Green STEM

How Environment Based Education Boosts Student Engagement and Academic Achievement in Science, Technology, Engineering and Math

Written by the National Wildlife Federation and the NYC Eco-Schools Green STEM Advisory Board
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National Wildlife Federation: A national leader in environment based learning programs, the National Wildlife Federation (NWF) has been bringing high-quality education to America’s K-12 classrooms for 50 years. NWF has done this by developing leading curricula such as its acclaimed NatureScope series and NASA-supported climate curriculum, producing its award-winning children’s publications Ranger Rick and Ranger Rick Jr., and using the school buildings and grounds and natural science to engage students in stimulating and effective STEM-based learning.

In 2008, NWF became the U.S. host for the international Eco-Schools program. Founded by the Foundation for Environmental Education, Eco-Schools has emerged as the largest green schools program in the world. Since its U.S. launch in 2009, more than 3,200 schools nationwide have registered and used this program to support real-world learning and problem solving both inside and outside the school facility. NWF’s Eco-Schools USA and Schoolyard Habitats™ programs provide opportunities for students to become inspired and engaged in exploring the STEM disciplines through the lens of environment based programming or “Green STEM.”

The Hearst Foundations are national philanthropic resources for organizations and institutions working in the fields of education, health, culture and social service. Their goal is to ensure that people of all backgrounds have the opportunity to build healthy, productive and inspiring lives. The charitable goals of the Foundations reflect the philanthropic interests of William Randolph Hearst.

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Letter from President & CEO of the National Wildlife Federation

As a proud parent of a three year old daughter, whose future depends upon both a healthy environment and a strong educational foundation rooted in science, technology, engineering, and math, I am excited to share the National Wildlife Federation’s Green STEM Guidebook with you.

The National Wildlife Federation is America’s largest conservation organization, with a long history of delivering engaging, action-based education programs, from our award-winning Ranger Rick and Ranger Rick Jr. magazines to environment-based science programming for more than five million K-12 students through our Eco-Schools USA and Schoolyard Habitats programs. The National Wildlife Federation is introducing millions of children across our nation to wildlife and the great outdoors—which often inspires a lifelong love of nature—and catalyzing creativity and innovation in problem solving through experiential nature-based education.

Travelling across our nation, I often have the pleasure of meeting with leading science educators who fundamentally understand the rapid changes that are occurring in our economy, to our natural resources, and throughout our society. Our world’s environmental challenges, from clean water and clean air to wildlife conservation and climate change, necessitate a revolutionary change that places “Green STEM” front and center in our efforts to ensure that all young people are STEM-literate. The Next Generation Science Standards will help us meet this goal, but ultimately we all need to join together to empower our students to become the inventors, scientists, and engineers who will make the world a better place in ways we cannot even imagine today.

I hope everyone reading this Green STEM Guidebook will be inspired to join our fantastic Eco-Schools program! The Guidebook shows how the program provides a clear pathway to excite, motivate, and educate the next generation of experts, innovators, and math and technology whizzes. The Guidebook also highlights, with detailed case studies, how students can put their STEM skills to work solving real-world environmental issues right in their own communities. With lessons on solar powered rescue hovercrafts, hydroponic agriculture, en-
ergy conservation, and school-wide sustainability, we demonstrate that learning can be fun (note all of the smiling students)!

Finally, I would like to commend the report’s authors, Elizabeth Soper, Emily Fano and Jennifer Hammonds, as well as our New York City Eco-Schools’ Green STEM Advisory Board members, the New York City Department of Education (special thanks to Anna Allanbrook and Linda Curtis-Bey), the Hearst Foundation for their generous support, and all our partners who made this Guidebook possible.

We look forward to working with you to expand Green STEM and our Eco-Schools program throughout New York City and across our entire nation.

Collin O’Mara

President & CEO of the National Wildlife Federation
Foreword

In 1994, I submitted my thesis, *Integration of a More Comprehensive Environmental Agenda into the New York City Elementary School Science Syllabus*, for a Master of Science degree in Environmental Sciences at Hunter College. At that time students in my classroom often thought of rural locations and the wilderness as the “environment” and only a small number of schools in the City were focusing on environmental studies. I suggested then that there was an urgent need for an infusion of a comprehensive environmental-study component into the science curriculum of NYC schools. In 1999, the North American Association for Environmental Education published *Excellence in Environmental Education: Guidelines for Learning (K-12)*. It is now in its fourth edition, evidence of the growing interest in this area.

In 2008, Richard Louv, lamented that “for a new generation, nature is more abstraction than reality.” And now, in 2015, an environmental curriculum also referred to as Green STEM, will thankfully be part of an enhanced New York City Science Scope and Sequence and part of a broader STEM initiative that will provide educators with opportunities to utilize the urban and built environment as a perfect context in which to study and teach Green STEM in New York City schools.

Students are natural scientists and today can use technology to monitor and mine data from gardens and green roofs, studying features such as soil moisture, precipitation, sunlight, and temperature to help them maintain healthy school gardens. Gardens and green roofs can be used as outdoor classrooms to study weather patterns, climate change, and solar energy. Green STEM helps city kids connect to the nature that is all around them in city parks, gardens, green spaces, beaches and waterways, both natural and built and to use their outdoor spaces as a learning laboratory of unique ecosystem(s). Green STEM students are addressing real-world problems in their communities, such as water and air quality, and through project-based and service-learning activities are taking action to measurably improve their environment and urban space. Elsa Youngsteadt (2015), a lead author and researcher at North Carolina State University, suggests in a recent study that although more than half of the world’s population lives in cities “urban ecology has not been widely researched and is often neglected in favor of studying protected natural areas.” Addressing real-world problems and issues in their communities empowers students with purpose and agency and the process of finding innovative solutions engages students, allows for divergent thinking and can lead to advocacy for a cleaner and
healthier community, city and planet. Eleanor Duckworth (1996) claims that “…one can familiarize children with a few phenomena in such a way as to catch their interest, to let them raise and answer their own questions, to let them realize that their ideas are significant – so that they have the interest, the ability, and the self-confidence to go on by themselves.” We should encourage our students to imagine the possibilities and release their inner scientist by asking questions, theorizing, hypothesizing, predicting, collecting data, testing, reaching conclusions and sharing their findings.

Grow their minds! Innovative thinking will help us find the answers to the environmental challenges we face. Can we or ultimately can our students clean up our environment? Of course, we can! I challenge New York City educators to embrace the opportunities to work collaboratively with colleagues across disciplines to plan experiences and develop units of study that will inspire our students to become stewards of our environment and responsible global citizens who value the planet they inhabit.

I thank the New York City educators whose knowledge, commitment and creativity helped develop this guidebook and I invite teachers to use the Guidebook to transform their pedagogy and create a community of innovative thinkers and real-world problem solvers with the knowledge, tools and critical thinking skills they will need to create a sustainable future. I thank also the National Wildlife Federation for 50 years of leadership in environmental education and Eco-Schools, the largest green schools program in the world.

Linda Curtis-Bey, Ed.D.
Executive Director, STEM
New York City Department of Education
March 2015

References
Visualizing Green STEM in Your School

In 1934, John Dewey, renowned philosopher and educator wrote: “The purpose of education has always been to everyone, in essence, the same—to give the young the things they need in order to develop in an orderly, sequential way into members of society.... Any education is, in its forms and methods, an outgrowth of the needs of the society in which it exists.”

John Dewey’s words remind us that the work that is done in schools needs to be vital, meaningful, and essential to the society in which our schools exist. At the Brooklyn New School (BNS), P.S. 146, environment based education and Green STEM has always been at the core of an interdisciplinary inquiry-based curriculum. It is this approach to teaching and learning that supports students to think independently and to find solutions to questions. And now in 2015, it is this approach that must be used to prepare our children to become informed citizens who can understand complex problems. Today, these problems include flooding, climate change and the decreasing supplies of fossil fuels. Our education, in its forms and methods, is connected to these contemporary issues. At BNS, we nurture a love for nature, a hope for change, and an understanding that it is each citizen’s responsibility to build a sustainable future.

We teach these big ideas through hands-on investigations and experiential learning. Our children go on field trips that are integral to our science/social studies/sustainability curriculum. We know that these experiences are as basic to instruction as pencils, papers and notebooks. In this time of anxiety about climate change, when more than 300,000 people made their way into Manhattan on September 21, 2014, to express concern about
the state of the world, we must make a point of educating our youngsters about the real science of sustainability. We raise awareness about climate change because of its impact on all of our students’ future. And we begin teaching these concepts from the day our children walk into our classrooms.

This is why our school has a garden, and why our children learn to compost and recycle. This is why we connect all of our studies to issues of sustainability, whether it is our four-year-olds learning about themselves, our seven-year-olds exploring how to get water from the mountains to the city, or our ten-year-olds harvesting the three sisters garden.

Last year, some of our fifth grade students, as part of the NWF Eco-Schools USA program, chose to form a Green Club and wrote their own Eco-Code titled “Brooklyn New School’s New Sustainable Society.” It said: “At the Brooklyn New School we want to escalate on the idea of making our school green. We are recycling, composting and gardening; we are also trying our best to save energy by turning off lights. We would like children to stop littering on school grounds, and we are planting more plants inside the school building. We want to improve our recycling program and see what we can do about lunch trays. We want to be the greenest school that we can be by having everyone help out with our green environment.” These are not the words of teachers or parents, but rather the ideas of kids, expressed so well because of the education that has enabled them to make meaning of this significant issue, climate change.

This type of inquiry results in students understanding the real meaning of sustainability and being able to articulate it. It is why our fifth graders were ready to join 100 middle school and high school students at City Hall on September 16, 2014, where they asked city council members to support a 10-cent fee on plastic bags. “Plastic bags cost way too much money,” Micah Abrams-Tweed explained. “They cost New York City $10 million just to bring to the landfill.”

As Nelson Mandela once said, “Education is the most powerful weapon, which you can use to change the world.” By teaching about sustainability, we are doing just that.
BNS 4th graders use maps to discover the Gowanus forests and wetlands of 400 years ago. Photo: BNS Ecorama blogspot.

BNS 1st graders visit the SIMS Municipal Recycling Center, in Brooklyn. Photo: BNS Ecorama blogspot.
Getting Started

Research shows that students are more motivated to learn and do better in school when they feel that their learning is connected to a larger purpose. The environment can be a compelling context for teaching STEM (science, technology, engineering and math). Students who may not otherwise be enthusiastic about STEM disciplines become inspired and often passionate about exploring the many real-world issues that environment based education offers, from designing local recycling solutions to addressing global fresh water shortages. This provides them with a realistic context and connection to STEM subjects that they can embrace and take action on to make a difference in their own neighborhood or in the larger world. For students already enthusiastic about STEM subjects, Green STEM offers an opportunity to take their skills to the next level by engaging in a variety of service-learning projects in their communities such as creating a green roof to mitigate stormwater runoff, or a pollinator garden to help imperiled wildlife. Such projects can have a range of real-world benefits, connect students with a range of interesting community partners from horticulturists and wildlife ecologists to urban planners and architectural engineers, and introduce them to innovative green career opportunities. Moreover, children have an innate love of nature; by showing students that their STEM skills can protect our natural world, students become passionate learners.

Top Left: BNS 4th graders test water powered grist mills and wind powered water lifters. Photo: BNS Ecorama blogspot. Right: PS 57 Staten Island student shows worms from compost bin. Photo: NWF
This Green STEM Guidebook was developed by teachers for teachers who wish to use the environment as a vehicle to engage their students in Green STEM. This guidebook includes background on Green STEM, best practices, and a series of Green STEM case studies and lesson plans—complete with photos and videos—to help educators visualize Green STEM in action.

**WHAT IS GREEN STEM?**

The National Wildlife Federation’s Eco-Schools USA program calls the marriage between traditional STEM and environment based education “Green STEM.” Ten years of research by the State Education and Environment Roundtable (SEER) and numerous other studies have revealed that environment based subject matter integrated into a school’s curriculum and overall pedagogical approach has a positive impact on science learning, literacy, ability to apply learning to new situations, and the ability to work collaboratively. Moreover, the SEER studies, which were done in concert with 20 state education departments and sampled from hundreds of schools, found compelling evidence that environment based education has positive impacts on underserved populations as well as on educator enthusiasm and effectiveness. How can educators capitalize on student “green” interests and build their desire to engage in science, technology, engineering and mathematics? Our solution: Green STEM.

**WHY GREEN STEM? WHY NOW?**

America needs to remedy what is often described as the “leaking” STEM pipeline. Out of every 100 U.S. elementary students, only four go on to pursue STEM-related higher education and careers. The problem exists throughout the U.S. education system, including in higher education, but much of the “leakage” occurs surprisingly early in a student’s education. Generations ago, the percentage of students pursuing STEM education and careers was much higher and helped the United States achieve and maintain global leadership in the scientific and technological fields. Researchers have examined the causes of this trend and have largely concluded that new and more exciting approaches to teaching STEM subjects are needed.¹ This is where Green STEM can support educators in engaging students and keeping them in the STEM pipeline.

This is an essential time for Green STEM. In the next three decades, as a result of global population growth, dwindling resources and climate change, the United States and other nations will be challenged to revamp their economies and embrace low carbon designs, systems and approaches. Societies will need to reexamine how they produce and distribute energy and food; design transportation systems, housing and consumer prod-

ucts; manage waste; protect wildlife habitat; and—equally important—how they relate to the natural world. This will require a profound transformation in our thinking, ways of living, infrastructure and means of production. The students of today will be the decision-makers of tomorrow. The STEM disciplines are an important avenue for fueling innovation and ensuring our youth have the skills to address these future challenges and opportunities.

There are several other important reasons why Green STEM is a critical tool for education today:

1. **The new national and state science standards support environment based education.**

   America is poised for a much stronger union between science and environment based education. The recent publication of the Next Generation Science Standards (NGSS) will, over the next three years, provide states and school districts with the opportunity to make more effective use of environment based education for teaching STEM subjects. These standards support: a) learning about natural systems, including climate change and ecosystems; b) learning science in context; c) applied science, including real world applications; and d) environment based education programming linked to science education that will boost early involvement in and enthusiasm about science education. The new framework will emphasize depth over breadth, using scientific inquiry and the engineering design process as part of the learning experience, and having core scientific concepts revisited at multiple grade levels to help build on prior learning and facilitate a deeper understanding.
2. Environment based education supports reading conceptualization and higher order thinking needed for the Common Core.

The primary purpose of the Common Core State Standards (CCSS) is to encourage deeper thinking, conceptualization and problem solving. Environment based education programs and the reading comprehension they involve require students to learn about cause-and-effect relationships and to understand complex systems. Inherent in environment based education efforts is the concept that learning about one set of circumstances and how to address them leads to a student grasping core concepts that can be applied in other situations with differing sets of facts. This is a skill that educators and employers are recognizing as a deficit in students today. Together, the NGSS and CCSS work to holistically develop a student’s ability to be successful in an ever-changing, fast-paced world. Green STEM programs such as NWF’s Eco-Schools USA and Schoolyard Habitats™ programs align seamlessly with the new NGSS and CCSS and can support educators as they strive to meet these new standards.


Over the past five years, more than 10,000 American K-12 schools have adopted comprehensive plans to green their buildings, grounds and curricula through programs such as NWF’s Eco-Schools USA. Green schools are now more than just sustainable buildings. They are places where students drive cultural and behavioral change and tackle real-world environmental challenges in the course of their daily studies. Curricula and student engagement are integrated with sustainability efforts in buildings, grounds and communities.

Moreover, one of the many benefits of green schools are cost savings. The U.S. Environmental Protection Agency estimates that more than 25 percent of America’s school energy is wasted, at a cost of $8 billion per year. Green school programs have the potential to restore this money back to the schools.

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2 Energy Efficiency Program in K-12 Schools. U.S. Environmental Protection Agency, 2011
ENVIRONMENT BASED EDUCATION AND GREEN STEM

Environment based education and STEM go hand in hand. It is emerging as an effective means for motivating students and making learning relevant through real-world projects and problem-solving opportunities. Environment based education is a general term for describing formal instructional programs that adopt local natural and socio-cultural environments as the context for students’ educational experiences. Its defining characteristics include:

- **Interdisciplinary learning**—Course content is connected to the local natural and/or socio-cultural environment, blurring the traditional lines between basic subject areas.

- **Project-based learning experiences**—Students are actively engaged in the learning process, posing and solving problems, investigating issues and creating products. The audience expands beyond the teacher, assuring students that their work has meaning and is worth doing.

- **Student-centered instruction**—The central focus of learning experiences grows out of students’ interests and questions; they have a voice in deciding what is needed and how to carry out their work.

- **Constructivist approaches**—New learning activities stem from previous activities, building on skills and knowledge gained from past experiences. Reflection is an essential component of each activity, helping students absorb and process what they have experienced.
Throughout National Wildlife Federation’s work with educators, students and schools, specific educational strategies have surfaced as “best practices” in Green STEM. These practices support the development and implementation of innovative curriculum and programs. A key aspect of STEM education is the ability to provide one’s students with the opportunity to engage in these multiple disciplines as they problem-solve. Green STEM is a perfect way to fuse these elements together.

One of the more challenging components of designing STEM projects is engineering. Engineering is a process that allows you to experiment, observe, analyze, redesign and then try again. This process, infused within the science and engineering practices of the NGSS, is a great model to use in any field, and particularly in environment based learning.

The best instruction is open-ended and inquiry-based. Below is a suggested six-step process that can help support the transformation of current pedagogy to include Green STEM.

1. Focus on real-world issues, problems and solutions. In Green STEM lessons, students address real environmental problems and seek solutions. Utilizing the school building or grounds is a great way to identify issues on which students can work.

Utilize the engineering design process (EDP). The EDP provides a flexible process that takes students from identifying problems—or design challenges—to creating and de-
veloping solutions. In this process, students define the problems, conduct background research, develop multiple ideas for solutions, create prototypes, and then test, evaluate and redesign them. An essential component to this process is to letting students know that it is okay to fail. The important part is to analyze, redesign and then retest until a viable solution is found.

**RE-THINKING TECHNOLOGY**

Most everything around us is technology-based. The “T” in STEM does not need to be a complicated piece of machinery, software or a GPS unit. Indeed, it is not the type nor amount of technology that is being used, but more the “intentional use” of technology tools to help students plan, implement and communicate results. The Next Generation Science Standards broadly define technology as all types of human-made systems and processes—not limiting the definition to modern computational and communications devices. Technologies result when engineers apply their understanding of the natural world and of human behavior to design ways to satisfy human needs and wants.

2. Immerse students in hands-on inquiry and open-ended exploration. STEM lessons should be open-ended, within constraints. (Constraints generally involve things like available materials, facilities/space, and budget). The students’ work is hands-on and collaborative, and decisions about solutions are student-generated. Students communicate to share ideas and redesign their prototypes as needed. Students should be able to generate multiple ideas for solving a problem rather than identifying just one right answer.

