Science Curriculum Content for Real World Application

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Much has been written in the last few decades about 21st Century skills that are needed for successful entry into today's workforce. Educators and corporate leaders agree that these skills are achieved through a deeper learning of content and an ability to creatively respond to real-world situations. Nowhere is this more evident that in the content area known as S.T.E.M., the acronym for science, technology, engineering and mathematics. It is through the lens of STEM that many of the social, economic and environmental challenges with which we are faced will be solved.

Given that the above statement rings true, it is the duty if educational leaders to provide students with the tools that will prepare them for both career opportunities and as members of the citizen science community. To spark this level of student interest, the curriculum being presented has to be timely, topical and immersive. Students must feel that they are an integral part of the learning process and that they have control in the outcome. I**n other words, they must feel that they have ownership and that they can collaborate in the learning process**.

Mueller, Tippins & Bryan (2012) describe citizen science as participatory democracy in a community setting, where teachers and students represent the community as a whole by engaging in scientific endeavors in their communities. Further, Angela Calabrese Barton (2012) emphasizes the community immersion model and the fact that the students have a "deep and critical connection to their community".

An exceptional example of these components of citizen science including the connection to the community is the Billion Oyster Project that is currently being conducted in New York City. The foundation of this restoration project is the introduction of oysters into New York Harbor. This project is currently being funded by the National Science Foundation DRL 1440869.

Historically, New York Harbor was once the proprietor of almost half of the world's oysters. New York City's harbor is one of the world's most imposing natural harbors, having a large outer harbor area that is fortified by an inner harbor. When the English invaded New York City on June 25, 1776, enough ships were able to enter the harbor that a sentinel named Daniel McCurtin exclaimed that he thought a fleet of pine trees trimmed had entered the harbor. "I though all of London was afloat". It was within this vast harbor that 350 square miles of oyster beds were found. Mark Kurlansky, author of The Big Oyster wrote, "The combination of having reputably the best oysters in the world in what had become unarguably the greatest port in the world made New York City for an entire century the world's oyster capital".

Through centuries of pollution, caused by growth in commerce and population and exacerbated by the over-harvesting of the oyster, the oyster beds dwindled and the oysters became too polluted to eat. In 1927, a ban was placed on harvesting oysters from the New York City harbor for consumption. It was not until 1972 that the Clean Water Act was passed. This limited the pollutant discharges into the waters of the United States and there was a resurgence in the waters of New York Harbor. However, oyster restoration efforts were not introduced for several more decades.

Through this National Science Foundation grant, the Billion Oyster Project has been initiated to combine Oyster Restoration in New York Harbor and situate this in community involvement - specifically with children in the New York City Department of Education. Research indicates that students who are engaged in real-world, hands-on science are more successful in science and have a deeper understand and appreciation of the content (Foley & McPhee, 2008). They are motivated and involved to a greater extent when actively engaged and intellectually interested.

BOP, the acronym for this project, combines the community-based interest in the environmental conditions of New York Harbor with the educational needs of the students by creating a standards-based middle school science curriculum.

Pillar 1 of the Curriculum and Community Enterprise for the Restoration of New York Harbor with New York City Public schools grant is teacher training and curriculum development. The key reason for developing a New York City – Billion Oyster STEM curriculum was to enhance the work of the project by providing a project-based, real world curriculum that could be used in place of an existing curriculum rather than as an add-on curriculum. Teachers are more prone to select a curriculum with which they are familiar and which provides easy access and embedded professional development and supplies (Eidietis & Jewkes, 2011). The challenge in creating a science curriculum that can be used by the New York City public middle school students involves a number of obstacles. To seamlessly merge the field experiences of the Billion Oyster Project with the classroom coursework, many factors have to be taken into consideration. There are two governing entities that control the science content that is offered to the children of New York City – the New York State Department of Education and the New York City Department of Education. Currently, the New York State Department of Education has just approved new P-12 Science Learning Standards (December 12, 2016) http://www.nysed.gov/news/2016/new-york-state-board-regents-p-12-committee-approves-new-p-12-science-learning-standards.

As stated by New York State Commissioner of Education, Mary Ellen Elia, "These standards reflect how students today learn science. Science, Technology, Engineering and Math are becoming more critical every day to innovation and competitiveness in both college and career. It's essential that our standards evolve to provide equitable learning opportunities so all students can benefit."

This decision was not done haphazardly and the revised standards were based on the National Research Council's "A Framework for K-12 Science Education"(2012) and Achieve, Inc.'s " Next Generation Science Standards" (2013). These standards were guided by the framework document and encompass a three-dimensional approach to science education with the goal of student proficiency in performance expectations grades P-12. The New York State Board of Regents had accepted a 5-year proposal for the review of the New York State Science Learning Standards (1996) with the possibility of revisions to include certain aspects of NGSS if not the entire adoption of the NGSS. Two committees were established – the Science Education Steering Committee and the Science Standards Writing Team. The Science Education Steering Committee, comprised of New York State science education stakeholders, was tasked with advising the NYS Education Department of the implementation of the Statewide Strategic Plan for science and revisions to the newly drafted New York State Science Learning Standards. The Science Standards' Writing Team was tasked with reviewing the draft of the NYSSLS and making recommendations to the draft that were considered, incorporated and open for public review. The public survey was closed in February, 2016 and the new NYS P-12 Science Learning Standards were made available for consideration by the Board of Regents as well as being posted:

http://www.p12.nysed.gov/ciai/mst/sci/documents/BoR-ConsiderationNYS%20P-12-ScienceLearningStandards.pdf The decision of the New York State Board of Regents on December 12, 2016 has "muddied the waters" when speaking to the development of a New York State Science Standard alignment for the Billion Oyster curriculum.

