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INSTRUCTIONAL PRACTICE

Bringing the Tools of Big Science to Bear on Local Environmental Challenges*

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Abstract

We describe an interactive collaborative environmental education project that makes advanced laboratory facilities at Brookhaven National Laboratory accessible for one-year or multi-year science projects for the high school level. Cyber-enabled Environmental Science (CEES) utilizes web conferencing software to bring multi-disciplinary, inquiry-based research opportunities to Districts who wish to participate. CEES serves as a model to show how students involved in distance learning and experimentation can engage in exciting, state-of-the-art research to that enhances their skills for future Science, Technology, Engineering, and Math (STEM) careers. High school research opportunities through CEES support all seven New York State Standards for mathematics, science and technology (MST), Common Core and 12 of the National Geography Standards.

Keywords: Education, science, environment, synchrotron, internet

Program Background

Brookhaven National Laboratory (BNL) has developed a high school research program in Cyber-enabled Environmental Science (CEES). Our mission is to develop individual expertise in basic and applied energy science, environmental science, science education, and workforce development to prepare students and teachers for the challenges of the 21st Century. The learning experiences of both students and teachers supported by this program are important in several ways. First, the program will increase awareness of the technologies, methodologies, and interdisciplinary nature of energy, environmental science, and research. Second, it will stimulate and maintain a diverse "pathway" to enhance the student's skills for future careers in science, technology, engineering, and mathematics (STEM). Finally, it will afford students interested in other careers such as industry, laws, government, and education

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a sound global outlook on environmental and energy problems we face as an international community.

CEES utilizes web-conferencing platforms to bring unique technology and research from the National Laboratories into the classroom. It is ideal for high-school courses since it encompasses a variety of science disciplines and technologies that integrate well with history, politics, and economics. High-school research opportunities through CEES promote scientific literacy and science as a process by offering access to science, regardless of age, gender, culture, or ethnic background, through collaboration with the National Laboratory as outlined in the National Science Education Standards. It also addresses twelve of the National Geography Standards.

Table 1.
Summary of interactions with schools and teachers at various locations. The color code identifies schools on Long Island, NY (green), New York City (pink), other states (blue), and foreign (yellow).

• Sayville	New School
• Islip	Kingsborough CC
• Bellport	Harbor School
• William Floyd	River Project
• Longwood	
• South Shore	Washington Math Science Technology Public Charter School, Washington, D.C.
• Westhampton	Southern U, New Orleans
• Syosset	
• Kings Park	
• Southampton	Pisa, Italy
• Patchogue	KFK, Budapest
• Comsewogue	MGIS, Ahmedabad, India
	Hyderabad, India
	Ste. Maxime, France
	Craponne, France

Not only has the CEES program been successful in the Long Island schools. But it has been favorably received by ones in Washington, DC, and New Orleans, LA. Importantly, while our program allowed local students to work with the equipment at Brookhaven, establishing it via the Internet allows students too young to work in experimental facilities to see research in progress and to talk directly to the scientists. This is an important advantage; the earlier we can engage students' interest in science, the more likely they will become scientists themselves. Furthermore, visiting the laboratory presents scheduling problems and time-consuming bus rides; learning via the Internet eliminates these drawbacks because we are able to confer directly with the people in the individual classrooms and so avoid this problem. In addition, using the Internet also opens our researches to the world so that we can work with schools and teachers in Europe, Asia, and elsewhere.

As a first approach, we chose to study topics germane to ecosystems worldwide. One universal problem relates to the fate and transport of metals in site-specific ecosystems. The metal-related environmental problems menacing the tri-state region of New York, New Jersey, and Connecticut are similar to many urban areas around the world, not only to those sited in coastal areas, but to developments located on the banks of rivers, streams, and lakes. Thus, the concepts discussed here are modifiable and applicable to different types of environmental problems.