3. Engage students in meaningful, productive teamwork and promote collaboration. Green STEM in action produces a highly collaborative environment resembling an authentic work environment where students come together to solve local, place-based problems.

4. Use Green STEM lessons to support all subject areas. In STEM lessons, purposefully connect and integrate content from the language arts, social studies, math and science courses (and potentially other subject areas such as art), which can play a critical role in the creativity and innovation of a student’s
design process. Providing students with this integrated approach to education adds relevance to their learning.

Allow for multiple solutions and embrace failure as a necessary part of learning. Let students know that there are often multiple solutions to a problem, and not just one right answer. STEM lessons should always provide opportunity for multiple right answers, approaches and rich possibilities for creative solutions. When students design and test, they may fail as part of the process. It is key to let them know that failure is actually considered a positive step in discovering and designing solutions.

**KEY THINGS TO REMEMBER FOR GREEN STEM TEACHING**

- Provide plenty of guidance but few instructions.
- Mistakes and design failures are part of learning.
- The STEM learning process is not linear—the sequence of events may change.
- Students work in teams using STEM to solve environmental challenges.
- Whenever possible, work with colleagues to write and implement STEM lessons.

Bronx Design and Construction Academy students draw plans for their new Energy-Environment Research Center. Photo: Nathaniel Wight
Green STEM in Action

During the 2013–14 school year, NWF’s New York City Eco-Schools USA program brought together a group of eleven dynamic and seasoned educators to form a Green STEM Advisory Board. The goal was to showcase practicing teachers who were implementing Green STEM in their classrooms and to provide other educators with ideas, information and sample lessons they could implement in their classrooms. The goal is to help students become active, informed and engaged problem-solvers, in school and beyond.

WHAT CAME OUT OF THE PROCESS IS THIS GREEN STEM GUIDEBOOK.

And what follows is a series of Green STEM Case Studies, exploring the compelling context of using the environment to motivate and inspire students, as well as challenge them in the STEM disciplines. From exploring engineering solar powered hovercrafts to oyster gardening in NYC harbors, these educators have used their passion and expertise to engage students to better understand their local environments and to use STEM concepts to become active, informed and engaged problem-solvers in and out of the classroom.

Please use this Guidebook as a tool to help you, as an educator or administrator, explore the concept of Green STEM. Each individual case study contains a backstory, problem/solution, setting/resources, outcomes and personal reflection. As well, each Advisory Board member has contributed a lesson plan that you can try out in your own classroom. Have fun and explore!

NYC Eco-Schools’ Green STEM Advisory Board. (Left to right) Ray Pultinas, Deise Kenny, Vicki Sando, Michael Ashkenazy, Emily Fano, Shakira Provasoli, Jody Reiss, Aaron Bell, Peter Mulroy, Tina Wong, Sam Janis. Photo: NWF
Green STEM Case Studies

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Solar Powered Flood Rescue Hovercraft

by Patricia Lockhart, Green Flag Eco-School
PS 57, Staten Island, NY

PS 57 Robotics Team students created several solar powered flood rescue hovercraft prototypes. Students started with building simple Lego hovercraft kits and then graduated to engineering and building actual life sized prototypes. This project was fueled by the fact that some families were actually left stranded on roof tops all night during Super Storm Sandy here in Staten Island, NY. After creating an extensive research presentation and building several hovercraft prototypes our school was able not only able to win the First Lego League local robotics competition against middle and high school teams for “Innovative Research”, but were also able to convince the Office of Emergency Management to purchase a rescue hovercraft for NYC.

BACKSTORY

PS 57 is a Title I, urban school located in Staten Island, NY, across the street from a HUD subsidized, low income housing project, homes and condo development. Although our school has a diverse population, a majority of our students emigrated from African countries. One third of our population is comprised of students with special needs and 10% are identified as English Language Learners. Our 4th grade science scores have remained high historically for all populations (over 70% at or above standards) when compared with our math and ELA scores. As a result of this data, Green STEM is used to enhance and enrich our school’s academic programs.

Top: PS 57 student assembles and tests Lego model of solar-powered hovercraft. Photo: Patricia Lockhart
Our school has embraced a culture of sustainability, from its edible gardens and ecological studies at a nearby wetland park, to overnight trips to the Catskills watershed and a Vermont dairy farm, and school-wide, environmentally themed teacher professional development workshops. PS 57 has received numerous grants, media attention and accolades for our “Green STEM” projects. We were the first NYC school to win both a NWF Eco-Schools USA Green Flag and U.S. Department of Education Green Ribbon School Award. All these accomplishments have been led by myself, Ms. Lockhart (science teacher), along with my student and faculty Green Teams. Feel free to view our PS 57 Green Team Videos.

PROBLEM AND SOLUTION

The First Lego League Robotics research problem was titled “Nature’s Fury”.

Teams were instructed to:

• Identify a community that could experience a natural disaster
• Identify a problem that happens when a natural disaster occurs
• Create an innovative solution that helps people prepare, stay safe, or rebuild
• Share your problem and solution with others

Although STEM is integrated into our science classes on an ongoing basis, we had specific teams set up for First Lego League, FLL competitions. These teams met during extended day, afterschool and Saturdays as well as during my free time – lunch and preparation periods. Participants consisted of 1 FLL Robotics team with 20 students from grade 5 and 2 Jr. FLL teams with 12 students from grades 2-4.

First students discussed and brainstormed ideas and solutions in relation to the contest theme “Nature’s Fury.” During that specific Socratic Seminar, we devised a plan to conduct a research project on the use of a solar powered hovercraft as a solution for improved flood rescue. This was based on authentic problems which occurred here on Staten Island during Superstorm Sandy. Students selected separate aspects of our research project to explore online in order to create a culminating PowerPoint presentation together.

Next our Jr. Robotics teams in grades 2-4 worked on building a small Lego solar hovercraft and several beach houses with families stranded on rooftops. Our FLL team grade 5 simultaneously engineered and built a life size “Do It Yourself” solar hovercraft that a person could actually ride on. Then we set up field trips to local water rescue units (Fire Department, Coast Guard). Finally, we conducted numerous presentations at our school for a variety of visitors, including the Office of Emergency Management, partner schools and FLL competitions locally and citywide.

SETTING AND RESOURCES

All of our online research was conducted in the school’s computer lab. Students separately created PowerPoint slides and saved them on a flash drive. Together we edited the

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1 Is a form of inquiry and discussion between individuals, based on asking and answering questions to stimulate critical thinking and to illuminate ideas. [http://hopemiddle.weebly.com/socratic-seminar.html](http://hopemiddle.weebly.com/socratic-seminar.html)
individual slides and compiled a final PowerPoint on the smart board in the science lab. (See appendix for presentation.)

Our small Lego hovercraft and beach homes with stranded families were built in our robotics room. We also had to add a solar panel and motor from an old Lego e-lab kit to make it operational.

Our DIY hovercraft was built in an open room with space. First we watched a Maker show video2 in our science lab to help us prepare for the work we were about to do. We then walked across the street to Home Depot to purchase a heavy duty shower curtain, cordless leaf blower, plywood, large screw and bolt, staple gun with staples and masking tape. We had to wear science safety goggles and our custodian was in charge of using the jigsaw and box cutter! We of course needed math tools such as protractors, measuring tapes, rulers and yard sticks to calculate diameter and circumference. We also used our school’s solar panel for charging purposes.

Our field trips were conducted outdoors touring an actual water rescue fire boat and coast guard speed boat. Our local FLL competition was at a local high school and the citywide competition at the Jacob Javitz Center in NYC.

OUTCOME
Our results were phenomenal! Due to the student’s impactful presentation, the Office of Emergency Management plans to buy a rescue hovercraft for NYC. Our three teams won “Innovative Research” locally and citywide. Our teams’ FLL rubric scores were lev-

2  https://www.youtube.com/watch?v=jGJCwcTTovM
el 4 “exemplary” in all categories. Student interviews are a part of the competition final score. It was evident that students throughout the entire school, Pre-K to 5, were able to extensively articulate the entire process of our hovercraft project in copious detail.

We are presently working on a more “complicated” DIY hovercraft that actually rides on water, and are partnering with Staten Island Technical High School and engineering experts to build the Universal Hovercraft 6F Trainer. We plan to convert the gas engine using a cordless electric lawn mower motor with lithium ion batteries and solar panel for charging.

**REFLECTION**

The technical and logistical problems have been resolved and/or solved for any educator who is challenged to work on this amazing project. Another U.S. Green Ribbon School is replicating our project with their students.

Green STEM is both exciting for students as well as educators! Students are using authentic experiences in a multidisciplinary way, thereby gaining knowledge while making a significant difference in the world. Differentiated instructional opportunities, which focus on the multiple intelligences of participating students, can be integrated throughout this unit. It was apparent that students naturally applied their newly acquired skills on a much higher level with purpose and meaning. Any problems encountered actually became teachable moments where students applied problem solving strategies based on evidence from multiple sources.
Solar-Powered Hovercraft
Renewable Energy Project

**STUDENT OBJECTIVES**
Students will explore how a hovercraft actually works by testing prototypes. They will make comparisons between hovercrafts using gas and electric/solar power. They will then apply this knowledge to design a new and improved solar electric hovercraft flood rescue vehicle.

**Standards and Benchmarks addressed:**
**NYC Science Scope and Sequence**
Grade 1 Weather
Grade 2 Forces and Motion
Grade 3 Simple Machines, Energy
Grade 4 Energy and Magnetism and Interactions of Land, Air and Water.

**BACKGROUND**
Our 2nd through 4th grade Jr. Robotics team students viewed and discussed research conducted by our 5th grade Senior Solutions, First Lego League, Sr FLL, team which included various videos and diagrams related to hurricane surge waves which flooded Staten Island during Tropical Cyclone Sandy. **Why were some families rescued from rooftops the night of the storm, while others were not?** Students concluded propeller boats were at risk of getting tangled in floating debris and were unsafe due to hazardous downed electrical power lines in the water. During a brainstorming Socratic Seminar, students concluded a rescue hovercraft would be able to maneuver through debris and submerged power lines to save stranded families by levitating above the water. Given the gas shortage which occurred during the storm, students also concluded using an electric hovercraft with solar charged lightweight lithium ion batteries would be more efficient.

Surge Wave diagram courtesy of Chatham County Department of Emergency Management

**Student Reseserched Resources:**
- Hurricane Diagram
- Staten Island water rescue during Hurricane Sandy
- Hovercraft rescue during Hurricane Katrina in New Orleans
- Hovercraft diagram
**Elicit prior understandings**

Our Jr. Robotics team students were asked: Suppose you were an engineer building a hovercraft for flood rescue. What would it look like and how would it work? Draw a blueprint with labeled parts and then share your design with your partner. Then students were instructed one at a time to share their partner’s design with the class.

**Example diagram:**

![Hovercraft Diagram]

**ENGAGE**

Capture student’s attention, activate student prior knowledge, stimulate thinking, and raise key questions

Students were engaged by revisiting and discussing the photos of various types of rescue hovercrafts from around the world.

**EXPLORE**

Allow students to observe, record data, isolate variables, design and plan experiments, create graphs, interpret results, develop hypotheses, and organize their findings.

Students designed various types of hovercrafts using:

- Base: CD, various sized plates - cardboard and plastic
- Neck: film canister with hole on top, soda cap with hole on top, top of squirt bottle
- Air Flow: different sized balloons
- Surface: flat, bumpy

Note: A hot glue gun was used to secure neck to base and a clothes pin was used to hold the balloon air until release.
Students tested their designs and charted data using bar graphs. They further added a hole on the side of the canister with cardboard rudders to see if the hovercraft would move forward on its own. It did!

**EXPLAIN**
Introduce laws, models, theories and vocabulary. Guide students toward coherent generalizations and help students understand and use scientific vocabulary to explain the results of their explorations.

*How long did the hovercraft stay afloat? Why?*

Students determined that the variables, balloon size and neck opening size, affected the amount of time the hovercraft stayed afloat regardless of design. Basically, the hovercraft was affected by the amount of air pressure or force, therefore, the larger balloons holding the most air, with the smaller neck sizes, releasing air slowly, stayed afloat longer.

*How well did the hovercraft move forward when pushed, blown with a fan, and/or used an extra hole on the side with rudders? Why?*

Students determined that hovercraft movement was affected by the variables, base design, weight and/or terrain. The hovercraft designed with a more evenly distributed balance, more weight and less friction, glided the best.

**ELABORATE**
Provide students with multiple opportunities to design and redesign, collect more data, leading to more valid conclusions.

Students then rebuilt amazing hovercraft designs based on their collected data and scientific reasoning.

**EXTENSION**
Provide students opportunity to apply their knowledge to new domains, raise new questions, and explore new hypotheses. May also include related problems for students to solve.

Student engineers were then challenged to build a solar powered hovercraft using a Lego kit with an extra motor and solar panel. *Now how were they going to convert a simple movable toy into a moving solar powered machine?*

- After following instructions to build the Lego toy hovercraft, they carefully observed how it worked. Students observed that when the wheels were pushed the fan propeller would move as a result of a series of different sized moving gears and axels inside the craft.
- After several attempts, students finally added a gear to the motor axel, attached the motor to the propeller axel gear (changing gear and axel sizes) which in turn made the toy wheels move.
- They even added a rubber band for axel stability
- They attached the panel and tried various types of lights to gain the most power.
Amazing success! Our Jr. FLL Team completed their solar powered flood rescue prototype and won citywide for their project!

EVALUATE
Review student research portfolios and PowerPoint presentations. Administer formative assessment (although checking for understanding should be done throughout the lesson).

Students were instructed to design a hovercraft that would work on water. New base materials were introduced such as tin foil, paper plates, and cardboard for students to test different bases.

VOCABULARY
Cyclone, debris, efficient, engineering design and scientific practices, force, friction, hover, hurricane, load, motion, renewable energy, simple machines, submerge, surge, variable, weight distribution

STEM
Science
Energy and magnetism, interactions between air, land, and water, balance and motion, simple machines renewable energy, variables

Technology
Lego robotics, PowerPoint and demonstration to community and city officials

Engineering
Multiple hovercraft design opportunities with common materials, Lego kit challenge powered by solar

Mathematics
Measurement, addition/subtraction, graphing, using formulas and equations to solve problems
Patricia Lockhart

Patricia Lockhart has been a Science Teacher and Sustainability Coordinator at PS 57 Hubert H. Humphrey Elementary School in Staten Island, NY since 2002. Pat has taught school for over 22 years and has developed an eclectic science curriculum that engages students in hands-on outdoor environmental education projects. The majority of her projects are conducted in school gardens and at nearby Eibs Pond Park, where she has initiated programs to address local environmental and health concerns, including airborne toxins, asthma and childhood obesity. Patricia created a healthy children’s garden at the school for students to grow their own fruit and vegetables and a butterfly and bee garden to attract pollinators and help students learn about plant and insect life. Her students make presentations to the school, community and elected officials, and consistently score between 60 and 70 percent above grade level on the fourth-grade state science tests. She has successfully integrated environmental education into the broader school curriculum, including art, math, social studies and language arts. Patricia also runs Robotics and Watershed programs for upper-grade level students and the Junior Ranger Science Club at the YMCA. As a result of her efforts, the Hubert Humphrey School has received numerous awards and grants and has been recognized in the news for its effective environmental education programs.
Biodiversity and School Grounds

In the 2013-2014 school year, I set out to complete all 10 of the Eco-Schools Pathways through a series of quarter long, challenge-based science electives. Each quarter my students were tasked with conducting a comprehensive audit on some aspect of our school’s environmental impact. After gathering data from our school environment, my students next analyzed the data they collected to identify opportunities to make lasting positive change, and finally proposed and implemented these solutions.

My participation in the Eco-Schools’ program was transformative for my school, my students, and my teaching practice. These Pathways and the courses I designed around them helped to bring global environmental issues to the students’ doorstep, allowing them to assess their role in creating these problems. More importantly, by proposing and implementing positive change on a local scale, students were able to overcome what seems to be an overwhelming sense of doom and gloom when it comes to global environmental issues resulting in confident, empowered students with a sense of stewardship and responsibility. It is quite simply the most meaningful, empowering, and inspiring project I have been a part of in my 8 years of teaching in NYC.
**BACKSTORY**

I am a science teacher at the NYC iSchool, a public high school with a student body of 400 and located in the SoHo neighborhood of Lower Manhattan. In addition to Earth Science and AP Environmental science, part of my teaching program each year requires me to develop *module classes*. Modules are 9-week elective classes, designed to challenge students to tackle a real world problem by creating authentic solutions. While modules are extremely challenging to develop, they provide a rare opportunity to develop courses based on teacher and student interest. I broke down the 10 Eco-Schools Pathways into three different thematic groups that I could build curriculum around. The resulting classes were iSchool Biodiversity, which incorporated the Biodiversity and School Grounds Pathways; iSchool Energy, which incorporated the Energy, Climate Change, and Transportation Pathways; and Poisoned Planet, which incorporated the Water and Consumption and Waste Pathways. These three courses were run respectively in each of the first three quarters of the 2013-2014 school year. The student population changed each quarter, and always consisted of a mixture of students from 9th through 12th grade.

**PROBLEM AND SOLUTION**

**Module 1: iSchool Biodiversity**

This course introduced students to the ongoing 6th Mass Extinction. I wanted students to be aware of the scale and causes of current extinctions, as well as potential solutions. The class goal was for students to be able to measure the biodiversity within a 2-block radius around our school, and implement a plan for increasing the biodiversity of our ecosystem based on the data they gathered.

**Module 2: iSchool Energy: Plan 2037**

The scenario given to students:

2037. That is the conservative estimate for the peak production of oil. The same oil that we refine into gasoline, kerosene, all plastics, paints, fertilizers, pesticides, herbicides, asphalt, etc. From that date forward we will never be able to pump as much oil as we did the year before.

You will conduct an extensive energy audit of sample classrooms around the iSchool to assess our impact on the global energy use and climate. We will take this information and create a plan to reduce our energy dependence as both individuals and a school community.

**Module 3: Poisoned Planet**

The scenario set up for students:

“My participation in the Eco-Schools program was transformative for my school, my students, and my teaching practice. These [Eco-Schools] Pathways and the courses I designed around them helped to bring global environmental issues to the students’ doorstep . . . .”
In this class we will examine the sources and effects of major atmospheric, aquatic, and terrestrial pollution. You will use this knowledge to conduct field tests and environmental audits to determine the levels of pollution present in the air, water, and waste in and around the iSchool, and use this knowledge to create and implement an environmental action plan to improve the quality of our school’s environment.

**SETTING AND RESOURCES**

**Course Structure:**

Although each of these three classes presents very different content, skills, and challenges, I designed each module using the same basic structure described below.

**Weeks 1-5:** For the first 5 weeks of each quarter class time was split between presenting content designed to engage students and getting them to buy into the importance of their work, conducting laboratory work to enrich student understanding of content, and field work focused on completing the audits. In general I spent 3 days covering content, 1 day in lab, and 1 day in the field.