Before the final decision by the New York State Board of Regents, the New York City Department of Education went through transitions of its own. In September of 2013, Bill De Blasio was elected mayor of New York City. Shortly after, he appointed Carmen Farina as the Chancellor of the New York City public school system. Within the first few months of her appointment, she re-established the Office of Teaching & Learning, which had been dismantled under the Bloomberg/Klein Administration. Chancellor Farina introduced Four pillars of Education, the first of which states, "Improve Student Achievement by aligning all instruction to the common core standards" and tasked the newly reinstated Office of Teaching & Learning with creating revised Scope and Sequence documents in Science and Social Studies. These documents were to include the Common Core Standards as well as the NYSED Standards in Science and Social Studies and would be integral tools needed to support teachers and school leaders. In the spring of 2015, the Enhanced Science Scope & Sequence was released and implementation began in the 2015-2016 school year.

Initially, it was through alignment with the New York State Science Standards (1996) and the Enhanced Science Scope & Sequence (2015) that the Billion Oyster Project science curriculum began to be developed. The synergy created through standards-based content and community based interest and fieldwork formed the foundation of the work done with the NYC middle school students in the BOP program. Currently, the New York City Intermediate (Middle) School Science Curriculum is taught as a spiraled curriculum. Each of the three grades consists of units of Life and Physical Science and is divided into four major units per grade:

Table 1. The New York City Science Middle School Scope & Sequence (2015)

Grade 6	Unit 1	Energy and Simple Machines	Physical Science
Grade 6	Unit 2	Weather and the Atmosphere	Physical Science
Grade 6	Unit 3	Diversity of Life	Life Science
Grade 6	Unit 4	Interdependence	Life Science
Grade 7	Unit 1	Geology	Physical Science
Grade 7	Unit 2	Energy and Matter	Physical Science
Grade 7	Unit 3	Dynamic Equilibrium: The Human Animal	Life Science
Grade 7	Unit 4	Dynamic Equilibrium: Other Organisms	Life Science
Grade 8	Unit 1	Reproduction, Heredity and Evolution	Life Science
Grade 8	Unit 2	Forces and Motion on Earth	Physical Science
Grade 8	Unit 3	The Sun, Earth and Moon System	Physical Science
Grade 8	Unit 4	Humans and the Environment: Needs an Tradeoffs	Life Science

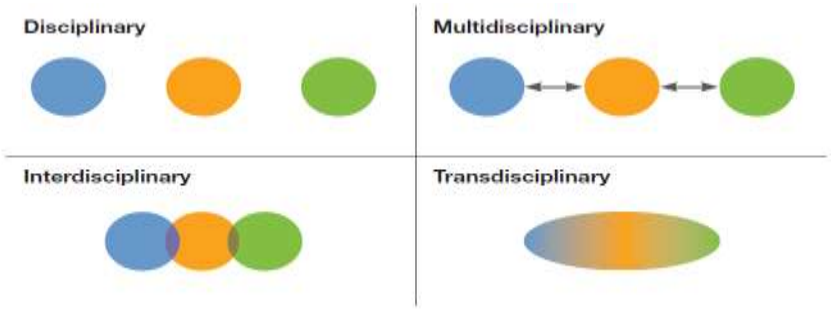
Work began with the units from each of the grades and an essential question that pertained specifically to the Billion Oyster Project was posed for the unit or units. Natural interconnections and merged units began to unfold and it was seen that the continuum could be built through both lateral (grade levels) and horizontal (unit levels) for the Billion Oyster Project Curriculum.

Table 2 - Billion Oyster Project Aligned with NYC Science Scope & Sequence (Grades 6 – 8)

6	Unit 1: Energy and Simple Machines	Unit 2: Weather and the Atmosphere	Unit 3: Diversity of Life	Unit 4: Interdependence
BOP: How do we get around? (Transportation in the NYC Harbor)		**BOP: Is it fair, How we share the air?**	**BOP: Why is life only found in biological communities?** Why is it that nothing lives alone?	
7	Unit 1: Geology	Unit 2: Energy and Matter	Unit 3: Dynamic Equilibrium: The Human Animal	Unit 4: Dynamic Equilibrium: Other Organisms
BOP: Why is New York City here?		**BOP: Why is it okay to dump some things in the water but not others?**	**BOP: Why are humans on the top (of New York City's marine food webs)?**	
8	Unit 1: Reproduction, Heredity and Evolution	Unit 2: Forces and Motion on Earth	Unit 3: The Sun, Earth and Moon system	Unit 4: Human and the Environment: Needs and Tradeoffs
BOP: Will New Yorkers always look so diverse?		**BOP: How else could we get around?**	**BOP: Why is life on Earth and when will it end?**	**BOP: Should we keep building New York City or** eventually **move away?**

When reviewing the initial work (See Table 2) done by the BOP Curriculum writers, an interdisciplinary/transdisciplinary curriculum is evident. The essential questions lend themselves to the broader aspects of the topics listed in the units. In addition, content areas such as mathematics, technology and engineering (STEM) can be explored through community related project based experiences. The addition of Common Core Standards in ELA ad an historical perspective are also easily integrated.

