital Platform

Starting in October 2014, we will commence a three-year National Science Foundation-funded implementation of the Billion Oyster Project for NYC middle schools. The goal of the project is embodied in its title: to build a "Curriculum and Community Enterprise for New York Harbor Restoration in New York City Public Schools." The combined curriculum and community enterprise includes five main pillars: Next Generation-aligned Harbor Literacy curriculum for grades 6-8, an accredited teacher training program in field science education, wrap-around after-school STEM mentoring, museum and aquarium based restoration-education programs, and a comprehensive digital platform to serve as the project's toolkit and communications hub. This work is being undertaken through a public-private partnership with Harbor School, the NYC Department of Education, Pace University School of Education, Columbia Lamont Doherty Earth Observatory, the University of Maryland Center for Environmental Science, the New York Academy of Science, Good Shepherd Services, and others.

Because BOP is both a citywide educational initiative and a Harbor-wide ecological restoration project a unique and extensive array of partners and resources are required to implement the project as envisioned. Of these five pillars, the digital platform is envisioned as the key supporting resource of both the education and restoration activities of the project. The platform will provide an interactive forum for recording, visualizing, and analyzing scientific data by and for students and professionals alike. The platform will display real time data feeds, connected sensors, and live streaming underwater video, all of which will be accessible and analyzable by students. For educators and teachers, the platform will serve as fully interactive curriculum archive. Teachers will upload, download, comment, and create lessons plans and educational resources. The archive will be organized around the eight limbs of Harbor Literacy (see figure 1.0). All curriculum and educational resources will be teacher generated, peer reviewed and field-tested.