**Weeks 6-8:** Through the next 2-3 weeks of the class students worked in groups of 3-5 on creating Action Plan proposals. These

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NYC iSchool students work together to assemble a raised bed planter box for their new garden. Photo: NWF
were completed using collaborative online tools like Google Docs. Each action plan required students to write an introduction describing the purpose of their work, an abstract summarizing the data they collected and how they collected it, followed by more detailed analysis of the data identifying areas for improvement. Finally, based on their analysis each group recommended 3 actions that could be taken by the end of the quarter to make a lasting reduction to our school’s environmental impact.

Each group presented their action plans to school community leaders including administration, teachers, custodial staff, and representatives from the National Wildlife Federation. After each small student group presented their individual action plans, we came together as one class to look for similarities and design a comprehensive action plan for the whole class.

**Week 9:** The final week of the quarter was spent implementing the group action plan. Some materials had to be purchased for the three modules, but I had most materials available at school. The items listed below are items you may need to purchase or spend time locating if you plan similar module experiences for your students:

**Biodiversity:** birdhouses, raised bed planters, seeds and bulbs

**Energy:** scale, collection bags, outlet electrical timers, recycling bins with material specific lids, and Snapcircuits Green Energy Kits

**Poisoned Planet:** collection bags, fecal coliform water quality test kits (Carolina Biological or other science resource distributor), paper recycling materials (mesh screen, bucket, sponge, paper)

**OUTCOME**

**NYC iSchool Biodiversity**

Based on their proposed action plans students took a three pronged approach to increasing the quality of our school’s habitat and biodiversity. We installed three 9ft³ raised bed planters around the perimeter of our school building to create a pollinator garden filled with native flowers selected by students. Students also created and painted bird houses to be hung around the school to create more nesting opportunities for native bird species. Finally, they planted daffodil and tulip bulbs in the beds of street trees in SoHo square. Their belief is that by beautifying the area we will be able to mitigate the amount of pollution in the park.

**NYC iSchool Energy: Plan 2037**

Student groups audited seven different rooms at the iSchool, representing a variety of spaces and uses. Each group tailored their action plan to the unique data from their sampled room. These action plans included the installation of electric timers on laptop cabinets to reduce overnight energy usage, switching our schools paper supply to 100% recycled, and promoting the use of natural classroom lighting when possible. These changes are projected to offset thousands of pounds of CO₂ each year!
Poisoned Planet
This module provided a bit of a challenge when it came to water for several reasons. First of all, NYC does not audit water use at public schools, so we couldn’t reasonably measure our usage. In terms of water quality, our results confirmed that NYC’s water supply is clean and safe. Instead of focusing on local water issues, students instead turned their attention to the developing world, where water quality is a major public health issue. They decided to organize a fundraiser to purchase a LifeStraw water filter for use in schools in developing nations.

To raise money for the water filter my students turned our school’s waste into a resource by upcycling, or repurposing waste from the iSchool into a variety of products such as lunch boxes, hanging planters, bracelets and baskets woven from plastic shopping bags, and cell phone holders. They organized the first ever iSchool Upcycling Sale and raised over $250 to purchase the water filter!

REFLECTION
Going into the 2013-2014 school year I was really nervous about attempting to do so many new classes and so many Pathways in one year. The biggest challenge I faced was in planning and organizing everything necessary to run the classes and audits. A tremendous amount of time and thought went into designing the curriculum for the modules, planning lab work, field trips, and assessments for each class. Teaching three new classes back to back was also very stressful because I didn’t know what to expect in any of them. Now looking back, while it was a tremendous amount of work designing these modules, they are now in place and the authentic learning experiences they provide my students is lasting and evident by their continuous excitement and work related to the environment. I feel like each class worked really well, and all of that hard work was rewarded by students who were more engaged, and inspired than in any class I have taught previously.

I think a great deal of the student engagement is a result of the authenticity that is inherently a part of this program. Because students have the chance to do real measurements, gather real data, and plan and implement real solutions, they buy into the class and engage with it on a deeper level. It makes global environmental problems more personal and more manageable when they see that their individual actions add up.
I can say with absolute sincerity that my partnership with NWF Eco-Schools, through these three modules, has been the most challenging and rewarding experience of my teaching career.

**MY A-HA MOMENT**

It was pretty cool when my students began proposing solutions to the problems they investigated that I had not thought of already and when they carried out their proposed actions you could tell it was meaningful to them.

NYC iSchool student teams present their NWF Eco-Schools Biodiversity Pathway Audits and Action Plans. Photo: NWF
Exploring Biodiversity

**ENGAGE**
Capture student’s attention, activate student prior knowledge, stimulate thinking, and raise key questions

*Play the embedded youtube clip*

Yesterday we learned three different methods of measuring and assessing the biodiversity of an ecosystem. Those same methods that we discussed are used by the conservationists in the video to identify these biodiversity hot spots.

What is a hot spot?
Why are they important?
Why do some areas like hot spots have more diversity than others?

**EXPLORE**
Allow students to observe, record data, isolate variables, design and plan experiments, create graphs, interpret results, develop hypotheses, and organize their findings.

**Workshop Description:**
Each table group of 4 students will be given a poster sized paper representing an island. Different symbols will be drawn on the paper to represent different species (shown in Legend) present on the island. (Use jpg. Island A Student handout)

In their table groups students will apply the three different methods of measuring biodiversity that we discussed to their island to calculate their islands species richness, evenness, and Shannon Diversity Score.

**Workshop Instructions:**
In groups at your table you will be given an island ecosystem. The different shapes on the paper indicate different species. Your group will be responsible for calculating the diversity of your island, in terms of Richness, Evenness, and Shannon Diversity Score.

**Share Out:**
When finished each group will share its results on the white board.

**EXPLAIN**
Introduce laws, models, theories and vocabulary. Guide students toward coherent generalizations and help students understand and use scientific vocabulary to explain the results of their explorations.

All of your islands had different measurements for biodiversity. Although we did this exercise on paper maps, we would find the same results when comparing the biodiversity of real ecosystems. So, what kinds of factors might affect the biodiversity of an area?

In general there are three major factors that affect the species richness of an area:

**Latitude**
- Areas near the equator, at lower latitudes have higher species richness in general. As you move towards higher latitudes away from the equator species richness declines.
• Why might this be? Discuss

**Habitat Size and Distance**
• Larger habitats in general have higher species richness.
• Why might this be? Discuss.
• Nearby habitats are likewise richer than distantly isolated ones.
• Why might this be? Discuss.

**Time**
• Older ecosystems have greater species richness than younger ecosystems.
• Why might this be? Discuss.

**EXTENSION**
Provide students opportunity to apply their knowledge to new domains, raise new questions, and explore new hypotheses. May also include related problems for students to solve.

We will now return to the results of our workshop to elaborate. Students have already calculated and listed the biodiversity of their group’s islands. Now I will show them a large map (Use: Map of Island.jpg) showing a coastline and several islands of varying size and distance from the coast.

Using the map, their results, and their new understanding of the factors that influence biodiversity, students will match each group’s data to the corresponding island on the map.

**EVALUATE**
Administer formative assessment (although checking for understanding should be done throughout the lesson)

See next page for assessment.
MEASURING BIODIVERSITY

Ecologists measure the diversity of ecosystems in several different ways. Species __________________ is a measure of the number of different species in an area. Factors such as __________________, ______________, habitat ______________ and _______________ all effect the species richness of an ecosystem. Species __________________ is a measure of diversity which can tell us if an ecosystem is numerically dominated by one species, or if the abundance of species is evenly distributed. The most comprehensive way of measuring biodiversity within a system is to use the ____________________________ using the species richness and evenness.

Which of the four island ecosystems below is likely to have the highest diversity:

Calculate the Shannon Diversity Index for the ecosystem described below:

<table>
<thead>
<tr>
<th>Species</th>
<th>Population</th>
<th>pi</th>
<th>Ln(pi)</th>
<th>Pi*Ln(pi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ H = \]

The Table below lists the number of individuals of each species found in 3 similar fields.

<table>
<thead>
<tr>
<th>Species</th>
<th>Field 1</th>
<th>Field 2</th>
<th>Field 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ant</td>
<td>20</td>
<td>91</td>
<td>10</td>
</tr>
<tr>
<td>Beetle</td>
<td>20</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Spider</td>
<td>10</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Termite</td>
<td>40</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Grasshopper</td>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Praying Mantis</td>
<td>1</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Centipede</td>
<td>1</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Millipede</td>
<td>1</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Earthworm</td>
<td>10</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Caterpillar</td>
<td>1</td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>
**LESSON: EXPLORING BIODIVERSITY**

1. Calculate the Diversity Index for each field.

2. Which of the four fields has the highest overall diversity?
3. Which of the four fields has the highest species evenness?
4. Which of the four fields has the highest species richness?
5. How can an ecosystem have high species richness but low diversity?

**VOCABULARY**
Hotspot, diversity, latitude, ecosystem, species richness, species evenness, Shannon Diversity Score

**STEM**
- **Science**
  Biodiversity, ecosystems, geographic location’s relationship to species richness

- **Technology**
  Using video resources to better understand phenomena

- **Engineering**
  Using models to represent real world systems and drawing conclusions based on the models

- **Mathematics**
  Calculating species richness, evenness, and Shannon Diversity Score
Peter Mulroy

Peter Mulroy has been teaching science to high school students across New York City for the past seven years. Now at the NYC iSchool, a public high school located in SoHo, Mr. Mulroy teaches Earth Science, AP Environmental Science, and serves as the school’s Sustainability Coordinator. A firm believer in authentic, place-based science education Mr. Mulroy has designed curricula at the iSchool, partnering with NYC based conservation groups such as Trees NY, the Lower East Side Ecology Center, and the NYC Audubon Society.

In the 2013-2014 school year, Mr. Mulroy designed and taught a series of 9-week intensive science Modules, incorporating 8 of the 10 Eco-Schools Pathways. In each of these Modules student groups collected data on the school’s environmental impact, and used the data to propose and implement lasting positive changes to make the NYC iSchool a more sustainable place. In recognition of Peter’s and his students’ work, the NYC iSchool received the NWF Eco-Schools Green Flag Award in February 2014 and the NWF National Conservation Achievement Award in the Education category in May 2015.
Sustainable Urban Agriculture

We teach what we already know, yes? Equally important in teaching however is an awareness of what is going on around us, what we might not already know. We always teach at a particular time and in a particular place and always within the context of a changing world. Observing what is happening directly around us and being willing to act are as important as what we know about any of our subjects.

BACKSTORY

In 2009 it was reported that over 62% of Bronx residents were obese, the largest rate of any borough in New York City and above average for the state. At the time, films like Food, Inc and Supersize Me and books like Fast Food Nation and Omnivore’s Dilemma were linking the fast and highly processed food we eat with the early onset of Type 2 Diabetes, cancer and heart disease, even among school aged children. It did not take long for me to understand that my students at our overcrowded and troubled public high school in the Bronx were among those who were most at risk.

At the time, I was already teaching an elective called the Witt Seminar, a class that I had started in 2005 during the same semester that metal detectors were introduced at our school and we became a closed campus. Students at this time were for the first time routinely subjected to security protocols that continue to this day and have now become completely naturalized. But back in 2005 it was frighteningly new. Students were searched and scanned upon entry and as the term “captive lunch” indicates, were to remain indoors for the entire school day (except for gym). Before we knew it security

Top Left: DeWitt Clinton students reaping the bounty from the garden. Photo: Ray Pultinas. Right: DeWitt Clinton students work together to build the garden. Photo: Ray Pultinas
issues seemed to dominate and students began to complain that our school had become like a prison. The motto for the Witt Seminar was “now that we are supposedly safe, what are we safe to do?” Our project-based curriculum involved students choosing or connecting to a social issue or problem, learning about it through research, then identifying, contacting, meeting and interviewing an activist engaged with their issue. Students then wrote profiles of their activists that were subsequently published in our decidedly activist literary magazine. We hosted annual school and borough-wide Activist Conferences where Witt Seminar students were able to introduce to fellow students their research on issues ranging from domestic violence, incarceration and Tourette’s syndrome to the War in Iraq. They introduced the activists they profiled and invited them to lead break-out sessions and workshops in various classrooms around the building.

**PROBLEM AND SOLUTION - SETTING AND RESOURCES**

This was the model we implemented successfully for four years. But by 2009 we were ready for a change and we decided as a class to focus on just one issue and with the encouragement and support of staff from our school-based Montefiore Health Center we chose our one issue to be food. Here we were in an urban public school of over 5,000 students with over 80% on free lunch in a borough where 62% of the population was obese. The food our students regularly consumed was a likely source of many of their own existing or potential health problems. We were full of questions: How did diet affect student performance and behavior in school? Could we as an “activist” class play a role in educating students about the increasing dangers from eating fast food? Could we encourage students to be more mindful of the food they ate? We knew we couldn’t just put down fast food when our own Witt Seminar students were unable to wean themselves from it. We felt that the best way we could have an impact on

Ray Pultinas and his students work to plant the new raised produce beds in the DeWitt Clinton Garden. Photo: Clare Hagan
students and the way they eat was to raise awareness about healthy food. We didn’t want to just tell students what not to eat. We wanted to introduce students to healthy alternatives. And so in the spring of 2010, we started a garden with four raised beds and soil donated by Montefiore on a small plot of school property adjacent to our gym building.

By the fall of 2010 our school was plagued with problems stemming from the fact that we were still a large high school in a school system that increasingly privileged small schools. We were still overcrowded and our students, a disproportionate amount of whom where ELL or had special needs were often underserved and underperforming. There was a spike in violence, despite the metal detectors and scanners, and armed police officers routinely walked our hallways. Over the next three consecutive school years we received “F” grades on our Overall Progress Reports and there was widespread fear that our school would be closed or phased out. We also felt the brunt of budget cuts. The Witt Seminar, for instance, along with most of the other electives at our school was abruptly cancelled in the fall of 2011.

Ironically, over the next three years and during our school’s darkest hours, our garden flourished. Though initially dismayed by the cancellation of the Witt Seminar with whom I expected to maintain and continue to develop food and gardening curriculum, I quickly seized on a vacancy as Environmental Affairs Club (EAC) Advisor and established this club and its members as the primary stewards of the garden. The students who worked in the garden quickly developed a caring relationship towards it and took pride and a sense of ownership in maintaining it. For EAC members, the garden became a local focus for their environmental concerns and actions. Lengthy meetings in classrooms to discuss abstract environmental concerns were reserved for winter months. I witnessed a doubling of membership in the club with students joining to become a part of something they understood to be meaningful. Our progress was evident in the growth of the garden, the increasing number of raised beds (from four to our present number of eighteen), a new 3-bin compost system, a fence and garden gate and a greenhouse all built on student ideas, labor and community participation.

With a garden under our care we gained a sense of legitimacy in our food activism. We implemented a pilot program in collaboration with the New York Coalition for Healthy School Food to introduce plant-based options in the school’s cafeteria twice per week. We began to host harvest sales and greenmarkets for faculty and students and featured our own garden grown carrots and kale beside local grown produce. We started and saved our own seeds and began growing a wide variety of vegetables, fruits, along with native plants to attract butterflies and other pollinators. It astounded me that none of our activities were reflected in our school’s abysmal Quality Reviews.

“The students who worked in the garden quickly developed a caring relationship towards it and took pride and a sense of ownership in maintaining it. For Environmental Affairs Club members, the garden became a local focus for their environmental concerns and actions.”
In the absence of school funding, I sought the support of dozens of public and private organizations, non-profit and government groups that have sponsored grants or donated expertise and funding for our garden. The New York City Compost Project, GrowNYC, Grow to Learn, Citizens Committee for New York City, Bronx Green Up, Greenthumb, the Walrath Family Foundation, Montefiore Medical Center are just a few of groups we have developed partnerships with over the past five years. In the Spring of 2012 we held our official opening ceremony for The Clinton Garden. In the Fall of 2013 we became an official compost demonstration site for the New York City Compost Project. In the Spring of 2014 we were awarded the prestigious Golden Apple Award from the Department of Sanitation as Borough and City-wide winners of the Trash Masters Team Up to Clean Up contest as well as the Bronx Golden Shovel Award from the New York City Compost Project for our exemplary compost system. This summer (2014), we began a paid internship program with five student interns who are spending a minimum of 30 hours learning about and maintaining the garden.

Sensitivity to and awareness of the immediate world have been keys to perceiving the problems we needed to help solve in the first place. But perhaps what is key also is having a sense of hope or a willingness to act and not despair about the problems we face. When the Witt Seminar was cancelled, we found it necessary to integrate the garden into core curriculum to maintain and expand the benefits it brought to our school. In the spring of 2012, I developed a unit in my senior literary criticism class on food awareness. Highlights of that semester included the staging of an event called “Occupy Lunch, Pe-
period!” in which students wrote and delivered a manifesto decrying the manipulations of the industrial food complex and hosted a series of student created workshops held in the library to raise awareness about the difference between real and industrial food. By the following year we had integrated a complete unit and lessons into our new unified 12th grade curriculum. Students write argumentative essays in support of an eco-design solution to an environmental problem. Each 12th grade class visits and explores the garden as an example of a small-scale eco-design project as they prepare a proposal for their own project. As an English teacher and school gardener I am drawn to making connections between my curriculum and the garden. For instance, while teaching Shakespeare’s *The Tempest* this past spring and focusing on the play’s use of the four humors, students recorded observations of the four associated elements they identified in the garden.

**OUTCOME**

Presently, our school has rebounded due in large part to a new administration with vision and a solid plan for restructuring. The garden has had outstanding support from our principal and I serve on the planning committee for our new STE\-M Small Learning Community (SLC). The E\-M represents Engineering and the Environment. I will be teaching an elective to incoming 9th graders on Agriculture and Sustainability, the environmental focus for our SLC. I am floating a proposal, approved by our principal, and raising funds to expand the garden and create an outdoor classroom on the site with sufficient seating and shelter to accommodate class and community visits. Everything looks promising for The Clinton Garden and our school.

**REFLECTION**

We English teachers might not commonly think of ourselves as social problem solvers, especially when to do so leads us outside of what we already know. But STEM education requires that we help students find solutions to real-life problems and to do so requires a multi-disciplinary approach and a willingness to actively engage in the social issues.
and problems that our students directly experience. In the last five years we have addressed some of the problems facing our school community: obesity and other chronic health conditions from unhealthy eating, heightened and oppressive school security, even summer youth unemployment. We did it by starting a garden and through meaningful collaborations, critical and creative thinking, and the willingness to tackle authentic problems. One might even say that the garden has been a factor in the transformation of our school. And so let’s talk about how English teachers can consider themselves genuine problem solvers.
The Clinton Garden is an NWF Certified Schoolyard Habitat.
Photo: Ray Pultinas
How Can We Use Our Senses

**STUDENT OBJECTIVES**

Students will make observations on their first trip to the Clinton Garden and convey them through writing narratives.