Figure 1. Disciplinary Spectrum



Now enter the adoption of the "new" New York State P-12 Science Learning Standards, which are set to be implemented during the 2017-2018 school year. Decisions will have to be made before any changes can be done to the BOP Curriculum. For example, the new Science Standards are very similar to the Next Generation Science Standards in that they are both three dimensional, having a performance expectation built on scientific practices, crosscutting concepts and disciplinary core ideas. The disciplinary core ideas are further delineated into four categories:

ESSS – Earth Science and Space Science
LS – Life Science
PS – Physical Science
ETS– Engineering, Technology and Applications of Science

As a school system that educates over 1 million students, approximately 170,000 in grades 6 through 8, decisions about the order of the disciplinary content must be made for citywide application. The need for consistency is of eminent importance due to the transient nature of a large urban community such as New York City. The importance of every child receiving the same education is not only sound practice but also the law (No Child Left Behind (2001); Race to the Top (2008)). In addition to the changes that will have to be made to the curriculum, professional development will have to be provided and pilot lessons will have to be tested before a state assessment can be put in place.

In the meantime, the Billion Oyster Project curriculum began with the premise that some form of the NGSS would eventually be implemented in New York City. With that in mind, some of the obstacles with which the NYC school system will have to grapple have been sidestepped by BOP. The BOP curriculum has performance expectations at its core, with field protocols that have been developed to go along with the restoration station work by each of the schools. The restoration stations (billed as "labs at the end of a line") consists of a standard oyster cage, mobile organism trap, sessile trap with ceramic tiles and graduated PVC tubing) are located throughout New York Harbor (1.05 acres with 19.5 million oysters). Several times a year, the NYC middle school students perform a series of protocols at these sites:

1. Site Conditions
2. Oyster Measurement
3. Mobile Trap
4. Settlement Tiles
5. Water Quality

Each of these protocol have been created with performance expectations in mind and so can be directly align to the "new" New York State Science Learning Standards. Some of the activities that the students will conduct are listed below:

Table 3. Measurements taken at the Oyster Restoration Stations in New York Harbor

Wind Direction and Speed	Depth of Oyster Cage	Oyster Growth
Humidity	Bioaccumulation on the Cage	Mobile Organism Type/Count
Tidal conditions	Live/Dead Oyster Count	Sessile Organism Type/Count
Water Quality (Dissolved O2)	Water Quality (Temperature)	Water Quality (Salinity)
Water Quality (Nitrogen)	Water Quality (Ammonia)	Water Quality (Phosphates)

These activities within the protocol align with the Middle School Life Science Standards:

I) MS. Matter and Energy in Organisms and Ecosystems

Which includes following performance expectations:

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical and biological components of an ecosystem affect populations.

II) MS. Interdependent Relationships in Ecosystems

Which includes following performance expectations:

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms in a variety of ecosystems.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and protecting ecosystem stability.

In addition to the performance expectation alignment, the protocols also match the three dimensions of science and engineering practices, disciplinary core ideas and crosscutting concepts in each of the standards.

Arguably, some of the other New York State Middle School Science Learning Standards can also be applied at varying levels. Examples would be MS.LS – Growth, Development and Reproduction of Organisms, MS.LS – Natural Selection and Adaptation, MS.ESS – Earth's Systems, MS.ESS – Weather and Climate, MS.ESS – Human Impacts and MS.ETS – Engineering Design.

It is here that the work of the classroom BOP curriculum needs further development. Building on the work done in the field, classroom tanks are being used to simulate the conditions in New York Harbor and provide a rich environment for the fleshing out of the New York State Science Learning Standards (2016). Each of the performance expectation can readily be accomplished utilizing and expanding the various components of the Billion Oyster Project.

This is a major shift in the current way that student in New York State and more specifically New York City, have been learning science. New York City Harbor provides fertile ground for the meshing of real-work educational opportunities and meeting the benchmarks in science on the local level as well as nationally and internationally.

As stated in the Carnegie Foundation report, "The Opportunity Equation" (2009), steps to transform the U.S. Educational system to increase global competitiveness should include,

- Incorporating math and science learning as part of the expected learning outcomes of initiatives in other areas, including literacy, social studies, art, and service learning
- Advocating for and support smart investments in K-16 mathematics and science achievement for a vital state, city, or regional economy
- Increasing the science and math content in out-of-school time programming through project-based, real-world activities
- Incentivizing the development of state, regional, and local science, math, engineering, and technology initiatives

These can all be accomplished through the lens of the Billion Oyster Project in New York City.

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