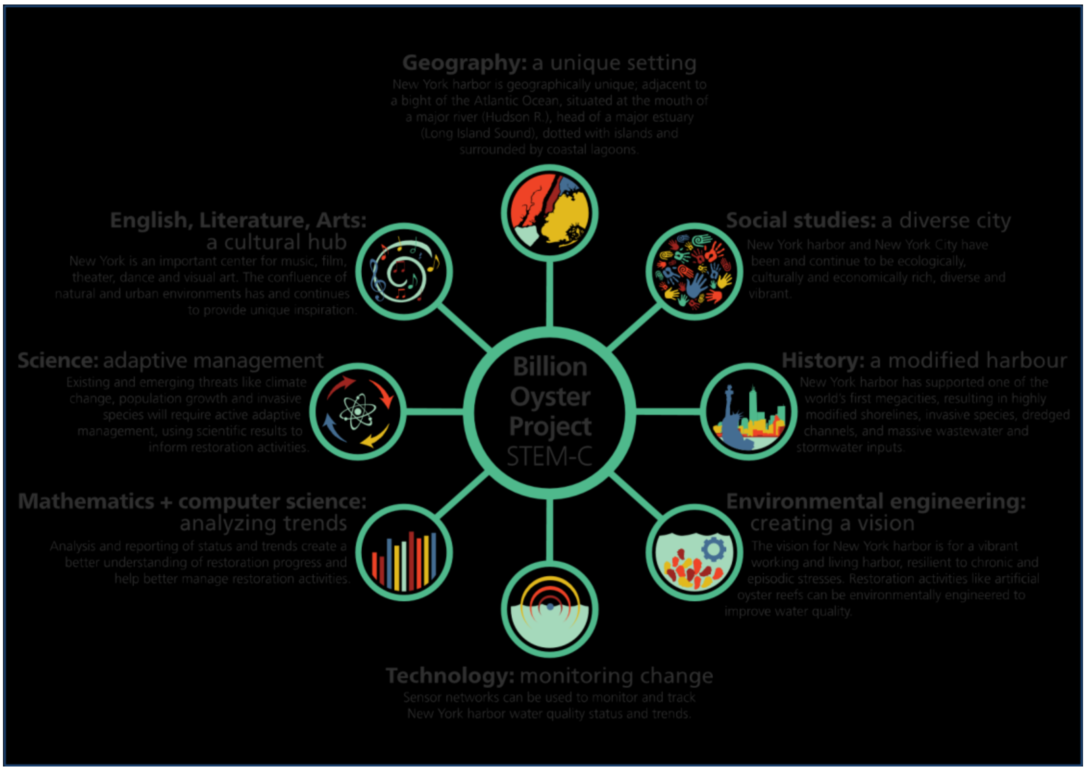

Figure 2 - Harbor Literacy Curriculum Overview

The New York Harbor School's initiative to build a comprehensive digital platform that supports scientific restoration projects and restoration based teaching and learning was spurred on by strong support from the Verizon Foundation beginning in 2012. Harbor School received funds to design and build a state of the art underwater equipment platform to monitor the Governors Island oyster reef restoration site and engage students in the process. The platform includes three separate underwater instruments that will continuously feed data to the surface: an YSI EXO2 water quality sonde measuring DO, pH, salinity, chlorophyll, temperature, conductivity, and turbidity; an YSI Argonaut XR multi-cell current profiler measuring water velocity and wave direction at set intervals throughout the water column; and a View Into the Blue self-cleaning HD video camera with pan/tilt/zoom controls and full spectrum lighting. The platform is both a tool for scientists and a real time "window" into the Harbor for all New Yorkers to observe aquatic life, understand key water quality parameters, and view the progress of habitat restoration projects including oyster reefs. Currently, there are no such systems in our region and the Governors Island installation aims to be the first of many and easily replicable throughout the Harbor. The project is fully funded by Verizon's Powerful Answers and is a result of more than six months of collaborative discussions with Harbor School CTE teachers and local oyster restoration partners including Stevens Institute of Technology and Columbia's Lamont-Doherty Laboratory. The digital tools and underwater instrumentation resulting from this partnership will play a central role in implementing and expanding BOP, substantively engaging public school students through the BOP curriculum. Students will benefit from instructional practices that encourage collaboration, investigation, the use of maniplulatives and scientific tools (Windshitl, Thompson and Braaten, 2011).

BOP is by definition a diffuse undertaking with potentially hundreds of schools and programs participating across dozens of shoreline oyster restoration sites, the project will generate vast amounts of environmental monitoring data, as well as a constant flow of new lessons, educational resources, ideas, and conversation. As such the project requires a digital platform that can serve as both a citizen science data factory and a curriculum repository network. Based on our initial experiences coordinating 25 schools working across 15 field sites, we have built out small pieces of the platform and generated a roadmap of what we would ultimately like to construct. We have integrated the findings of two current and comprehensive academic surveys of citizen science platforms (Azavea and SciStarter 2014, Roy et al 2012). These recommendations fall into two general categories: social and technical. The most salient social recommendations for the BOP platform are: make the data and the software accessible under open source licenses and use agreements; create internal mechanisms for validation of crowd-sourced (citizen science) data; create incentive structures for participation, i.e., points, rewards, badges and other types of gamification; integrate with social networks for the purpose of authentication, social endorsements, sharing activity, and analytics; and focus heavily on understanding the motivations of all types of users and participants. In terms of technical attributes, the recommendations of Azavea and SciStarter are to: integrate data visualization tools and widgets, develop a single sign-in feature for multiple projects, use cloud infrastructure for hosting, plan for internationalization and translation into multiple languages, and implement open-web APIs.

VI. The Pedagogy And Curriculum

A. Technology

Currently, students in the oyster gardening program record their data on paper in the field and submit data using a simple WordPress form from a PC in the classroom. The data are delivered to the BOP program manager and automatically aggregated with data from all schools and student groups, collected over the duration of the project. There is presently no common forum or online tool for students to communicate across schools, let alone compare their data with those from other teams and oyster restoration sites. This system is largely a one-way street where students and teachers are asked to submit their data, but cannot see the aggregated results.

A possible solution to encourage student engagement and interactions, is the online interactive platform (depicted in wireframes below), built with Web 3.0 technology, that will allow students and teachers to see their data in the larger context of: 1) the bioregion they are helping to restore and 2) a peer network of fellow students-as-restoration scientists. Each site and school will appear as an icon (displayed via the underlying Google Maps Engine API). Users will click to a site, revealing a profile page with media files, real-time text updates, and downloadable data tables. In addition the platform will offer an interface for data analysis with a graphical interface for tabulating, graphing, and comparing data over time and across sites. The platform will be built in Java and HTML, with an underlying MySpl relational database. This interaction between students and teachers and students amongst each other within the community is further substantiates the idea of both inquiry based learning and project based teaching (Minner, Levy, and Century, 2010).