Students will understand and demonstrate the difference between an historic and a contemporary scientific perspective.

**Standards Addressed:** CCSS.ELA Grade 11-12 Writing Standard 3

Write narratives to develop real or imagined experiences using effective technique, well-chosen details, and well-structured event sequences.

**ENGAGE**

Capture student attention, activate student prior knowledge, stimulate thinking, raise key questions.

Students will practice “walking meditation” on their walks from the classroom through the halls and out the exit to the garden. Students are instructed to remain silent from the time the meditation bell is first sounded to the time it will be repeated ten minutes after they arrive in the garden and after they have begun their observations. During their walk to the garden they are to remain quiet even if they see a friend or teacher who they know. They may only use hand gestures to indicate that they are quiet as a part of their class activity. In this way students will prepare for quiet observation and personal reflection having first “emptied their senses” through meditative practice.

**EXPLORE**

Allow students to observe, record data, isolate variables, design and plan experiments, create graphs, interpret results, develop hypotheses, and organize their findings.

Students are instructed to use their five senses to make and record observations about where and how each of the elements (water, earth, air and fire) exist in the garden. Students are asked to be detailed and describe what they observe using figurative language, comparisons, and their own way of describing their experiences in the world. A series of guiding questions are provided (see EXPLAIN).

**EXPLAIN**

Introduce laws, models, theories, and vocabulary. Guide students toward coherent generalizations, and help students understand and use scientific vocabulary to explain the results of their explorations.

Water: while a body of water is not visible from the garden, the Jerome Park Reservoir is nearby and even if it wasn’t, there is moisture. What parts of the garden seem to hold the most moisture? Why? What are the driest parts of the garden? Why might some parts of the garden be drier than other parts?
Earth: While soil scientists might observe variations in the soil types of one region or one locality to another, don’t stop after describing the look and feel of the soil. What kind of plant and animal life do you observe and what is their relationship to the soil or earth?

Air: Breathe, sniff and feel the breeze. Take deep breaths. We are intimate with the air - it flows in and out of us mostly without our noticing. What is the air like in the garden as opposed to the air in the classroom?

Fire: Certainly and thankfully there is no fire in the garden, but there is heat. How warm is it today? Is the sun out? There are processes that take place in the garden that generate heat. What are they? Where are the warmest parts of the garden? (hint: greenhouse? compost?)

EXTENSION
Provide students opportunity to apply their knowledge to new domains, raise new questions, and explore new hypotheses. May also include related problems for students to solve

Discussion: How did people “look” at the natural world during the time of the Renaissance? Consider what we have been studying as we’ve been reading The Tempest by Shakespeare about how Renaissance scientists and physicians used the four humors to determine and assess human temperament. Based on your understanding of Galen’s Four Humors or Temperaments and their associated elements (sanguine/air, choleric/fire, melancholic/earth, and phlegmatic/water) how do you think Renaissance era scientists would describe...
what you have observed today in the Clinton Garden? What language could you borrow from one of Shakespeare’s characters to describe what you have observed today?

**EVALUATE**

*Administer formative assessment (although checking for understanding should be done throughout the lesson)*

For homework, write a brief narrative using the first person and based upon your first visit to the Clinton Garden today using your observation and discussion notes. Use one of the options below:

- Describe the garden from a Renaissance perspective paying particular attention to the four elements.
- Compare and contrast the Renaissance perspective of the natural world with a modern day perspective of the natural world.
- Create two characters, one from the present and one from the Renaissance past. Write a dialogue that might occur between these two characters as they observe the garden alongside one another.

**STEM**

*Science*

Science practices, properties of matter, habitat elements

*Technology*

Student signed up and applied for grants and communicated their work with various members of the community in a variety of settings

*Engineering*

Planning and creation of gardens both vertical hydroponic and outside raised beds

*Mathematics*

Measurement and solving equations related to building gardens, maintaining health of living systems, and ratios related to population vs. food availability
Raymond Pultinas

Raymond Pultinas is a teacher, advisor, Sustainability Coordinator, school gardener, and master composter. He maintains the blog Witt Seminar on Sustainability in Schools at wittseminar.blogspot.com. Originally from Waterbury, CT, he has been a resident of New York City since 1983 and has taught English at DeWitt Clinton High School since 1992. He has MA and EdM degrees from Teachers College, Columbia University where he also taught and advised for over 10 years. He is a recipient of numerous grants and awards including the 2010 Helen C. Reel “Keeping it Real” Environmental Education Award from the Bronx Council for Environmental Quality and the 9/11 Tribute Center’s September 11th Teacher Award 2013. In 2009, he helped create The Clinton Garden with The Witt Seminar, an elective class he taught on activism and publication. In the Fall of 2013, The Clinton Garden became recognized as an official compost demonstration site in the Bronx by the New York City Compost Project. In 2014 he launched plans to expand the garden to include an outdoor classroom to be named the James Baldwin Memorial Outdoor Learning Center and presented on the Poetics of Compost at the Fall 2014 Annual Convention of the National Council of Teachers of English in Washington D.C..
The Billion Oyster Project (BOP) is an ambitious plan to meaningfully engage New York City students, teachers, and schools in the hands-on process of restoring New York Harbor both in the field and in the classroom. The project begins with the idea that urban public school curricula, particularly in the STEM subjects, can be enhanced and student outcomes improved by explicitly linking teaching and learning to localized environmental science that demands authentic research, data collection, and experimentation. In New York City, there are numerous local environmental problems that merit inquiry based research by students; however, none is more fundamental than the question of human impact on our watershed.

**BACKSTORY**

**Demographics**

While our mission is primarily focused on engaging high-need schools and economically disadvantaged, environmentally vulnerable communities, BOP Schools do cover the full range of NYC demographics, from elite Manhattan private schools to public schools in the South Bronx with 95% or more students receiving free or reduced price lunch. Our BOP network is extremely diverse and representative of the total diversity of NYC public schools. Much like Harbor School, we pull from a very wide geographic area - all five boroughs and about 60 zip codes. Currently BOP serves 25 schools across the 5 boroughs, mostly middle schools with a good mix of elementary and high schools as well.

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 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 of 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. **To restore the harbor is to restore this keystone species.** The goal of BOP is to engage New York City public school students in every aspect of this process, from design and implementation to monitoring and evaluation.

**PROBLEM AND SOLUTION**

**Problem**

The project confronts two problems at once. Problem #1: NY Harbor, our biggest public park and most valuable natural resource, has been severely degraded after centuries of industrial pollution and urbanization. Problem #2: the vast majority of New Yorkers today, in particular young people growing up in low-income communities, are disassociated and physically cut off from the water’s edge and the 300 square miles of marine environment enveloping their city. An additional and related problem is the perception in the minds of most New Yorkers, that the Harbor is still too polluted to touch. “Dirty!” is far and away the most common answer we get when asking students to describe their preconceptions of New York Harbor.

In reality, the water quality of the Harbor – indicators like dissolved oxygen, bacteria, and nutrient levels – have improved dramatically since the passing of the Clean Wa-
ter Act in 1971 and Ocean Dumping Act in 1988. Today many forms of marine life, including the iconic oyster upon which countless other species depend, are returning naturally to our City’s shorelines and shallows. While this comeback is slow and largely invisible from the surface – sewer systems are still inadequate and 27 billion gallons of combined runoff still ends up in the harbor every year – it is noticeable and profoundly encouraging for those who make the effort to get down and explore the water’s edge.

SOLUTION
The BOP Oyster Gardening program is a platform to enable local students and teachers to do this. BOP Oyster gardening is an authentic marine science research project which by definition must take place primarily “in the field.” The goal in this case is to restore local keystone species and habitats of New York Harbor. Students and teachers need to be trained and equipped to conduct valid experiments and collect valid scientific data. This is not a trivial undertaking. New York Harbor School on Governors Island has spent the past ten years developing the curriculum, pedagogy and support systems to enable authentic environmental science education in, on, and around the waters of New York City. The result is a comprehensive package that we now seek to export to local teachers. It includes curriculum, equipment and supplies, professional development training, free resources, follow-up support, and most importantly a sustaining connection to the broad
community of scientists, educators, students, and families dedicated to restoration-based education in New York City.

While everyone’s first question about BOP is almost always “so, how many oysters have you grown?” it must be said that our primary goal is education (then restoration). In order to achieve the project’s restoration goals students first need to understand and learn to practice authentic science and engineering in a real-world, interdisciplinary context. Students need to see oyster restoration as just one component of a complex, long-term process that depends more on changing human behavior and reengineering cities than on how many oysters we can grow and place on the bottom. We want our students to understand the local human conditions that caused the degradation of our environment in the first place. We want them to confront the reality of antiquated sewer systems, dredging channels for cargo ships full of Chinese manufactured goods, PCBs and heavy metals dumped upstream 40 years ago, and ongoing oil spills that make more than 90% of NYC waters unsafe for swimming. On top of all that we want our students to understand the fundamental principle of restoration ecology that “nature bats last” and outcomes are inherently unpredictable. We want them to realize even the most carefully designed and monitored projects can fail or generate unintended results. Restoration is ultimately a natural process. If we are extremely persistent and highly adaptive in our approach then perhaps we can begin to see evidence of successful human assisted restoration projects. If BOP influences students to think like a scientist, to consider the environmental impact of their decisions, and to direct their lives in the long-term toward a more sustainable, environmentally just future then the project can be considered a success. If in the process of doing this we begin to see system wide ecological improvements in New York Harbor and City, then we will have achieved the ultimate bonus.

**SETTING AND RESOURCES**

Scroll down toward the bottom, under resources, click “View downloadable Curriculum Files.”
OUTCOME
Since June 2012 we have developed a diverse and durable network of teachers and students who have helped us pilot the new BOP oyster gardening program and hone the essential characteristics of “Restoration Based Education.” We have engaged more than 65 middle school teachers and after-school educators in more than a dozen two-day BOP Teacher Trainings. These trainings and curriculum are centered around the project of oyster gardening. Thus far the protocols have been relatively simple; make a wire mesh enclosure (the cage), fill the cage with a set number of baby (<1cm) oysters growing in clusters, install the stocked cage on a dock, and bring students to monitor on a monthly basis, tracking oyster growth, species richness, and water chemistry. Currently we have 18 total schools and seven afterschool programs participating. 36 individual teachers and educators have one or more cages installed at 23 waterfront sites across New York City. In total more than 80,000 oysters are currently growing in BOP oyster cages around New York City. The true oyster gardeners are some 1500+ middle school students who have experienced oyster garden monitoring and scientific data collection. Together they have collected more than 46 data sets across the 23 total sites. BOP students and schools are extremely diverse. About 70% of BOP schools are NYC DoE middle schools designated as Title I (our target demographic). 75% or more students at these schools receive free or reduced price lunch. BOP students are representative of the larger NYCDoE student demographic. The majority of BOP students are from low-income households and primarily Black and Latino ethnic background. These students are also the most historically underrepresented in STEM fields. Even more importantly, the vast majority of BOP students have never had direct experience with marine science or rigorous environmental science education. Monitoring the oyster garden is for every student in the program a myriad of firsts; from identifying sea squirts and sea robins to measuring dissolved oxygen and sampling the benthos, oyster gardening opens the door to a strange new world that most students never knew existed.

In terms of ecological benefits of the program, it is far too early to make conclusions. The oldest of the 36 BOP oyster gardens is about 18 months. Even with 80,000 breeding oysters in the Harbor, we do not expect to see system wide changes. While an oyster filters up to a gallon of water an hour and a billion oysters could filter the entire standing volume of the Harbor in three days, 36 disperse populations of 500 or fewer oysters each will not have a measurable effect on surrounding water quality. This is not to say there is no causality, but we may and often do find correlation. Water quality changes with season, rainfall events, and gradually over time as we continue to improve storm water management. We do however expect to see near instantaneous changes in biodiversity and species richness as a direct result of oyster gardens. Wherever oysters are planted, gardened, or grown,stu-
dent-scientists consistently find significant increases in biodiversity. Before the oyster garden the Harbor is a flat mucky bottom; after it is a complex structural environment with self-regulating pH and nutrient levels. This is in fact the ultimate function of an oyster restoration: to create a habitat for marine life that includes a myriad of predators and reef associates, from the prolific and benign sea squirt to the deadly efficient oyster drill to the cute and coy sea robin. Seeing this diversity of life appear overnight and tracking the changes as the garden matures is one of the most gratifying aspects of the program for students and teachers alike.

Introductory lessons are wide ranging and adaptable to the specific background of the teacher and interests of the students. Oyster history of New York City, estuarine ecology, watershed geology, water chemistry and the principles of scientific research are just a few options. The overarching goal of BOP curriculum is to foster in students a passion for the marine environment and a rigorous ethic of restoration-science and stewardship. Students are posed the essential questions, “how can science and technology help to restore the degraded ecology of the New York Harbor Estuary?” and “What can people do to change their impact on the marine environment?” Oysters are one crucial component of our solution, but by no means the only response.

In order to help students formulate theories of environmental restoration, teachers present the full array of environmental stressors and historical statistics around overfishing
and declines in native species; industrial pollu-
tion incidences such as PCBs in the Hudson
and the Newtown Creek oil spill; dredging
of modern shipping channels; urbanization,
bulkheading and shoreline hardening; and
wastewater treatment and combined sewer
overflows. Students are asked to analyze the
depth causes for these problems, both socially
in terms of human behavior and in terms of
local urban planning and infrastructure de-
sign. Inevitably, the discussion of environmen-
tal stressors leads students to ask themselves
what they can do personally and collectively
to improve our overall impact on the environ-
ment (e.g. conserve water, build green roofs,
use less plastic). Students eventually come to realize that BOP oyster gardening is one
practical step in the long-term process of attempting to assist nature in restoring native
habitats and species.

Oyster restoration research trips occur once per month. A teacher leads his or her class
of up to 30 students on three-hour field excursions to measure oyster growth, monitor
water quality, and assess the overall condition of the waterfront site. Students collect
a standardized field data set and follow standard operating procedures laid out in the
BOP Oyster Gardening manual. Over time these data sets help students to plot changes
in water quality, atmospheric conditions, and species richness surrounding the oyster
garden. Compiled datasets from all 22+ oyster gardening sites allow students to compare
conditions and make correlations between environmental conditions and oyster growth.

When students return to the classroom after each trip, teachers have the opportunity
to extend and deepen oyster related STEM lessons. Students are taught advanced top-
ics and extension activities in oceanography, currents, and tides; climate change, severe
weather, and sea level rise; and marine engineering and reef building. Time permitting,
some teachers or classes will allow students to develop their own BOP related oyster
restoration research projects. Examples from years past include: “the effects of enter-
coccus bacteria on oyster growth,” “dissolved oxygen tolerance levels for oysters; a com-
parison study of five sites” and “oyster reef breakwaters; an experiment in bioremedia-

Students and teachers enrolled
in the Project check their oyster
cages monthly to measure oyster
growth and biodiversity and
monitor water quality.
Photo: NWF
tion.” Finally at the end of each year’s course of study, students and teachers from BOP middle schools are invited to Governors Island to present their research to a panel of Harbor School teachers and students. These same schools are also encouraged to bring their gardened oysters for planting on the community reef. The experience of presenting research and planting oysters provides a powerful culminating experience. The hope is that BOP students generate a lifelong appreciation and understanding for marine STEM, apply to Harbor School, and become a steward of their local marine environment (not necessarily in that order)! Of course the program is still a work in progress and the impact is not comprehensive for every student; however, the experience of measuring an oyster, identifying a sea squirt, testing for dissolved oxygen, and observing the myriad of creatures found in the New York Harbor does have a profound impact on all. At the very least, all students who have completed the BOP curriculum realize NY Harbor is not nearly as “dirty” as they thought.

**MY A-HA MOMENT**

With the little creatures flapping about on their latex gloves, the excited student-scientists proclaimed: “these are baby oyster toad fish! They are trying to eat our oysters!” This comprehensive understanding of an oyster reef ecosystem alongside a severely degraded but resilient urban shoreline was for me nothing less than miraculous.

**REFLECTION**

My “ah-ha moment” to begin the process of adapting the oyster gardening curriculum and redesigning the cage occurred while following a group of students along a stretch of South Brooklyn shoreline known as Erie Basin. Erie Basin is a semi-enclosed embayment with a strong tidal exchange that draws in the cleaner and more saline waters of the Lower Bay. Historically there was a small Island at the southwestern tip of Brooklyn known as Fort Defiance and beyond that only marshes and inlets; no seawalls or basins. Erie Basin of today was constructed as a shipyards and warehousing area, conveniently located for goods entering the Harbor from the Atlantic Ocean. For more than 150 years, it served as one of the most active waterfronts in the City. Today almost all of that industrial activity has ceased, save for a Water Taxi dock and some fuel barges that use the basin as overnight parking. In its place IKEA has built a mega store and restored the shore-

In two hours, these oysters filtered a tank of algae-filled river water from the Chesapeake Bay, benefiting the entire ecosystem. Photo: Maryland Seafood
line with grassy promenades and native tree plantings. Walking along these promenades the waters of the Basin look similar to most of the 22 other BOP oyster gardening sites; murky with bits of seaweed and plastic debris floating by. Oil streaks occasionally bubble up from the bottom. This is the Harbor that most people see.

Not so for students of Middle School 442 who use Erie Basin as their oyster gardening site. When I joined them for their monitoring trip in late spring of last year, they were eager to show me what lurks below the surface. Before hauling up the cage they guided me around shoreline to where the wall of the promenade ends and a short section of rocky revetment begins. Bypassing a small fence we climbed down to the water’s edge and observed at very close proximity a literal backwater of New York Harbor teeming with life. Amidst all the plastic waste floating and strewn about the rocks were schools of glistening silver Killifish, large moon jellies floating in and alongside the garbage eddies, and two large horseshoe crabs attempting to hide out in the kelp beds on the bottom. This was mind-blowing to me but seemingly ordinary to the MS 442 students, who had been monitoring the site for nearly a year now.

Walking back up to the promenade the students told me that this type of discovery was a regular occurrence at Erie Basin. As they hauled up their oyster cage, they told me visibility is sometimes so good they can see fish swimming around the cage five to six feet below. The final epiphany of the day came when the students placed their cage on the grass for monitoring. Before opening the lid they pointed out several species of crab, shrimp, and worms that had slithered out through the one-inch mesh. When they finally opened the cage and began removing the oysters for measurement, they expertly scooped up several small black slimy fish that had become trapped inside the cage. With the little creatures flapping about on their latex gloves, the excited student-scientists proclaimed: “these are baby oyster toad fish! They are trying to eat our oysters!” This comprehensive understanding of an oyster reef ecosystem alongside a severely degraded but resilient urban shoreline was for me nothing less than miraculous.