Students will create and manage customizable real-time dashboards with fully customizable widgets (gauges, dials, video feeds, etc.) taking feeds from any device with a digital output, including of course the BOP network itself. The BOP platform will serve to increase student motivation and discreet skills as restoration-scientists while expanding student and teacher interaction with the larger bioregion and network of participating schools. These interactions will encourage and promote studentbased inquiry and investigation. Engagement in this form allows for students to acquire investigative skills, interact in collaborative groups, problem-solve and develop independence as a novice researcher (Bonnstetter, 1989).

The platform is web-based, cloud-hosted, and customized for mobile and tablet devices. It is a practical tool for enabling and learning environmental field research methods, data collection, statistical analysis, and basic computer programing. It has been designed for mobile data collection and analysis in the classroom, but students can access and use the platform at any time through any internet connection. The user interface is expressly designed for middle school students with advanced functionality, for high school apprentices and science teachers. It provides compelling graphical illustrations of key content and an array of interactive tools for uploading and analyzing data. Additionally, it includes built-in programming and design features that allow students to create their own dashboards, widgets, and data information resources and feedback.

Five main functions of the designed platform are: 1) students upload, share, and compare data in real time with other schools and sites across the city using tablets or smartphones; 2) students learn database management, graphing, and basic principles of statistics with desktop-based interactive tools 3) students create their own dashboards with widgets to display their environmental monitoring data and web-based feeds 4) students view Harbor Literacy modules and discreet content through interactive and graphical displays; and 5) teachers access a curriculum repository with built-in discussion board to share, critique, and collaboratively develop BOP related educational resources. By investing in the construction of this open source software platform during the implementation phase, the BOP model of restoration-based teaching and learning will be made more accessible and readily deployable in other settings across the county and the world.

Feature	Functions	User Group
Remote Uploader	Upload manual data from he fieldUpload media files from the fieldDocument/ID Species Record phenological (climate) dataConnect sensors and realtime feeds	Students, teachers
Database Management	Manage shared databasesCreate and manage unique databasesTrade datasets Search data	Students, teachers
Display and Analysis tools	Design dashboards Create widgets Graph, map, visualize, display data and realtime (sensor) feeds	Students
Harbor Literacy Education	Search Harbor Literacy Resources Upload Harbor Literacy Resources templates Create Harbor Literacy Resources using internal	Students
Curriculum Repository	Upload CurriculumDownload Curriculum Comment on/Critique CurriculumOrganize Curriculum	Teachers
Internal Communications	Internal Messaging/Email Networked Communications/Discussion Badges Missions/Games	All