Seeing students with this palpable connection to place and expert understanding of local fauna is extremely encouraging indeed. However, we can’t be satisfied with just that. In order for the BOP oyster gardening program to succeed in the long term and
become a durable, adaptable curriculum, we, teachers and educators, need to be able to channel this enthusiasm and knowledge into increasingly complex and independent learning activities. In short, students need to dig deeper. They need to be facilitated and equipped to formulate their own experimental questions and conduct authentic research to answer them. The goal is nothing less than true project-based inquiry science. Why is gas bubbling up from the bottom? Why do horseshoe crabs thrive on a rocky revetment surrounded by garbage? What impact is the oyster toad fish having on the oyster population? How does the sea squirt filter contaminants from the water and what is the effect on its anatomy? These are the questions students need to be asking (and answering) in order for the project and the curriculum to succeed.

The oyster garden and its accompanying classroom curriculum need to be built in such a way that students are equipped to ask and answer these questions. They need to see an ever-increasing range of possible experiments. They need to be provided a versatile toolkit to carry these experiments out. Creating this authentic curriculum from scratch is a process of pilot testing and continual iterations. Most importantly, it is a process of listening to and observing students in action, in the field, on and around the water of the New York Harbor Estuary.
Harbor School student measures an oyster with a caliper. Photo: NWF
Billion Oyster Project

**STUDENT OBJECTIVES**

Students will be trained to conduct environmental science fieldwork on their local waterfront; students will help build a Harbor wide citizen science data set; students will follow standard procedures to record environmental conditions, measure water quality with electronic sensors, and document biodiversity and species richness; students will be taught to analyze this data with digital tools and develop authentic research questions; at the end of the unit students will research what they see as systemic causes of environmental degradation and propose solutions that address both environmental restoration and social justice.

**ENGAGE**

Have students work in groups to find the answers to these questions:

1. What are the three closest bodies of water to our school?

2. Where do these bodies of water empty into?

**EXPLORE**

For more detailed directions you may want to visit the [Windowfarms website](http://windowfarms.com).

Included are directions for one whole class of 28-32 students. This lesson is modified from a [New York Sun Works](http://sunworks.org) lesson in a fourth grade Sustainability Curriculum.

You will need to precut all the tubes and draw the outline of the “window” on the bottles ahead of time. In addition you will need to cut a hole in the bottom of each bottle ahead of time, as this is too difficult and dangerous for the students. Assign each student one of the following tasks:

<table>
<thead>
<tr>
<th>Number of students</th>
<th>Step number</th>
<th>Directions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>Hammer a nail into the air lift tube (6 inches from bottom) to make a hole. (Twice)</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Wrap the large end of a bike needle with the plastic plumbers tape, at least ten times around. (Twice)</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Wrap one end of a long clear tube with plastic tape, at least ten times around. (Twice)</td>
</tr>
<tr>
<td>1-2</td>
<td>4</td>
<td>Push a wrapped bike needle and a wrapped tube into the short connector tube. (Twice)</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>Push a wrapped bike needle attached to tubes, into the nail hole. (Twice)</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>Cut the outlined shape out of the bottle to make a “window.” (Three times)</td>
</tr>
<tr>
<td>4-6</td>
<td>7</td>
<td>With a partner, wrap duct tape around the top of a bottle, up to the cut “window” on the bottom.</td>
</tr>
</tbody>
</table>
3 8 Use a zip tie to attach the air lift tube to the rod. Make sure the bottom of the air lift tube is flush with the rod.

2-3 9 Use duct tape to attach bottles to rod, and leave near an outlet.

1 10 Fill up the bucket with water and a scoop of nutrients (or other liquid), and leave near the outlet and the system.

1 11 Place cups inside bottle “windows.”

1 12 Place plants in cups.

1 13 Place Hydraton clay pebbles under and around plants.

2 14 Attach the long clear tubes to the pump, scraping away the inside of the tubing if necessary.

1 15 Plug in the air pump and check the flow of water.

1. Assist students in building two Windowfarm systems. This will most likely take the duration of two to three lessons.

2. Explain to students that they will compare the plant growth of a system with commercial hydroponic nutrients to a system with polluted water. Allow students to discuss possibilities, and vote on a final liquid. Most students will opt for a slightly polluted water such as salt or animal waste. Fill one bucket with the selected liquid. Instruct students to write a hypothesis.

3. Select and label (A-F) six identical plants to place in the two systems. Instruct students to draw, measure, and write a detailed description of the plants. Insert the plants in the cups. Place the two systems next to each other near a window.

4. Monitor the growth of the plants from the two systems at least once a week, for one month. Instruct students to continue to draw, measure and write about the plants.

**EXPLAIN**

1. Introduce the concept of Water Conservation. Initiate the discussion by asking students to describe water pollution. Students will likely explain that polluted water is dirty and unhealthy, and they may begin to describe some of the items that can be found in polluted water. Ask if polluted water is healthy for plants, and students will respond in the negative. Remind students that their project is testing whether other liquids can be used for growing plants as well as regular hydroponic solutions. Reinforce the concept that students are still collecting data, and may only make assumptions at this point, not conclusions.

2. Explain to students that polluted water may be cleaned with a filter, but that the optimal choice is for humans to work on ways to keep water clean, and to use less water. Ask students why using less water will help keep our water cleaner. Students will respond that when less water is used, there is less that can get polluted. Emphasize that using less water is known as water conservation. Reiterate that humans must consider ways to decrease water pollution and increase water conservation.

3. Tell students that of all the water in the world, 97% is salt water, and thus unable to be used for cleaning, cooking, washing, drinking, irrigation, and manufacturing. Of the 3% remaining, 2% is frozen in glaciers. Emphasize that 45% of the 1% of water available for all citizens of the globe is used for agricultural purposes. Ask students what they believe
probably happens to the majority of water that is used to water crops in an outdoor soil garden. Students will respond that most of the water drips down deep into the soil, below the crops. Emphasize that in a hydroponic system, the water is continuously recirculated.

**ELABORATE**

1. Assign a water use chart for a weekly homework in order to push students to consider how the Windowfarm system helps to conserve water. A suggested chart can be found [here](#).

2. After calculating their weekly water use in gallons, students should be encouraged to discuss what they noticed. Inquire as to how people can conserve more water. Students will explain that people can turn off the water when brushing their teeth, take shorter showers, use a low flow toilet, etc. Remind students that 45% of the 1% of fresh water is used for agriculture. Inquire again as to how people can use less water in the world. Students will look at their Windowfarm systems and explain that a homemade hydroponic system can help to conserve water.

3. Offer students resources for researching water conservation, and explain that students will create a computer based project to teach others about water conservation. Brainstorm with students possible projects, including a Powerpoint presentation, an Animoto video, an iMovie news show, etc. Demonstrate how to create an Animoto video, which may be unfamiliar to students. Share all of the electronic projects on a class website.

**EVALUATE**

1. Instruct students to compare the data collected from the plant growth, and to create a line plot.

2. Instruct students to analyze their data and generate conclusions.

3. Remind students to look back at the original hypothesis and compare it to the final results.

4. Invite an audience to listen to the students explain their projects.

**VOCABULARY**

Agriculture, conservation, ground water, hydroponics, nutrient water, pollution, run-off, storm drain, system

**STEM**

Science

Human impact on water sources, water cycle, systems, plant life cycle

Technology

Constructing Windowfarm systems and presentations using PowerPoint, Animoto, or iMovie

Engineering

Constructing Windowfarm systems

Mathematics

Percentage-parts of a whole, measurement and graphing
Samuel Janis

Sam would rather be in nature almost all the time; but a love for humanity causes him to keep coming back to his hometown of New York City for work. Sam began his career teaching history in New York City public schools for six years, two of which were at Harbor School in Bushwick, Brooklyn. After earning a Master’s degree in public policy and working on issues of water, development, and climate change in South Asia for five years, Sam came back to run Harbor Foundation’s environmental restoration programs in 2012. He now manages the Billion Oyster Project, a large-scale oyster restoration and education initiative in partnership with New York City schools, universities, non-profits, businesses, and government agencies. BOP is a platform not only for restoring New York Harbor’s most important keystone species, but for reconnecting all New Yorkers, especially public school students, to the water and life of the estuary that surrounds us. Sam is responsible for the BOP Schools program, a five-million dollar National Science Foundation funded educational research initiative to create “restoration based education” and field science curricula for NYC public schools. Sam is also an adjunct at Pace University School of Education where he directs the BOP STEM Collaboratory, a two-year paid fellowship and technical training program for NYC middle school teachers working in Title I schools.
Saving Heat Energy

Every year I begin an energy unit with my third graders with a project on saving energy. When students hear about saving energy, they consider alternative sources of energy, and turning off lights. Of course these are incredibly important concepts, but I wanted to teach my students that one way to save energy is to not lose it in the first place! This lesson can be used to teach about heat energy, conductors, and the importance of insulation. There is also a lot of math involved, both in reading a Celsius thermometer, searching for changes in temperature, and creating a graph. This can be a one time project, or it can be performed multiple times. There is not a lot of set up and clean up, and it can be conducted in any classroom, with any grade.

BACKSTORY
I teach K-5 environmental science in a hydroponic greenhouse rooftop classroom. My students are engaged in hands on activities and are constantly designing experiments and learning how to care for the plants, animals, and equipment surrounding us. The life sciences are easily integrated into our daily activities and studies. I find it more difficult to integrate energy activities. I enjoy the concept of teaching about energy, but the project ideas do not come as easily to me, so I must research lessons. One place I always find amazing projects is a website called Engineering Go For It! I loved the idea of using hot water and finding a way to keep the water insulated.

Working with water is not new for students at Manhattan School for Children, for they attend science class in a 1,400 square foot rooftop hydroponic greenhouse laboratory that serves as their classroom. This greenhouse was the brainchild of two parents at the

Top: MSC students measuring heat-conserving properties of insulating materials.
Photo: Justine Gilbuena
school who envisioned a true learning space for environmental education. This greenhouse is a collaborative project with New York Sun Works, a non profit that aims to build hydroponic learning labs in New York City schools.

The public school is a K-8 community on the Upper West Side of Manhattan. Most of the students live in the neighborhood, although children with severe motor impairments attend from all five boroughs. Manhattan School for Children (MSC) has a large number of occupational, physical, and speech therapists to meet the needs of students with conditions that limit their physical and verbal capabilities.

**PROBLEM**

I was seeking out a way to introduce the concept of energy and how to save it. I was looking for a new way for students to process how to understand the concept of energy, and what it means to not

*During this experiment, young students learn how to read temperature on a Celsius thermometer. Photo: Justine Gilbuena*
waste it. I was also trying to include more design options and opportunities to demonstrate necessary math skills, all with an environmental twist. At the time that I was first seeking out a lesson, I did not have my own classroom as the permits for the greenhouse were still in the works. This meant that I had to travel with a large amount of materials to each classroom, so I needed an easily transportable project.

**SOLUTION**

I searched on *Engineering Go For It*, and adapted a lesson to fit the needs of my students. The lesson links insulation in buildings to conserving heat energy by wrapping materials around bottles of hot water. I wanted my students to learn to read Celsius thermometers. I also required that they write down part of the project in their notebooks, and some on a worksheet. I was seeking a collaborative project. I liked the idea of each student in a group selecting one material to cover the bottle of hot water, along with a control that did not have a covering.

For different classes of third grade students, I have adapted this lesson to fit the needs of the children. For most classes, I start off by linking the need for warmth with the components of ecosystems, which they have all studied. I teach the students how to insert the thermometers into the bottles, record the temperatures, and then wrap newspaper, plastic, and tin foil around three bottles, with one bottle remaining uncovered as a control. I explain that students will have to record the changes in temperature after two intervals of five minutes, and then after 10 minutes, for a total of 20 minutes. A class that has trouble following multistep directions will need additional time to learn how to read the thermometers and record the changes in temperature. A class that needs limited choices will only be given plastic and tin foil to wrap around the bottles. A creative and focused group can be invited to bring in their own materials that they believe will hold in the heat energy.

**SETTING AND RESOURCES**

Materials: bottles and thermometers, 1 per student, plus 1 extra per group; a variety of materials to cover the bottles: cotton cloth, wool, paper, plastic, aluminum foil, fleece, etc. Other useful materials include rubberbands and one stop watch per group.

As aforementioned, although I currently teach in a beautiful hydroponic rooftop greenhouse, this lesson was originally taught in a classroom. Any space with a flat area such as tables or desks, along with access to hot water, is suitable. I used an electric tea kettle in order to make sure that we had very hot water, which I find makes a more dramatic change. I poured the hot water into small heavy bottles over the sink, and then brought the bottles to the tables for the students. Students had one Celsius thermometer per bottle, so that the thermometers would not have to be taken out. This allowed for

“When students hear about saving energy, they consider alternative sources of energy, and turning off lights. Of course these are incredibly important concepts, but I wanted to teach my students that one way to save energy is to not lose it in the first place!”
more accurate temperature readings. If you do not have enough thermometers you will need to allow for time for the readings to change.

OUTCOME
Students always enjoy this lesson, and it has been successful many times in introducing the concept of saving heat energy. There are some aspects that the entire class understands, and other topics that only some students demonstrate comprehension of. All students have shown that they understand that when a bottle stays warm, the energy is saved, and not lost. All students are able to explain that there are some materials that keep the bottle warm and other materials that don’t. When they are introduced to the vocabulary terms “insulators” and “conductors,” most students are able to understand that the materials themselves can be grouped into these two categories. Some students are able to apply their understanding to discuss other materials that may be insulators or conductors. Very few of the students are able to explain what happens to the heat energy if it is lost.

Students utilized important math skills when they demonstrated how to complete a chart, find the “difference” between two numbers, make a graph, and read a Celsius thermometer. For some students the math skills involved made the project more meaningful, and for other students it made this a more daunting lesson.

REFLECTION
The first time I taught this lesson I realized that it was a complex concept to start a unit with, and I felt that I had failed. My students took so much time understanding how to fill out the worksheet that many of them didn’t come to their own understanding of insulators and conductors. I thus decided to do the same project twice. On the first day, I started with explaining how to fill out the worksheet, and I only gave students a control
bottle, a plastic covering, and aluminum foil to cover. In this way, I was able to lessen the anxiety of checking all the bottles, writing them down, and of understanding the science involved. I selected aluminum foil and plastic because I wanted students to understand that metal is a typical conductor and plastic is a typical insulator. Obviously there are more, but these were the main two I wanted my third graders to start off understanding. Then, I introduced the topic again, after students had had more experience with insulators and conductors, and this time students selected materials from choices I laid out on the table. This allowed students to experiment with additional materials, or to put two materials together.

Each time I have taught this lesson I have realized a new way that it can be adapted to different grade levels and subject areas. For younger students, ice water could be kept cold with insulators and conductors, thus limiting exposure to hot water. This could also be a great project for science buddies from different grade levels to work on together. An extension to this lesson could be for students to build an insulated cardboard box house with the materials from this lesson.

What I really love about this lesson is that it pushes students to take the abstract concept of saving energy, and make it tangible. In this way, this project has proven to always succeed. However, more intricate views of energy and ways to conserve it are not as obvious to the students, until ideas are brought up in a discussion. This is an introductory lesson, one that starts students out on the pathway to comprehending energy conservation. For this reason, this lesson should not stand alone if a teacher is serious about instilling a deeper understanding of ways to save energy.

Something else that I like about this lesson is the natural way in which math is included as a necessity for conducting the lesson. This could in many ways be considered a math as opposed to a science lesson. In fact, math teachers could focus more on the charts and graphs, and teach the relationship between mathematics and science.

An aspect that I find rather lacking in this lesson is the creativity of design. There is very little room for students to stray from the directions. I usually try to invoke stu-
dents’ personal ideas into any project, and I am always on the lookout for ways to bring in original designs. For this particular lesson, there are few ways for students to create their own experiments. However, as I mentioned, when I teach it a second time, I allow students to select more materials. If you were to teach this lesson with older students, you might choose to offer students the opportunity to bring in their own materials, in order to have more variety.

Overall, I would highly recommend this lesson to any teacher looking for an introductory lesson to Green STEM. Many times teachers force students to jump in too quickly when studying this abstract concept of energy. Learning what it means to save energy is helpful for students before they can begin to understand electricity and alternative sources of energy.

ADDITIONAL INFORMATION
I try to weave environmental aspects into everything I teach. The Eco-Schools program helps me stay on track. It also helped me to connect this lesson to the concept of ecosystems. I teach my students that the components of an ecosystem are: heat, light, water, living things, and growing substrate. Heat is an essential component, for it allows living things to survive. Temperatures vary according to climate, and living things adapt to these fluctuations. Heat energy is stored in an ecosystem. Students at Manhattan School for Children refer to our greenhouse as an ecosystem, and they can observe how heat is stored and released to the living things.

AHA MOMENT
The first time I taught this lesson I did it in a very disjointed way. Afterwards, I realized that I could use it to actually introduce vocabulary terms that are difficult for third grade students to master. Hands-on projects encourage memory retention, and they serve as shared experiences for future reference. The following year, when the same students are in fourth grade and learning about electricity, I can refer to the saving energy lesson and what they learned about conductors and insulators.

Once created, I find that a Green STEM lesson is easier to carry out over time. The more that I teach this particular lesson, the more I find ways to integrate it into the curriculum. For example, the last time that I taught this lesson, the students had been learning about the components of ecosystems. Since one component of an ecosystem is heat, we tested out different materials to find out what would retain the heat in an ecosystem. Students tested materials that were similar to the materials tested in this lesson. Students made mini ecosystems and measured the temperature inside. Students used metal and plastic containers. Unfortunately, we didn’t find a huge difference in the temperatures so it was a bit of a failed attempt, but the students were very engaged in seeking out insulator/conductor types of containers. I feel that relating the lesson to a previous unit strengthened the students’ understanding.
Saving Heat Energy

**STUDENT OBJECTIVES**
Students will record changes in temperature. Students will categorize materials as insulators or conductors. Students will record the differences in temperature. Students will demonstrate an understanding of heat as a form of energy. Students will learn the vocabulary terms “insulator” and “conductor.” Students will apply their understanding of insulators and conductors to explain how to reduce energy loss. Students will collect data. Students will create line plots based on their data.

**STANDARDS**
CCSS.ELA-Literacy.W.3.8: Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.

CCSS.Math.Content.3.MD.A.1: Tell and write time to the nearest minute and measure time intervals in minutes. Solve word problems involving addition and subtraction of time intervals in minutes; CCSS.Math.Content.3.MD.B.3: Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step “how many more” and “how many less” problems using information presented in scaled bar graphs.

**SCIENCE STANDARDS**
M3.1 Explore and solve problems generated from school, home, and community situations, using concrete objects or manipulative materials when possible; M3.1a Use appropriate scientific tools, such as metric rulers, spring scale, pan balance, graph paper, thermometers [Fahrenheit and Celsius]; PS3.1g Some properties of an object are dependent on the conditions of the present surroundings in which the object exists. For example:• temperature - hot or cold; PS4.1b Energy can be transferred from one place to another; PS4.1c Some materials transfer energy better than others (heat and electricity)

**ENGAGE**
Ask students if they know how to save energy. Students will quickly list ways to turn off lights and electronics, such as televisions and computers. Congratulate students on describing ways to reduce electricity usage. Emphasize that in order to actually save energy, it needs to not be lost in the first place. Pour hot water into a bottle and insert a thermometer with Celsius readings. Tell students that the water has heat energy, and that you can record how much heat energy it has using the thermometer. Explain that for this lesson students will use bottles of hot water, and cover them with various materials to find out which materials save the most energy and do not allow the heat energy to escape.

**EXPLORE**
1. Distribute the charts, bottles with hot water, and thermometers to each group
2. Demonstrate how to take temperature readings of each bottle in Celsius and record on the paper.
3. Explain that students will record the temperature readings before wrapping the bottles, and then afterwards. Tell students that they must follow the correct intervals during a 20 minute period: 5 minutes after the first temperature reading; 5 minutes after that; 10 minutes later.

4. Emphasize that students are searching for the differences in the readings, and explain that this means students will have to compare the readings to the original temperatures.

5. Direct students’ attention to the graph and demonstrate how to create a line plot to indicate the temperature readings for each bottle.

6. Instruct students to write about which material was most successful at preventing heat loss.

EXPLAIN
1. Gather students for a discussion and encourage students to share their findings with each other, while the teacher writes down on chart paper what the students say.

2. Direct students’ attention to the aluminum foil and plastic and tell students that scientists have names for materials that prevent or allow heat loss. Explain that a material that does not allow much energy to escape is called an insulator, and a material that does allow energy to escape is called a conductor. Tell students to talk with a partner to decide if the aluminum foil and plastic are insulators or conductors.

3. Congratulate students on selecting the correct definitions. Tell the students that plastic does not allow as much heat energy to escape, so it is considered a good insulator. Ask students if they have ever held a hot mug of tea or other beverage that was steaming hot, but still comfortable to hold. Emphasize that the clay mug is an insulator, and does not allow much heat energy to escape. Ask students if they have ever put a metal spoon into the mug of hot tea, and if the spoon felt hot. Emphasize that metal is a conductor. Explain that aluminum foil is a metal, and emphasize that metal allows energy to flow from one object to another. Explain that in this situation, the heat energy is flowing from the bottle, to someplace else. Ask students if they can figure out where the energy is flowing. Students will explain that it is flowing from the bottle to the air.

4. Offer students the opportunity to decide if the newspaper and wool are considered insulators or conductors, based on their findings. Encourage students to consider their daily activities, and to generate a list of possible insulators that they normally encounter.

ELABORATE
1. Allow students to conduct the experiment a second time, but with a variety of materials to choose from to wrap the bottles, including adding two materials together. This will encourage students to design more effective insulators, and to test out new ideas.

2. As an alternative, students could attempt to allow the most heat energy to escape, and to thus design effective conductors.

3. As an alternative, students could start with ice water, and design coverings to keep the bottles cold, thus preventing energy transfer with insulators.

4. As an alternative, students could apply their understanding of conserving heat energy to insulation in homes, and build a cardboard dollhouse with walls for rooms made from
the same materials used to cover the bottles in the project. Students would be able to test out the concept of energy conservation as it applies to families trying to insulate their homes to prevent heat loss. Students could put a warm or cold object in the room along with a thermometer, in order to test if the material can keep the room warm or cool and prevent energy transfer.

**EVALUATE**

Students respond to a set of questions that lead to conclusions

- Which material kept the bottle the warmest? Give evidence to explain.
- Is this a material that saves energy or one that allows it to escape?
- An insulator prevents energy transfer from one object to the next, while a conductor allows for energy transfer. Name the insulators and conductor in the experiment.
- If you wanted to keep an icy drink cold, what material would you wrap around it?
- Can you think of any objects in your home that are conductors?
- Can you think of any objects in your home that are insulators?
- Homes have insulation in the walls to prevent energy transfer. What materials do you think would make good insulation?
- Energy is never lost; it is transferred from one place to another. Where does the energy go when a conductor allows the energy to leave?
- Can you think of a time when you might want energy to flow from one object to another, using a conductor?
- Now that you have learned about saving energy, what tips would you give someone who wanted to build a new home?
- Enter your data on the class wikispace page. Make at least two comments to respond to the data entered by other groups.

**VOCABULARY**

Insulator; conductor; heat energy; Celsius

**STEM**

**Science**

Reading a Celsius thermometer; energy conservation

**Technology**

Students post their findings on the class wikispace, and respond to other students’ responses

**Engineering**

Designing materials to act as insulation

**Mathematics**

Subtracting to find the difference
Shakira Provasoli

Shakira Provasoli has been teaching elementary school in New York City and Scarsdale, NY since 1999. Ms. Provasoli has a B.A. and an M.S. Ed from Sarah Lawrence College. Earlier in her career Ms. Provasoli was a classroom teacher, with experience teaching kindergarten through third grade. Ms. Provasoli emphasized science as a means of discovery and understanding the world with all her elementary students, and she sought to bring science to the forefront of her elementary school. Ms Provasoli was part of the first cohort of the NASA Endeavor program, and after receiving her STEM certification, she was offered the position as environmental science teacher in the newly constructed hydroponic greenhouse classroom at her school. For the past four years Ms. Provasoli has integrated hydroponics into the regular science standards, thus teaching a Green STEM curriculum for K-5 students. Ms Provasoli has also written curriculum for New York Sun Works, a non-profit organization that installs hydroponic laboratories in New York City schools. In addition, Ms. Provasoli also teaches a course for New York City educators to earn P credit, sponsored by New York Sun Works.

When she is not teaching or working in her greenhouse, Ms. Provasoli can be found running, reading, or enjoying the natural world with her daughters.
I started my teaching career in Cambridge, New York, a rural community abutting the Vermont border and known for its ample spaces, dairy production, and farmers’ markets. Agriculture surrounded my students then and it wasn’t hard for me to connect students to their food – many lived that connection. Farms with hundreds of acres and heads of cattle were the norm. When I moved to Queens, New York, I discovered that my urban students knew little about food production, and almost none had participated in it. Maspeth High School, my new educational home, is housed in a state-of-the-art building yet possesses a relatively tiny urban footprint. Aside from meters-wide strips of green space, the four-story campus is surrounded by concrete. Growing produce in traditional large flat plots is out of the question.

**BACKSTORY**

Seeking relevancy and discovery for my students, I saw my adopted urban landscape as an inspiring challenge. How could I deliver meaningful lessons about plant biology, ecology, and human impacts without being surrounded by nature? The answer, and a career spark, came with a visit to the American Museum of Natural History (AMNH). The museum, even if best known for its static exhibits (think dioramas and dinosaurs) also houses temporary exhibits that are anything but stale. Instead, they push people to think about some of the most pressing issues of our time. The Our Global Kitchen: Food, Nature, Culture exhibit, designed to showcase the evolution of food production
and food culture, was the perfect entry point for my students to learn about the complex process of bringing food to their plates.

Twenty students from my Green Club joined me for a trip to Manhattan sponsored by ACE, the Alliance for Climate Education. At the AMNH, we enjoyed the diversity of offerings in Our Global Kitchen; we ate an Aztec meal, observed the wonders of artificial selection and genetic engineering, and learned about the scale of engineering required to feed seven billion people. What stood out most, however, greeted us upon entry. Under an array of LED lights, edible vegetables and salad greens overflowed out of futuristic plastic planters arranged in vertical columns stretching from floor to ceiling. Water pumped quietly to the top of each apparatus and dripped from one planter to the next. This, for my students and me, was the link we were looking for: farming made possible in the center of a city. It was also our introduction to Windowfarms, a crowd-sourced enterprise, hydroponic tool kit, and urban farming instrument that had all the ingredients of Green STEM built in.

PROBLEM AND SOLUTION

Back to my problem, “How could I deliver meaningful lessons about plant biology, ecology, and human impacts without being surrounded by nature?” By having students install a four-column Windowfarm in south-facing window space in my classroom, I sought to have students construct a tool that could provide an array of learning opportunities in an ongoing and participatory manner. I wanted them to think of the Windowfarm not as a perfectly refined product, but instead as a laboratory in which they could ask questions, determine answers, and create solutions on their own. My vision was to have students be responsible for all aspects of hydroponic gardening, from the assembly of the vertical garden to the maintenance of its produce. As I teach biology in New York State, I saw the completed Windowfarm as something I could turn to in multiple lessons throughout the school year. The growing plants could be referenced in my photosynthesis lessons, in biochemistry lessons regarding pH, micronutrients, and macronutrients (ex. carbohydrates), in teaching about the differences between autotrophic and heterotrophic nutrition, as a support for my plant tropism lab, and as a part of food web discussions. Perhaps most importantly, it would allow me to teach about agriculture and food production in a place not renowned for farming: New York City. It would make students more accountable for their learning.

Shortly after visiting Global Kitchen, I purchased a four-column Windowfarm online for approximately $400. This included all hydroponic equipment and starter plants grown
in Upstate New York. My Green Club students built the hydroponic system on their own and were responsible for maintaining its produce.

**SETTING AND RESOURCES**

My Green Club students took an afternoon in my classroom to assemble the parts and position the plants. They filled sixteen net cups two-thirds full with clay pellets to serve as soil-free substrate, perfect for hydroponic studies. Displacing the pellets, they placed the roots of four warm microclimate plant varieties at an angle into the net cups. The varieties were: red-veined sorrel, red romaine, watercress, and wildfire lettuce. To construct the hydroponic towers, students placed gaskets around the net cups and placed them into drip planters, which were then stacked four-high in four separate wireframe towers. At the base of the wireframe towers, the students added one liter water reservoirs and outfitted them with reservoir covers. On the covers they placed two-port rubber connectors which they then connected to an underwater in-reservoir tubing assembly. To the first port, students attached flexible tubing leading to air pumps. To the second port, students attached a rigid tube (curved at the top) to bring water and nutrients to the top of the apparatus.

When finished, the students marveled at their completed devices; before them were four hydroponic towers, sixteen planters each with one or two starter plants, two air pumps, and tubes seemingly everywhere! The sleek hydroponic stations looked ready for space travel. Our “lift-off” meant placing the towers near my classroom’s south-facing windows to optimize sunlight and connecting the air pumps to an automatic timer set to pump air into the reservoirs for fifteen minutes out of every hour. Air bubbles in turn pushed water from the reservoir to the top of the hydroponic system. Seeing pockets of water rise up the tubes and subsequently fall and filter through the planters was rewarding for everyone.

Red-veined sorrel, red romaine, watercress, and wildfire lettuce were some of the hydroponic crops grown by Maspeth High School students. Photo: Aaron Bell
Green Club members were responsible for refilling the hydroponic reservoirs, apportioning nutrients into solution, monitoring the growth of the plants, checking the pH of the solution, and best of all, harvesting and sampling the greens! They placed a few plants in a traditional soil-based garden to compare growth using traditional and hydroponic methods.

**OUTCOME**

In just a week, the plants had more than doubled in size, far outpacing their counterparts placed in soil. Each day after, the vertical gardens supplied edible greens for in-lesson snacks and demonstrations, so many in fact that our sun-supplied garden looked healthier and more productive than the LED-bathed Windowfarm that originally inspired my students at the American Museum of Natural History. The planters overflowed with greens, all without soil or outdoor space, a wonderful testimony to local, urban agriculture.

As the academic year drew to a close, Maspeth Green Clubbers harvested all of the plants and prepared a large salad for an end-of-the-year feast. They invited others from the student body to share in their experience. Many students (inside and outside the club) noted how the Windowfarm plants were free of packaging, quite a contrast from the bagged and wilted choices they had seen at the grocery store. One student said, “That salad looks so fresh!” It certainly was, as its colorful components had been cut just minutes before! Even with delayed ripening in transit and modern misting systems in place at supermarket chains, the produce available to most urban children can’t mask distant origins, a rough shipping journey, and inevitable shelf storage. At the picnic, students discussed the food that endured such a path and the food they had grown for themselves. The side-by-side comparison was in front of them. This is the real success in the Windowfarm project: students used their senses to determine that urban-derived food is not just a trendy option – it is better than food from elsewhere. The small footprint, low resource consumption, and high yield of the hydroponic gardening experiment confirmed that urban gardening is a viable complement, or alternative, to traditional gardening.

With the positive results of the Windowfarm, I designed a lab for students to explore experimental design. The hydroponic system is perfectly suited for a controlled experiment lab. It is highly mobile, easy to manipulate, and

“The hydroponic system is perfectly suited for a controlled experiment lab. It is highly mobile, easy to manipulate, and has dozens of potential experimental variables for students to choose from.”
has dozens of potential experimental variables for students to choose from. I look forward to having students design and conduct experiments using the Windowfarm for years to come. With each experiment, I hope students will discover on their own how remarkable locally-sourced, urban agriculture can be.

**REFLECTION**

The Windowfarm plants became renowned in my biology lessons. I pointed to tilting watercress leaves when discussing phototropism. I had students taste the difference between red romaine bought in a plastic bag at a grocery store and that picked from a still-living root system. One student exclaimed, “Wow, it tastes so different! I didn’t expect that!” I love that the Windowfarm’s test subjects are not fleeting or perishable; instead, they are self-replenishing and accessible without a field trip. One day they might demonstrate the carbon-oxygen cycle, the next the importance of producers in a food chain.

The aesthetic value of the Windowfarm columns can’t be overstated. Students from other biology classes at my high school visit my classroom just to see how alive it is, with plants literally reaching to the ceiling. With a minimal countertop footprint, the vertical hydroponic systems nevertheless maximize output, each column delivering a salad or two a week. When a device not only looks cool but delivers tasty produce that makes cafeteria food look fatigued, students can’t help but connect to their subject matter.

The plants facilitated questions and discussions without my prompting, which is a victory for any teacher. Some would ask, “How is that even possible? How can they grow with-
out dirt?” Others would lift the reservoir cover to peek at the tubing assembly to try to determine how water was being pushed against the force of gravity, piquing their interest in engineering design. My favorite question was a disbelieving “You can eat that?” Some students had never before contemplated the production and delivery systems already in place to feed New York City’s population. Few had questioned how those systems can be improved to reduce environmental costs. We live in an age where talking about calorie consumption is just a starting point in a food discussion. The consumption of fossil fuels for fertilizers and transportation, the consumption of water for irrigation, the consumption of open spaces for farmland, and even the consumption of people for labor all have their rightful place in the discussion. The questions born out of that discussion, and the STEM-inspired solutions, will dictate the future health of our citizens and of our planet. The Windowfarm columns were great initiators when it came to exploring the benefits of local, pesticide-free, urban agriculture.

Many teachers are daunted by STEM activities, either finding them too involved or too resource intense. My advice is to pick a project that can incrementally introduce students to science, technology, engineering, and math and that can be reused on an ongoing basis to showcase connections between the four subcategories. The Windowfarm can be the centerpiece for thousands of lessons, preferably hands-on and student-led! Putting it all together and choosing the depth of exploration is the fun part. Students can use math to quantify and depict flow rates, nutrient concentration, light intensity, or growth rates depending on their interest. They can engineer solutions to problems, as my students did when plant roots clogged the drip planters or when pest insects appeared. They can suggest improvements in engineering design, which is how Windowfarms was devised in the first place. In taking part in Green STEM activities with a hydroponic lab, students observe first-hand how innovation is born from technology.

“Some students had never before contemplated the production and delivery systems already in place to feed New York City’s population. Few had questioned how those systems can be improved to reduce environmental costs.”
Hydroponic Gardening

**STUDENT OBJECTIVES**
- SWBAT use engineering design to construct a Windowfarm hydroponic system.
- SWBAT carry out a controlled experiment using the Windowfarm hydroponic system.
- SWBAT use engineering design to create a novel hydroponic system.

**STANDARDS ADDRESSED: CCSS.ELA-LITERACY.WHST.9-10.7**
Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

**ENGAGE**
Capture student attention, activate student prior knowledge, stimulate thinking, raise key questions, etc.

Students will be supplied a leaf of watercress from a grocery-bought plastic bag to consume to start the lesson. After eating it, they will be asked, “How does it taste?” “What steps were taken to get that food to your table?” “What resources must be consumed to grow the plant and deliver it to you?” “What are the drawbacks of the process?”

**EXPLORE**
Allow students to observe, record data, isolate variables, design and plan experiments, create graphs, interpret results, develop hypotheses, and organize their findings.

Students will be split into four teams. Each team will be supplied the parts of a Windowfarm hydroponic garden and four plants. They will be asked what they think the function of each part is. Students will then refer to [www.windowfarms.com](http://www.windowfarms.com) to determine how to assemble their column and to research the basics of hydroponics. Once their columns are assembled, students will be asked to condense into two teams, each with two columns. Each team will be asked to develop a controlled experiment using their devices and prior knowledge from their scientific inquiry unit. Students will be responsible for formulating a question, developing a testable hypothesis, determining the independent, dependent, and controlled variables, and devising procedural steps for data collection and analysis. Students will be given one month to conduct their research. Team members will write individual lab reports in the scientific journal format.

**EXPLAIN**
Introduce laws, models, theories, and vocabulary. Guide students toward coherent generalizations, and help students understand and use scientific vocabulary to explain the results of their explorations.

The teacher will define and demonstrate hydroponics. The teacher will revisit the reactants and products of photosynthesis while introducing plant nutrient acquisition and root biochemistry. The law of conservation of matter will be discussed, as will nitrogen and phospho-
LESSON: HYDROPONIC GARDENING

Hydroponics cycles. The teacher will lead a discussion comparing hydroponic gardening to traditional soil-based gardening. Water delivery and recovery, weight savings, and other benefits of hydroponic gardening will be explored. Students will complete online research to depict the differences between hydroponic and soil-based gardening (ex. Venn diagram).

The teacher will ask, “Why is hydroponic gardening beneficial to urban farmers?” “How can hydroponic gardening reduce resource consumption?”

EXTENSION
Provide students opportunity to apply their knowledge to new domains, raise new questions, and explore new hypotheses. May also include related problems for students to solve

Students will complete independent research and summarize their findings using the scientific journal format. Once completed, students will be asked, “What is a second question that could be explored using your Windowfarm?” After, “what are some flaws of the Windowfarm?” Reservoir size, planter or tower stability, and water or nutrient delivery are all possible answers. Students will be asked, “What changes would you make to the system?” Students will return to their original groups to design a novel system using re-purposed materials (plastic bottles, aluminum cans, cardboard) obtained from the school’s recycling bins. The students will be tasked with creating reservoirs, net cups, and planter cups for a “home-made” hydroponic system. A contest to grow the most biomass in one week will ensue.

Maspeth High School Green Club members received several donated trees from MillionTreesNYC which they planted on their school grounds.

Photo: Aaron Bell
LESSON: HYDROPONIC GARDENING

EVALUATE
Administer formative assessment (although checking for understanding should be done throughout the lesson)

Think-Pair-Share/Exit Card: “Why is hydroponic gardening a useful method in urban farming?”