Figure 3 - Digital Platform Design Features

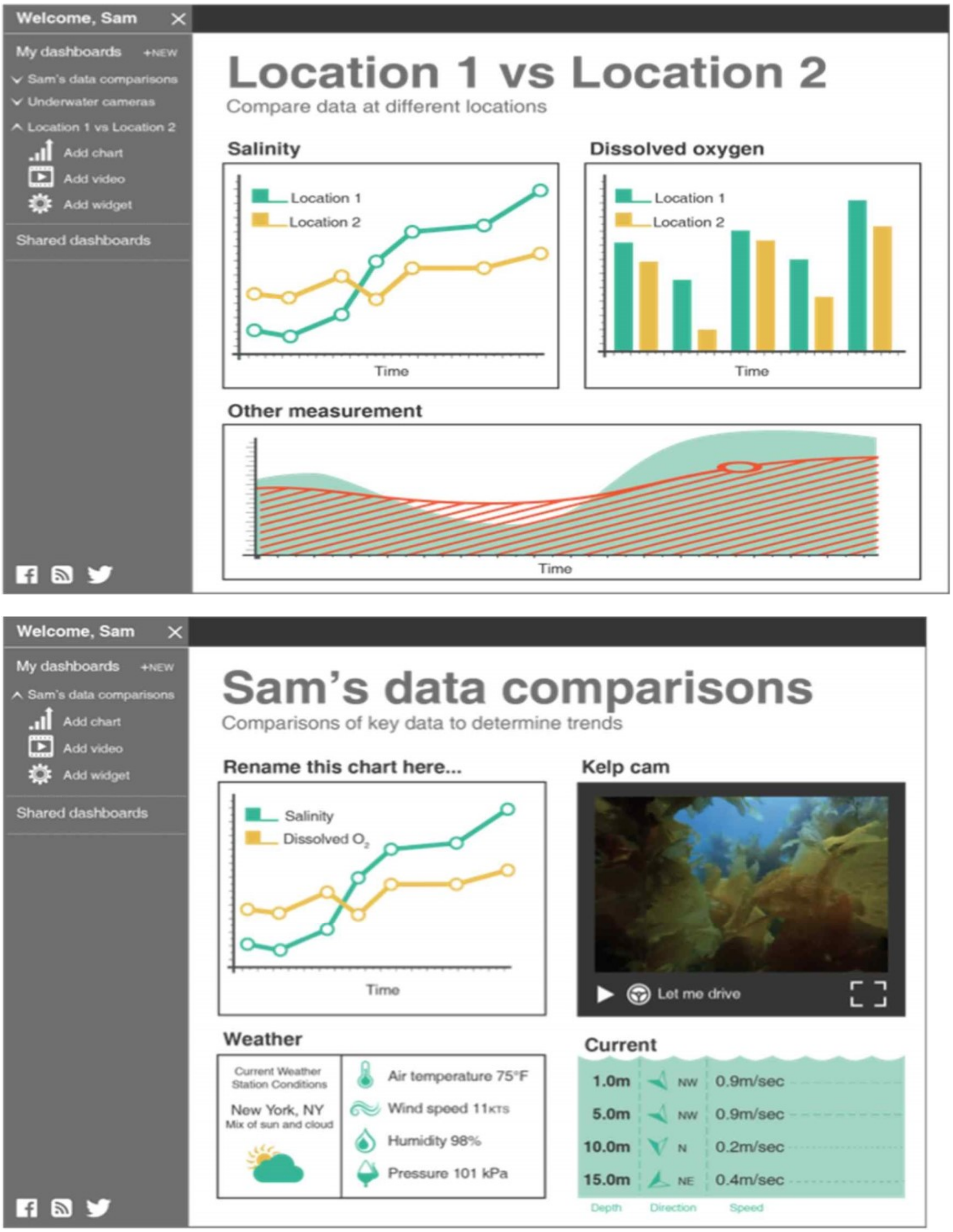

Figure 4 - Digital Platform Wireframes

To better understand the above questions and determine how particular subsets of students and teachers engage with the BOP, the digital platform will include underlying design features that track and encourage the user experience. Each new user will be required to create a user profile with basic demographic details at the time of sign-up. This will include gender, age, household economic status, and ethnicity. The latter two will be generated through proxy questions. The user profile feature will also require each user to choose, at the time of sign-up, his or her affiliated school or organization.

Each participating school will be pre-registered on the site by the administrator. School level data will be standardized and include the New York City Department of Education's (NYCDOE) School Quality Review and Progress Report demographic and achievement data. School level data will be used to examine whole-group user experiences and provide a further level of analysis on the individual user experience. Comprehensive user profile data will allow us to draw conclusions about student and teacher engagement with field science data collection and curriculum creation respectively.

Individuals and groups of users will also be able to track themselves and compare their own participation with that of peers and colleagues. The goal of self-tracking and peer comparisons is not to facilitate competition, winners and losers, but rather to facilitate enhanced peer to peer collaboration, skill sharing, and awareness of one's personal preferences and innate capacities. For example, if a student excels at species identification or graphing then he or she will receive a badge that denotes his or her specific expertise. Additionally, students may then ask for assistance or skill sharing in that particular area. While it is possible to incentivize participation of teachers in a similar manner, the focus of the teacher role will be to monitor and support student participation. Whole classes or small groups of students will also be provided with incentive points or material rewards related to the project for completing a certain task or mission. In this way, teachers will be considered part of their students' team and experience; a sense of accomplishment when a badge/reward is attained by their class or group. Teaching students how to do scientific inquiry is part of the objective. Students are encouraged to conduct an empirical search for answers based upon their data collection. Seeking evidence that supports their hypothesis and proposed ideas creates on opportunity for student exploration, adventure and query (Leonard and Penick, 2009).