VOCABULARY
Agriculture, biomass, hydroponic, nutrient solution, nutrient delivery system, soil-based gardening, system, vertical gardening, urban farming.

STEM
Science
Inquiry, conservation of matter, photosynthesis lessons, biochemistry lessons regarding pH, micronutrients and macronutrients, differences between autotrophic and heterotrophic nutrition, plant tropism, food web

Technology
Research, creating various formats to share content, Windowfarm system as an innovation in agriculture

Engineering
Construction of a Windowfarm system, design solutions to problems encountered using vertical hydroponics, such as pest management and system clogs, construction of a self-designed hydroponics system.

Mathematics
Measurement, solving algebraic and geometric problems related to space, growth, population size, etc.
Aaron Bell

Aaron Bell started teaching on 9/11, beginning his career at Cambridge Central School in Upstate New York. There he taught physics and biology for seven years. In his spare time he enjoyed kayaking the famed Battenkill and hiking the forty-six high peaks in the Adirondacks. Aaron lived in Avignon France for a two-year stint. Abroad, he taught English and witnessed the power of government-led sustainability initiatives. Aaron is a founding teacher at the now four-year-old Maspeth High School in Queens. His classroom abounds with life and includes two 330 gallon fish tanks, a turtle tank, a lizard tank, a mouse habitat, and plants everywhere. Copper, once a classroom rabbit, has become Aaron’s home pet. He is committed to empirical science in his Regents Biology and AP Biology classes. Maspeth students have one or two double periods per week dedicated to hands-on lab activities. They have excelled on the Living Environment Regents, already ranking at the top of New York City’s open-enrollment schools. Aaron is proud to serve as the advisor of the Maspeth High School Green Club. In its short existence, Maspeth High School has been awarded three DSNY Golden Apple Awards and honored as an NWF Eco-Schools USA Green Flag school, largely because of the efforts of the Green Club. Aaron continues to journey around the world with his partner Adriana whenever he can, having travelled to four continents and seventeen countries together. Last summer they backpacked South America with a special stop in the Galapagos. Aaron graduated from Union College New York with a Bachelor of Science in Biology and from Stony Brook University with a Master’s in Education. He is the chair of the Maspeth High School science department and also serves as the school’s Sustainability Coordinator. Aaron is proud to be an identical twin.
Gardening - indoors or outdoors - provides countless Green STEM opportunities: mapping out the garden, studying plants and insects, nutrition, decomposition, weather patterns, and charting growth.

Photo: Teri Brennan
Our children will be facing enormous environmental challenges when they reach adulthood, and it is vital that they have a thorough understanding of these complex issues, and the tools to help to solve them. The most important challenge will be access to clean water. Water covers almost 71% of the earth’s surface, yet much of it is contaminated. Every day, 2 million tons of sewage and industrial and agricultural waste are discharged into the world’s waterways, the equivalent of the weight of the entire human population of 6.8 billion people.

Unless there is a global effort to make changes, two-thirds of the world’s population will face water scarcity by 2025. As an educator, it is very important to me that my students understand how critical water conservation and preservation are for life on earth.

**BACKSTORY**

**Demographics**

PS 41 has 791 students, twenty-one percent are students who are non-Hispanic Caucasians, seventeen percent of students receive special education services and two percent are English Language Learners, ELL. Our school has a very strong science program, thanks to the support of our Principal. Currently, I’m one of four science teachers and my role is to focus on environmental issues and sustainability. Incorporating Eco-Schools USA and Green STEM into the curriculum has been a terrific way to cover environmental topics with hands-on problem solving and team work.
In science, the students have been studying solids and liquids; their properties and ways in which they interact. As part of their science enrichment class, I wanted to make the connection between the properties of liquids and our environment. Oil spills are an unfortunate part of human’s use of fossil fuels, and they can have a disastrous effect on ecosystems.

**PROBLEM AND SOLUTION**

I wanted students to understand how their understanding of solids and liquids and the idea of water conservation is connected to real environmental problems, such as oil spills and how they impact entire ecosystems.

The solution was to allow students to devise their own systems that would contain and extract the oil from the water and from wildlife. Students brainstormed, developed plans, and created testable models. Students were able to compare systems from the results that each team gathered.

**MY A-HA MOMENT**

As I combined STEM with environmental topics I found it a terrific way to cover my curriculum, because students were more engaged and learning was more meaningful: hands-on, collaborative and problem-based.

**SETTING AND RESOURCES**

I conducted this lesson in the classroom, which is a science lab, but could easily be modified to be taught in a carpeted classroom or outside. Materials for each team were prepared in advance and placed at each table before the lesson began. For younger students, I limit the amount of supplies to keep the design process focused. After the introduction and review of oil-spills, students moved to their tables to discuss, as a team, how they were going to design a containment system and clean-up system with the available supplies. Since we were using water, I wanted to stress to students that they needed to draw their systems first, before their hands got wet. (Put a container of water in front of children, and there is always at least one student who has their hands in it before they are supposed to start!) It was necessary for me to circulate to each table quickly to hear about their ideas, and make sure that they had their designs completed before testing it. Furthermore, in group work, there usually is a student who likes to dominate the team. It is important that all opinions and ideas are heard, so I recommend mentioning this before students begin.

Materials for this lesson were readily available in my lab. I just needed to purchase the cotton balls.
Supplies for Each Table:

1 clear bin of water/ blue food coloring added
1 piece string
1 container rubber bands
6 Popsicle sticks
1 container of cotton balls 6-8 pieces
1 cup of eye-droppers
1 small paper cup with powdered cocoa 1/4 full
1 small paper cup of cooking oil 1/4 full
1 small cup of Dawn dish soap 1/4 full (given after)
1 empty large cup to put wet cotton balls in
1 feather
Paper towels
Worksheet/clip boards/pencils

OUTCOME

I was impressed with how each team designed different containment systems; some using only string, others a combination of the Popsicle sticks and string, while other teams just used the Popsicle sticks with rubber bands, with varied results.

The next step was to try to remove the oil from the water, which was not as easy as students had expected. They quickly used up all the cotton balls that were allocated to each team. Students tried using eye-droppers to remove the oil, but that was very time consuming. After the Dawn dish liquid was added, students could see how the oil congealed...
together, which made it slightly easier to remove. In the end, students could appreciate how hard it was to remove the oil and there was no easy way to extract it.

Students said they really like the hands-on experiments! Specific to this lesson, students commented and had genuine concern for wildlife that were injured or who perished as the result of the oil spill. This care and concern for the environment made them more eager to solve the problem of containing and removing oil in the water.

**REFLECTION**

One of the biggest challenges in teaching this type of hands-on lesson is TIME! There is not enough after the experiment is over to have each group share their findings with the class. One possible solution is to extend the lesson over two classes, but that ends up cutting into the future curriculum. The best solution I have found to this constant problem is to review the last lesson when I introduce what we are currently going to learn, and make a connection between the two. These types of hands-on lessons take additional time to plan, setup, and manage. However, I have found that students are much more engaged and continue to reflect on the lesson long after we have completed it!

I have created a lesson plan and worksheet template that, over time, has made it significantly easier to transfer or create new lessons. Also with time, I have honed my management skills so that setup, instruction, experimentation, sharing, and clean-up go more smoothly. It takes a couple of learning experiences for the students to get the hang of it, but once they become familiar with the structure and flow they really shine brightly!

*PS 41 students invented various means to try to remove vegetable oil from water and discussed the impact of oil spills on our environment. Photo: Vicki Sando*
Water and Oil Spills

**STUDENT OBJECTIVES**
Students will have an understanding of the causes of oil spills and how they impact water quality and ecosystems. Students will learn how experts try to manage oil spills. Using various supplies, students will learn which materials are more suitable to build a system that contains and removes oil from water. Students will learn the value of teamwork to solve problems.

**ENGAGE**
Students gather on the rug, and the teacher asks, “Does anyone know what an oil spill is?” Have students share what they know about oil spills. If possible, show some photographs of wildlife impaired by oil spills. Ask students “do you think it is hard to remove the oil from the water, off the wildlife? What are some different methods that were used to contain and remove the oil?”

**EXPLORE**
Read: *Oil Spill* by Melvin Berger

**Focus Question:** How can we clean up after an oil spill?

**EXPLAIN**
Now that we know how oil spills can occur and damage the environment, each table will work as a team to design a system to stop the spread of oil in water, and try to remove as much oil as possible. The spill will be a controlled small amount of vegetable oil, which is poured into the water basin. The container of powdered cocoa is added to replicate what oil looks like. Students swirl the mixture with the feather to see how it gets coated with the oil. Students use worksheets (clipboards help prevent worksheets from becoming wet) and discuss how they would design a containment and cleanup system using the available supplies on their tables. After their systems are designed on paper, students proceed to build and test them. Questions to think about: Is the system working? Is it containing the oil in one area? Is most of the oil being removed? How easy or hard is it to remove the oil from the feather? Students evaluate their system on the worksheet. Now give students the small container of Dawn dishwashing soap and have them pour it in the water. What does it do to the oil? Does it make it easier to remove the oil from the water and feather?

**EXTENSION**
Depending on time, have at least one team share their findings with the class. Ask students, “Did any other team build a similar system? Did you have the same or different results? Would you change your system, if you did the experiment again?”

**EVALUATE**
Collect recording sheets and use a grading rubric:

1. Understands the causes of oil spills and how they affect wildlife.

2. Makes a drawing of both their containment and clean-up system, labeling the supplies used.
3. Is able to evaluate how the system worked.
Students will receive a check minus if they don’t understand and complete all tasks, a check if they do comprehend and complete all tasks, and a check plus if they complete all with detail.

**VOCABULARY**
Absorb, boom, contain, Environmental Engineer, float, isolate, oil spill, skimmer, spread, system

**STEM**
**Science**
Properties of matter, cause and effect relationships-human impact on ecosystems, systems, limitations of models

**Technology**
Construction of a water filtration system and containment system

**Engineering**
Construction of a water filtration system and containment system

**Mathematics**
Counting, measurement, comparing results
Oil Spill Solution

Name/Team ______________________________________________________

You are part of a team of engineers who have been given the challenge of first containing, and then cleaning up an oil spill. You have to remove as much as possible.

Draw what your containment system looks like and label what supplies you will use.

Draw your clean-up system and label what supplies you will use.

Check off how your system worked:

<table>
<thead>
<tr>
<th>Water is clear of all oil</th>
<th>A little oil is left in the water</th>
<th>A lot of oil is left in the water</th>
<th>No change, water is the same</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Vicki Sando

Vicki Sando is the Environmental Science Program Developer and Science Enrichment teacher at Public School 41, a K-5 grammar school located in Greenwich Village, New York City. In 2003, she initiated the school garden program and in 2006, she founded The GELL Project, a Green Roof Environmental Literacy Laboratory that opened to students in 2012. Working with various industry leaders, Ms. Sando fosters partnerships, develops curricula, and teaches students “farm to table” agriculture, green building technologies, and wildlife conservation.

Under Ms. Sando’s leadership, The GELL Project has received numerous grants and awards, including notable mention from The New York State Green Ribbon Schools Program in 2012, inclusion in Carrot City- Designing for Urban Agriculture, an international traveling exhibit, and the National Wildlife Federation Eco-Schools Bronze Award and grant in 2011. Currently, Ms. Sando initiated and is the project leader for a K-12 Green Roof Curriculum Guide in partnership with fellow NYC Eco-Schools MS 442 and The Bronx Design & Construction Academy. It is slated for publication in the fall of 2016. The group recently launched a website www.greenroofeducation.org. Vicki’s greatest accomplishment is inspiring children to reconnect with nature.
School-Wide Sustainability

Here at PS 154Q we believe that educating the whole community is essential in order for us to meet our sustainability goals. In order to achieve our goal we rely on educating our students through Green STEM, identifying sustainability issues within our school, collecting and analyzing data, and discussing and planning student projects to tackle each issue. Our students range from Pre-kindergarten to fifth grade and we also house a District 75 school (that serves students with special needs) within our building. Together with the help of NWF’s Eco-Schools USA, GrowNYC’s Recycling Champions Program, the Recyclarium, and most importantly PS 154Q’s own Green Team, we have involved students, teachers, school staff, cafeteria workers, custodians and administrators in our efforts to become green by implementing a recycling program, energy conservation initiatives, indoor gardening and sustainability education curriculum integration. Our goal is to have sustainability become part of our students’ everyday routine and lives. Our recycling efforts are quite strong; we have started working on gardening goals, reaching out to our local Assemblywoman for funds for a possible green roof. Our next goal is to further our energy conservation efforts by exploring the possibility of installing solar panels.

Top: PS 154 students conducting water experiments. Photos: Deise Kenny
BACKSTORY

PS 154Q houses a student population of approximately 650 students of which over 80 percent are from non-Caucasian ethnic groups. Twenty percent of our students are English Language Learners (ELL) and a little over 14 percent receive special education services. As a Title I school, 80 percent of our students qualify for free or reduced lunch. We have almost an even split of boys and girls, with girls taking a slight lead, and we have a dynamic attendance rate at 95 percent. It was a challenge to get many of the adults to buy into our sustainability efforts. They had many concerns, but we found that having meaningful conversations with each of the groups, i.e. staff, custodians, administration, increased support, as did seeing the numerous awards, grants, and media attention we were receiving for our work.

Our Green Team is made up of fourth and fifth grade students, the Sustainability Coordinator, teachers, administrators and the custodial engineer. Our first goal was to focus on recycling. The team met, discussed, created a school-wide plan and implemented that plan, providing labeled bins for mixed paper, plastic and metal, and trash for every room. We created a school film and presented an assembly for every student and staff to launch our recycling initiative. The Green Team also worked with the Recyclarium and GrowNYC’s Recycling Champions Program to reinforce recycling in every room, including the cafeteria. Green Team members trained classroom Green Team liaisons to support recycling and energy conservation in every room. In 2014, the Green Team launched a new system of “spot-checks” and displayed classroom “green grades” based on a student-created rubric. This allowed students to collect, track and analyze our school’s “going green” data and plan for different ways to further support our classes. The Recycling Champions Program has been very involved with our school for two years, providing workshops for all students and all school staff on best recycling practices, helping us launch a cafeteria recycling system, and providing us with new paper recycling boxes. PS 154 participated in and won Recycling Champions’ recycling contest. Students weighed and tracked all trash and recyclables from our school once a week, starting with a baseline in hopes of increasing recycling and decreasing waste. We increased our recycling rate by 268 percent and reduced our trash disposal rate by 46 percent.

OUTCOMES

With the help of a parent volunteer and the Green Team’s fundraising efforts, we have started our gardening initiatives. We have purchased several Earth Boxes and started planting, observing and using our indoor gardens for teaching curriculum. As part of our “Big Lift” contest win, we received a raised flower bed garden and outdoor planter, which we use to involve students in planting, caring for flowers, and as an outdoor classroom. We have also

“I want my school to be a completely sustainable school, for students and teachers alike to not only understand the importance of sustainability, but also to be willing to change their everyday habits in order to bring about positive change within their school environment.”
applied for and received a $2,000 garden grant through Grow to Learn, which enabled us to purchase compost bins, rain barrels, gardening tools and additional raised beds. We would like to continue to expand our gardens. As part of our Earth Day celebration, our school also participates in a school-wide Earth Week, in which each grade focuses on one aspect of sustainability including energy and water conservation and recycling. Our teachers link our curriculum to this theme and provide students with Common Core Learning Standards based activities that focus on sustainability.

In 2014, PS 154 was the second school in NYC to earn NWF Eco-School’s Green Flag award. Our school worked on developing our own Eco-Code and conducted environmental audits, reviewed data, established and are carrying out action plans. Our school is currently working on the following Eco-Schools Pathways: Healthy Schools (conducting Hazardous Materials and Indoor Air Quality audits, sharing concerns of using air fresheners within classrooms with teachers and students, and encouraging use of green cleaning products in every room, including supplies lists), Consumption and Waste (working with Grow NYC Recycling Champions to plan, create and implement recycling measures school wide, as well as PS 255-District 75 school within our building), Healthy Living (promoting healthy habits throughout our school by increasing physical activity through the curriculum and exercise integration through Move To Improve, Cookshop and recess), Sustainable Foods (encouraging balanced, healthy and nutritious eating habits through integration of the Cookshop curriculum, encouraging healthy snacks, and healthy snack sales in school (we also discussed adopting healthier lunch options for school) and Energy Conservation (entering the Green Cup Energy Challenge, affixing “turn lights off” signs in every room, checking and assessing energy use throughout the building, entering the Energy Efficiency Calendar Contest).

**REFLECTION**

One thing I have learned from being a teacher in a school that’s embraced sustainability is that my passion for the field has the power to inspire others. It’s extremely rewarding to see and know that my efforts have catalyzed positive change within and beyond my school community. My advice would be to dream big, but start small. I wanted, and still want, my school to be a completely sustainable
school, for students and teachers alike to not only understand the importance of sustainability, but also to be willing to change their everyday habits in order to bring about positive change within their school environment.

Teachers need to choose something that would be easy to implement within their school, and yet have a big impact. I started with recycling, collecting baseline data, analyzing these results in order to begin to bring about change by creating and installing labeled bins for trash, paper and plastic in each classroom. Of course in order for these changes to “stick,” teachers must educate all members of the school community about the issue. We accomplished this in various ways including conducting recycling assemblies, teaching through games and speakers, as well as entering different contests to instill a sense of competition and pride throughout our school. We also enlisted the help and support of experts and organizations in our community including NWF. Entering contests is always a good way to motivate students, ensure high levels of participation and provide opportunities to highlight and celebrate successes.

I realized that Green STEM was powerful when students got so involved in researching and implementing our recycling program that they began educating the teachers and holding the staff accountable. They were totally invested in the process. In fact, a group of former Green Team members who had moved to a junior high school, convinced their principal to set up a meeting with PS154Q’s new Green Team so that their school could learn how they could start sustainability initiatives too. We knew then that what our students had learned at PS154Q had stayed with them.

Our main goal is to continue our sustainability efforts through the integration of Green STEM across grades and curriculum; increasing involvement of the entire community by holding open Green Team meetings monthly and inviting “green” guest speakers. We also want to continue to work with NWF’s Eco-Schools USA program to fulfill additional sustainability Pathways. In 2014-15, we participated in NWF’s U.S.-Taiwan Sustainable Schools Partnership Program, to provide collaborative educational experiences for students from diverse cultures through the use of technology, with the goal of sharing and increasing our sustainability efforts.

“I realized that Green STEM was powerful when students got so involved in researching and implementing our recycling program that they began educating the teachers and holding the staff accountable”
Lesson

Water
This unit introduces students to the importance of water, which easily lends itself to teaching about fresh water cycles, uses/consumption by humans and wildlife, habitats and ecosystems, water pollution, climate change and extreme weather impacts on fresh water sources, and the need for water conservation.

OBJECTIVES
In order to assess students at the end of a FOSS Water science unit in which students are involved in hands-on problem-based investigations, students are asked to complete an independent or partner project in order to demonstrate their learning. The following can be adapted to different grade levels and be used as a model for different units.