B. Pedagogy Model and STEM CCE Program Structure

The Billion Oyster Project Teacher Fellowship Program at Pace University is a two-year immersion in the knowledge and pedagogy of place-based, environmental STEM and Ecology (STEEM). As a BOP Fellow, teachers will gain in-depth and interdisciplinary knowledge of restoration with regular opportunities for applied learning and fieldwork. The basis of the course is a colloquia style class meeting in which teaching fellows will meet with scientists and STEEM professionals to learn and write curriculum collaboratively. Additionally, fellows will receive a kit consisting of equipment, supplies, and live oysters to conduct waterfront restoration research (also called "Oyster Gardening") with their students. Fellows will be taught to build, deploy, and conduct research experiments with this unique inquiry based learning kit. Students will use the kit to monitor oysters and their surrounding environment, conduct experiments and long-term research, and ultimately create powerful data and experiences that students can use to help to restore their harbor and their city. Throughout this process, teaching fellows will be learning new STEEM knowledge and writing curriculum that meets both the everyday needs of an inner city teacher as well as the long-term goals of the STEM CCE Project.

Instructional practices implemented in the Teacher Fellowship Training Model are based upon the 5 E Instructional Model. The 5E Model is a learning cycle model consisting of five different phases: engagement, exploration, explanation, elaboration, and evaluation (Bybee, R., Taylor, & et.al. 2006). This model will be implemented throughout the trainings and teachers will incorporate this format of instruction within their own classrooms. Teaching fellows are required to attend field research trainings, monthly meetings, presentations, and annual symposia. We anticipate that this training, guidance and practice will result in a more impactful instructional practice for the teaching fellows (Kanter & Konstantopolous, 2010).

C. Field Research Training

In total, the field research training includes nine monthly meetings, three days of field training, and one symposium each year. The fellowship is a two-year commitment and teachers must attend all of these events each year to receive their annual stipend and graduate credit. Second year BOP teachers will take on a mentoring role for first year teachers. There will be other variations between first and second year teacher participation that will be articulated as the program develops during its inaugural year.

D. Monthly Research Colloquia and Analytical Forums

The monthly teacher fellowship course is designed as both a colloquium for presentation of scientific/technical knowledge and as a workshop for collaborative curriculum development between teachers and STEEM professionals. Each class is divided in two parts. The first half of the class will include a presentation from one or more guest content experts followed by a discussion or guided activity related to the focus of the talk. The second half of the sessions will consist of teacher-led presentations of curriculum followed by feedback and, time permitting, a breakout session for additional curriculum collaboration. Curriculum presentations will be done in small groups of two to four teachers each. Small groups and scheduling will be defined at the beginning of each semester. Teaching Fellows will be required to present at least once during their first year of the fellowship and share their vision, feedback and resources on a private online forum.

E. Teacher Fellowship Course Logistics

Each participating teacher will be enrolled in the Pace School of Education as a non-degree student. This will allow for full access to all Pace resources and receipt of one graduate credit annually. Teachers will also receive a stipend for their indispensible endeavors on the project and have access to Pace University amenities and resources. Teaching fellows will be an integrated component of the School of Education at Pace University and will allow for them to access additional resources, supplies, and support services as needed (Martinich J. & Solaraz, S. L. et al, 2006).

F. Research and Dissemination: Symposia, Conferences and Presentations

Annual Spring Symposia at Pace University and Governors Island for the BOP schools will be held for teachers and students to present the results of their monitoring and research to academic and professional audiences. Teaching Fellows and their students will also be included to engage in research and presentations by all ten participating organizations. Additionally, Teaching Fellows will become ambassadors of the STEM CCE project and are an integral component in the large-scale project restoration of the New York Harbor project.

VII. Conclusion

The overlay of emerging digital technology on an innovative but technically pedestrian curriculum allows us to address some intriguing questions. To what extent does digital networking enhance experiential learning? Is it instead orthogonal to, or even distracting from “the moment”? Does broader social context motivate increased involvement in field-based team learning? Or is remote engagement largely substitutional in practice, with students “watching” instead of “doing” authentic research? Do teachers (and their students) subjugate new classroom technology to their projects? Is there a lengthy period during which the technology, per se, becomes the focus? Finally, what is unique about the engagement of poor and working class urban children in digitally linked ecological restoration projects? Does participation in the “global village” encourage identification with a culture of stewardship? Do they self-identify as powerful actors? Or are they humbled by their place in the larger struggle for a just and sustainable relationship with nature?

The experiences of piloting Billion Oyster Project (BOP) at the New York Harbor School and 25 partner middle schools across New York City over the past two years have allowed us to draw some initial conclusions regarding the practice of restoration-based education. Firstly, we find that the majority of participating students are strongly motivated by the opportunity to conduct their school day in the field, authentically studying local ecology and playing a direct, meaningful role in restoration ecology projects. Middle school age students do grasp the significance of keystone species restoration and the notion that to restore the oyster is to restore the Harbor. Students also necessarily confront and begin to understand the inherent unpredictability, divergent problems, and virtually unlimited time scale of authentic restoration-based education projects. We have found that BOP student-scientists approach these issues with a surprising degree of patience and curiosity. Where one might expect a loss of excitement over time, we find that given the right support from teachers, students consistently experience a sense of wonder and astonishment during each day of their fieldwork (Walderman, 2000). Whether students are discovering seasonal changes in water quality, documenting the effects of rainfall induced sewage overflows, or recording the abundance and diversity of marine life found in their dockside oyster gardens, students are strongly and consistently engaged by the hands-on research components of the project. The experience of returning regularly to collect standardized data on oyster growth, species richness, and water quality leads not to boredom but to a sense of purpose and commitment that informs and potentially inspires students’ everyday experiences back in the classroom (Bouillon and Gomez, 2001).

While it is still too early to judge whether and in what capacity these authentic field science experiences will be enhanced by the development of customized digital tools, it is clear, however, based upon feedback from current students and teachers in the oyster gardening program, that there is strong demand for digital resources that enable and enrich the marine monitoring data collection and restoration ecology projects they are already doing. It also clear that the National Science Foundation (NSF) funded Curriculum and

Community Enterprise for New York Harbor Restoration in New York City Public Schools (STEM CCE) project to be implemented over the coming three years requires an underlying digital backbone to link together its four offline pillars. As such, we have the unique opportunity to build from scratch a digital platform whose core functions are to support restoration based teaching and learning. The platform will integrate features and recommendations from the current state-of-the-art in citizen science data collection and online curriculum sharing websites. Most significantly, the platform will serve as an internal project evaluation mechanism, allowing us to answer questions about how specific users engage with specific components of the project and how students' uses of digital tools impact retention of STEM-C knowledge, overall disposition toward the sciences, stewardship, and potentially their long-term educational and professional trajectories.

NSF STEM CCERS Project Update

The NSF funded project, of which the BOP STEM Collaboratory NYC™ is the central pillar, includes in total ten partner organizations and five main program pillars. These are: Pace University School of Education, teacher training/fellowship and grant recipient; New York City Department of Education, internal school support and coordination; New York Harbor Foundation, project management and curriculum development; Columbia's Lamont Doherty Earth Observatory, field science research and teacher training support; New York Academy of Sciences, afterschool STEM mentoring and curriculum; Good Shepherd Services, provider of afterschool STEM mentoring and BOP activities; University of Maryland's Center for Environmental Science, digital platform development and educational media; Wildlife Conservation Society's New York Aquarium, marine science education and exhibits (Ocean side); The River Project, marine science education and exhibits (River side); SmartStart Educational Consulting and Gaylen Moore, research and evaluation. The title of our NSF project is "Curriculum and Community Enterprise for New York Harbor Restoration in New York City Public Schools" (*Award Abstract DRL #1440869*). The STEM CCE project commenced in February 2015 with the first cohort of Teaching Fellows from New York City Public Schools.

The premise of the BOP STEM CCE project is that public school students can and should play a direct role in restoring their local environment, and that the practice of teaching and learning is enhanced as the work and study of restoration is integrated into a school's curricula and activities. This vision is particularly relevant for high density urban school districts where the student population is more confined to traditional classrooms, the surrounding natural environment is more degraded, and there are fewer resources to bridge the gap between classroom and field. By enabling urban students materially, logistically, and intellectually to participate in restoration and environmental monitoring during their regular school day, and linking those experiences to a broader focus on place, stewardship, and inquiry, schools fundamentally alter the quality of the education they offer to their students (Bouillon and Gomez, 2001).

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