OVERVIEW OF UNIT/BIG IDEAS/EVIDENCE OF LEARNING:
By the conclusion of this unit, students should self assess by ensuring that they state the following:

- I can observe, investigate and describe the physical properties of water: color, texture, odor, sound, changes in shape, changes in the amount of space occupied by water, volume and mass.
- I can describe the water cycle, and how water is recycled by natural processes on earth (precipitation, evaporation, condensation).
- I can predict, and observe substances and their ability to mix with water.
- I can test and observe whether objects sink or float and reasons for it.
- I can explore and describe the transformation of matter from one state to another, and how heat energy affects this change.

STANDARDS AND BENCHMARKS ADDRESSED
Science:
- Observe, describe, and explore the physical properties of water: PS 3.1a,b PS 3.1c,d,e
  - Color, texture, odor, sound
  - Changes in shape
  - Changes in the amount of space occupied (compare using containers of different shapes and sizes).
  - Volume, mass (weight)
- Explore how different factors affect evaporation. PS 2.1c PS 3.2a,b,c LE 6.2c
- Describe the Water Cycle. PS 2.1c LE 6.2c
- Test objects to determine whether they sink or float: PS 3.1e,f
  - Different materials (plastic, rubber etc.)
  - Different shapes
  - Boat design
- Predict, observe, and examine different substances to determine their ability to mix with water (e.g., oil, water; sugar, water; wooden block, water). PS 3.1e,f PS 3.2c
- Examine and describe the transformation of matter from one state to another, e.g., solid water (ice) to liquid (water) to gas (water vapor). PS 3.2 a,b
- Water is recycled by natural processes on earth.
• Precipitation
• Evaporation PS 3.2 a,b
• Predict and investigate the effect of heat energy on objects and materials. (e.g., change in temperature, melting, evaporation) PS 2.1c PS 3.2b,c PS 4.1d
• Describe the physical changes of materials. PS 3.2c

COMMON CORE STATE STANDARDS ELA:
• RI. 4.3 Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.
• RI.4.4 Determine the meaning of general academic and domain specific words or phrases in a text relevant to a grade 4 topic or subject area.
• W. 4.8 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources.

ENGAGE
Capture student’s attention, activate student prior knowledge, stimulate thinking, and raise key questions

1. Students are introduced to this topic by sharing what they know about water. They work in groups to discuss uses, importance, places where water can be found and known properties of water, students then draw a group circle map or any other thinking map of choice (including a frame of reference) to record their information. Students display their circle map around the class and share what they know through a class gallery walk. As students walk around to observe each group’s thinking map, writing reflective comments on Post-Its for different groups.

2. Next students conduct their first series of hands-on water experiments during this first investigation, to begin to learn about different properties of water. Students conduct group experiments, recording data in their science journals.

☆ Investigation 1 Experiments/lessons/activities:
Looking at Water, Surface Tension, Water on a Slope
- What happens when water gets spilled, splashed, or dropped on something?
- Does water do the same thing on all surfaces? What shape does water make on a flat surface?
- Why does water form a dome on flat surfaces?
- How can you change the surface tension of plain water?
- Does water always flow downhill?
- How does changing the slope or quantity of water change the speed at which it flows downhill?

EXPLORE
Allow students to observe, record data, isolate variables, design and plan experiments, create graphs, interpret results, develop hypothesis, and organize their findings.

Students conduct a series of water experiments, collecting data, researching information, creating “thinking maps” to record their thoughts, and using these maps to write short responses.
Investigation 2:
Hot Water, Cold Water: Build a Thermometer, Sinking and Floating Water, Water as Ice
- What happens to water when it is heated? What happens to water when it is cooled?
- Is hot water denser or less dense than room-temperature water?
- Is cold water denser or less dense than room-temperature water?
- What happens to water when it freezes? What happens to ice when it is heated?
- How do the masses of equal volumes of ice and water compare?

Investigation 3:
Water Vapor: Evaporation, Evaporation Locations, Surface Area, Condensation
- What happens when two paper towels are allowed to dry, one cup with a lid and the other in an open cup?
- What effect does air temperature have on evaporation?
- What effect does surface area have on the rate of evaporation?
- What happens when the surface area of an object or material is cooler than the air surrounding it?

Investigation 4:
Waterworks: Water in Earth Materials, Waterwheels, Water From Home, Choosing Your Own Investigation
- What happens when you pour water through different earth materials?
- How does a waterwheel work? What is the best design for a waterwheel that will efficiently lift objects?
- What are some of the properties of water that affect its quality?
- What types of water can be used for different purposes?
- How can we choose our own water question to research and investigate? (Water Project)

EXPLAIN
Introduce laws, models, theories and vocabulary. Guide students toward coherent generalizations and help them understand and use scientific vocabulary to explain the results of their explorations.

Students will have a chance to learn vocabulary throughout the unit; there are many ways to incorporate vocabulary into daily activities. Teacher should have science vocabulary word walls or charts with definitions and picture support. Students can also watch videos such as Brain Pop to reinforce concepts learned in class activities. One great resource to ensure all students are given an equal opportunity to learn, and for differentiation ideas, is the CAST website.

Teachers can also have students create vocabulary dictionaries.

WATER CYCLE DICTIONARY
During the Water Cycle Unit you will complete a Water Cycle Science Dictionary. You will need to choose, define and draw an illustration for 20 water cycle words. Your dictionary must include:
- Cover with illustrations
- Written information must be accurate, neat and detailed
- Illustrations must be clear, colored, and science related
- All words must be spelled and defined correctly
- Table of contents must be in alphabetical order
- All pages must be numbered
- At least 20 words are included

**WATER CYCLE ASSIGNMENT**

**Student Directions:**
Use all the information you have learned from reading, SmartBoard lessons, hands-on experiments, Water Cycle Jump Song, and class discussions about the Water Cycle to:

1. Organize the Water Cycle information in a thinking map of your choice. Be sure to include a frame of reference.

2. Draw a detailed, labeled diagram of the water cycle, or design a model of the water cycle.

3. Use the information from steps one and two to answer the following question: “How does the sun help water to cycle through the earth? Explain each step, be sure to include science academic vocabulary learned in class.”

**HERE ARE THE COMMON CORE LEARNING STANDARDS THAT YOU WILL BE ADDRESSING:**

**RI. 4.3** Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.

**RI.4.4** Determine the meaning of general academic and domain specific words or phrases in a text relevant to a grade 4 topic or subject area.

**W. 4.8** Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources.

**Here is the rubric that will be used to assess your work:**

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Common Core Learning Standards for Student Performance- for each standard consider:</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Demonstrates performance that consistently exceeds expectations, as described in the targeted Common Core Learning Standards.</td>
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</table>
ELABORATE
Provide students with multiple opportunities to design and redesign, collect more data, leading to more valid conclusions.

WATER Project
As part of our end of unit assessment you will be required to complete a project. You can choose from a variety of topics listed below to show what you have learned about this topic.

You may create a PowerPoint presentation, a video presentation, a detailed poster, an informational book or you may choose another format (if choosing a different format, you must get teacher’s approval first)

Below is the rubric that will be used to grade this project. You can earn a total of 100 possible points. Please be aware that the Project is due on ___.

• Investigate what happens when different materials float in salt water compared with one other liquid. What observations can you make about the density of different materials compared to each liquid? How does learning about this information help solve real-life problems?
• Investigate what irrigation is and where it is used around the world. Using your new knowledge, create an irrigation (model, computer model, detailed drawing) system that would help a local garden in your community to conserve water.
• Further research and investigate waterwheels. Design a new type of waterwheel that can use the power of water to make life (think of a farm job/task) easier for farmers who live near water sources that would power a waterwheel.
• Design a new type of machine that uses water to do work. Think of a real-life problem and explain how using water for power would be a practical, accessible and economical solution.
• Investigate and research where the water in the school’s drinking fountain comes from. Design a model to demonstrate the path water must take from the original source to the site of your school. Explain why learning this information is important when thinking about water conservation and water contamination.
• Investigate and explore the different soil types you have within your community. Create a model to illustrate what happens when water is added to each soil sample, and how water pollution affects the soil and the community at large.
• Investigate different types of water pollutants within your community. Design and conduct an experiment to illustrate the effects of different pollutants on local plant life. Describe how you would share your findings with your community.
• Investigate, research and describe the types of chemicals that are added to make drinking water safe. Create a homemade water-purifying model that people could use without the use of chemicals.
### LESSON: WATER

#### Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Explanation</th>
<th>Possible Points Awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Student includes a creative and interesting title of project.</td>
<td>5</td>
</tr>
<tr>
<td>Name and Class</td>
<td>Student includes his/her name and class on the bottom right of project.</td>
<td>10</td>
</tr>
<tr>
<td>Due Date</td>
<td>Project is handed in on time, fully completed.</td>
<td>10</td>
</tr>
<tr>
<td>Question</td>
<td>The question student investigated is clearly displayed.</td>
<td>15</td>
</tr>
<tr>
<td>Materials/References</td>
<td>A list of materials used and all the references (books, websites), or information used is included (bibliography).</td>
<td>15</td>
</tr>
<tr>
<td>Procedure/Steps</td>
<td>A list of steps or procedure student used to answer the question is included.</td>
<td>15</td>
</tr>
<tr>
<td>Information Learned and Illustrations</td>
<td>Student answers the project question in his/her own words and is detailed using information learned. Creative illustrations are included.</td>
<td>30</td>
</tr>
</tbody>
</table>

### EVALUATE

Administer formative assessment (although checking for understanding should be done throughout the lesson)

#### Great Lakes Ecosystem

**Common Core Learning Standards Addressed:**

- **RI.4.1** Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.

- **RI.4.4** Determine the meaning of general academic and domain specific words or phrases in a text relevant to a grade 4 topic or subject area.

- **W.4.4** Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience.

Read the *New York State Conservationist for Kids: The Great Lakes*

Use the text and illustrations to help you answer one of the following (your answer should include texts, illustrations, and labels):

1. The Great Lakes Ecosystem includes watershed and basins. What is the difference between watersheds and basins? How can we determine which one of New York State’s basins we live in? Describe the ways in which people depend on the Great Lake Basins to meet their daily needs.
2. Describe the ecosystem of the Great Lakes. What is an environmental steward and why is it important for all of us to become one? Describe some of the responsibilities an environmental steward needs to think about.

3. What are invasive species? How can invasive species affect an ecosystem? Describe ways we can determine whether a species is a “pal” or a “pest”.

4. What are environmental “pests” and how can they affect the land and watershed they live in? Describe ways we can assess and manage pests.

Rubric/Checklist:

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PART I: BACKGROUND TEXT

Oceans of Trash

Jumbo patches of junk floating in the world’s oceans cause problems for humans, wildlife, and planet Earth

By Dante A. Ciampaglia

Litter isn’t just a problem in local parks and on sidewalks. It’s also threatening the health of the Earth’s oceans.

According a report released by the United Nations (UN), our oceans are filling up with trash. The garbage gets into the oceans when people litter. Some boaters and beachgoers throw their trash directly into the water.

Trash also gets thrown into rivers that flow into oceans. In fact, most ocean trash comes from rivers. In Australia, for example, 80 percent of ocean trash comes from waterways far from the sea.

The biggest concern about ocean trash is that most of it is plastic. In some places, nearly 80 percent of the ocean trash that has been collected is made of plastic, according to the UN report.

Plastic can take up to 1,000 years to biodegrade, or break down into smaller parts, once it’s thrown away. So all of the plastic that ends up in the ocean sticks around for a really long time. These plastic products get caught in ocean currents and end up in large “garbage patches” in the water. One of these garbage patches is about the size of Texas, according to scientists.

Danger to All

People rarely see these garbage patches because they are created in areas of the ocean far away from land. But they pose a big problem for both humans and wildlife.

Plastic and other junk that ends up in the ocean can wash up on beaches. This can be harmful to birds and other animals that live on the shore. Seagulls are one example. If plastic gets mixed in with the food that these birds eat, it can hurt their stomachs.

Humans can be affected by beach trash as well. Some plastic objects can have sharp or jagged edges. People who walk barefoot on the beach could cut themselves on trash hidden in the sand. Also, trash can carry germs that make people sick.
Plastic can be deadly for animals that live in the ocean. For example, turtles and seals think plastic bags floating in the ocean are jellyfish. The turtles and seals swallow the bags. That can cause the animals to choke, drown, or starve.

**How to Help**
Without urgent action, the UN says in its report, the ocean trash problem will only get worse. The report suggests several ways to address the problem. These solutions include better enforcement of littering laws and creation of programs to raise awareness of the problem. What can individuals do to solve this problem? They can drink from reusable water bottles. They can use cloth grocery bags instead of plastic ones. People can also volunteer with groups that clean up beaches and rivers.

One of the largest volunteer groups is Ocean Conservancy. In 2008, 400,000 Ocean Conservancy volunteers collected 6.8 million pounds of trash from beaches. By doing that, the volunteers kept the trash from getting into the oceans.

The problem of ocean trash “is entirely preventable,” Ocean Conservancy spokesman Tom McCann told the news organization CNN. “It’s something we can solve ourselves.”

**PART II: USING AND ANALYZING DATA**
Researchers can collect and analyze data. Below is a chart of the estimated amount of trash in the ocean near different locations and the amount of pollution around each location.

**Estimated Size of Ocean Trash Patch**

<table>
<thead>
<tr>
<th>Location</th>
<th>Pollution</th>
<th>Estimated Size of Trash Patch in the Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia (urban)</td>
<td>High</td>
<td>4,000,000 square miles</td>
</tr>
<tr>
<td>New York (urban)</td>
<td>High</td>
<td>5,000,000 square miles</td>
</tr>
<tr>
<td>Hawaii (suburban)</td>
<td>Moderate</td>
<td>1,000,000 square miles</td>
</tr>
<tr>
<td>Alaska (rural)</td>
<td>Low</td>
<td>250,000 square miles</td>
</tr>
</tbody>
</table>
**Question 1: Represent the Data**
Using the information from the chart above, complete the bar graph below.

![Estimated Size of Ocean Trash Patch](image)

**Question 2 (A/B): Analyze Data**
Using the data from the *Estimated Size of Ocean Trash Patch* chart and the information from *An Ocean of Trash*, describe what is happening to the health of the ocean in different areas of the globe.

Based on the chart and graph, how does location (country and type of community) and amount of pollution affect the size of the trash patch in the ocean?

**e)** What specific evidence supports your description? Give examples from the chart and graph as well as the passage to support your thinking.
PART III: SYNTHESIZING TEXT & DATA TO CONSTRUCT RESPONSES
Question 3: Construct Explanations
What conclusion can you make about how pollution created by people on land affects the ocean and the health of animals and people? Be sure to use evidence from reading An Ocean of Trash and the chart/graph on your answer.

PART IV: ASKING QUESTIONS: IDENTIFIES TESTABLE QUESTIONS
Question 4 (A/B): Identifies Testable and Non-Testable Questions
Scientists all over the world are trying to further research the problem of pollution and trash in the ocean. They need to create experiments to figure out how ocean pollution affects animals and people and how to solve this problem.

In order for a question to be considered testable, scientists need to design and conduct an actual experiment in order to answer the question. A non-testable question can be answered without conducting an experiment; it can be answered by simply counting, measuring or reading about it.

Below are four researched questions, some are testable questions and some are non-testable questions.

**Question 4a: Identify Testable Question**
Circle one testable question you think scientist should investigate.

a) How much trash is currently in each area of the ocean?
b) How does the amount of trash in each area affect the ocean animals living in that area? 
c) How far away from each country and community are ocean trash patches?
d) How can we use technology such as “robotic ocean sweepers” to clean up the ocean trash pollution?

**Question 4b: Identify Non-Testable Question**
Choose one question above that does not need to be tested using an actual experiment. List the letter of the question you feel is not a testable question: __________

Explain your reasoning as to why you would NOT need to design an experiment to answer this question:
PART V: CONSTRUCTING EXPLANATIONS: FORMULATES HYPOTHESIS

Question 5: Formulates Hypothesis

Scientists often come up with a hypothesis (what they think the answers may be) to the questions they would like to investigate based on the information that they know.

- Write a hypothesis for the testable Question 4a based on the text, chart, and graph you read.
- Use information from the text, chart, and graph to help you explain your thinking.

VOCABULARY

absorb, algae, bead, blade, condensation, condense, contract, cycle, denser, dissolve, dome, drain, earth materials, evaporate, evaporation, expand, flash flood, float, flow, freeze, gas, glacier, gravity, ice, iceberg, less dense, liquid, matter, melt, molecule, property, seriate, shaft, sink, slope, soak, solid, storm surge, surface area, surface tension, thermometer, water, water cycle, water quality, water vapor

STEM

Science
Reading charts and graphs, pollution, water, science and engineering practices, aquatic ecosystems, watershed

Technology
Research local issues related to watershed health and pollution, locate chemicals found in local waterways as reported by city water department

Engineering
Design a new type of machine that uses water to do work and is used to solve a real life problem

Mathematics
Reading charts and graphs, estimation
Deise Kenny

Mrs. Deise Kenny is currently a fifth grade science and social studies teacher and Data Specialist in a NYC DOE school, PS 154, in Fresh Meadows, Queens with degrees in science education and geology. She is a Common Core Fellow - science specialist - and worked on reviewing the city’s educational materials in order to assess alignment to Common Core standards and science standards. She also helped to create New York City DOE’s fourth grade Measures Of Student Learning (MOSL) standards, and write unit tasks for the city’s Common Core library. She is part of PS 154’s science and social studies vertical team, leads the school’s science and social studies task force, MOSL Committee, and teacher leaders. She is her school’s Sustainability Coordinator - working with the student Green Team to develop school-wide recycling and energy conservation practices and also helped the school become a Move-to-Improve All-Star school. Her efforts and collaborations with students and staff have helped PS 154 win numerous awards and contests including GrowNYC’s “Big Lift” recycling contest and NWF Eco Schools’ Green Flag award. This has garnered positive media attention for the school and resulted in the school being featured on the NYC DOE Sustainability Initiative website. Mrs. Kenny has spent most of her teaching career as an elementary upper grade science teacher, and believes in a fun, hands-on rigorous inquiry approach to teaching and connecting learning to real life experiences. She also serves as a Scholastic National Advisory Board member.
Second grade students at PS 29 Brooklyn learn about the importance of pollination, and display insect, beehive, and pollen specimens from their science classroom.

Photo: Cynthia Carris
A student stands by a rainwater harvesting tank and holds a tray of greens in NY Sun Works' hydroponic greenhouse at Green Flag Eco-School Manhattan School for Children. Photo: Courtesy of NY Sun Works
Eco-Schools is an internationally acclaimed program that provides a framework to help educators integrate sustainability principles throughout their schools and curriculum.

To learn more and to register your school for free visit [www.eco-schoolsusa.org](http://www.eco-schoolsusa.org)