The goal of the study on which this topic is founded is to conduct a broad-scale-screening of heavy-metal uptake by mussels and oysters from local embayment's and tidal creeks since they are an excellent indicator of environmental conditions related to water quality and to toxic compounds circulating in the aquatic environment. Concomitant investigations of soils, sediments, water, and biota will aid in defining the fate and transport of metals in Long Island's ecosystems.

This topic is a natural for us since our location on Long Island places us in close proximity to four major estuaries: Long Island Sound, South Shore Estuary Reserve, Peconic Estuary, and the lower Hudson Estuary. Furthermore, heavily populated urban and suburban-regions surrounding these estuaries, exposing them to impacts from human activities.

Program Components

1. Recruiting Schools.

We recruited schools and teachers for the CEES through science-education programs run by BNL's Office of Educational Programs. The teachers, from varied backgrounds, teach courses with different objectives. The environmental field demands expertise and interest in all the STEM fields, and hence, effectively can engage teachers with different approaches to teaching.

2. Student Levels

Students of all ages and aptitude levels are interested in environmental topics. The CEES program offers mentoring and academic engagement to advanced placement students and to students with typical course loads. Web –based conferencing is an essential component of both interactions.

3. Site Selection

The sites investigated are chosen in collaborations between BNL's participants and the teachers. We try to arrange selections and topics covering experiments and collections that are convenient to the locations of individual schools, yet that are relevant to a broad understanding of the regional environment.

4. Students' Collection of Samples in the Field

Students who participated in this project gathered bivalves from their designated study sites and prepared them for laboratory analysis by separating tissue and shell. As they collected their biological samples they also collected sediments from the areas where the bivalves were anchored. Our field protocols and experiences support curriculum content and hands-on techniques that are useful in introducing course content covered in their earth science, biology, chemistry, physics, and environmental science classes. By collecting samples in the field, students are enabled and encouraged to take ownership of the project, so spiking their interest in the laboratory work and supporting their drawing satisfying conclusions from examining their samples and discussing their views.

5. School Laboratory Work

Students handled the initial preparation of bivalve shells, sediments, and soft tissues themselves. Preparing the shells entailed washing them thoroughly with soapy water, while brushing them to eliminate mud and other surface deposits. Sediments and tissues were oven-dried at temperatures less than 30° C. The shells were reduced to a powder with a mortar and pestle, and pressed into disks a few mm thick with a high-pressure press at 34.5 MPa (5000 psi). Soft-tissue samples were prepared from homogenized whole bivalves, and in some cases, from individual organs. Hands-on preparation of samples is important; students learn about the geology of an area from working with the sediments, as well as gleaning the basics of biology and morphology, respectively, from identifying the bivalves themselves, and their internal organs. Instruction on weight measurement and microscopy is covered, as needed. Figure 2 shows laboratory work done at a high school.

6. Analysis of Samples at BNL's National Synchrotron Light Source

The big science tool we employ for this work is BNL's NSLS facility, http://www.nsls.bnl.gov The NSLS generates intense x-ray beams that serve for investigations on a micrometer-size scale. We used a specific x-ray technique called x-ray fluorescence in our studies. The technique is simple to explain. The incident x-rays interact with the atoms in the sample and cause them to emit secondary x-rays that are specific signatures for particular elements. The secondary x-rays are collected, and the displays show the number of X rays at particular energies. The energy identifies the element; the number of events is proportional to its concentration in the material tested.

To eliminate all risk to the experimenters, we conduct our experiment in a shielded enclosure. The system's major items are the focusing lenses to focus the x-ray beam to about 10 micrometers, moveable stages to position the sample in the beam, an x-ray detector, and video cameras to remotely view the sample and other equipment. Figure 3 shows the equipment inside the hutch. Computers sited in an open laboratory outside the hutch control the experiment.

Figure 1. High School students gathering a sediment core sample from a creek located close to the school (Left). Students from other schools carried out similar collection exercises (Right).

Figure 2. Students prepare samples for analysis at the NSLS at their school laboratories. Sediments collected by the students are shown at the left. A student preparing samples for analysis at the NSLS is shown on the right.

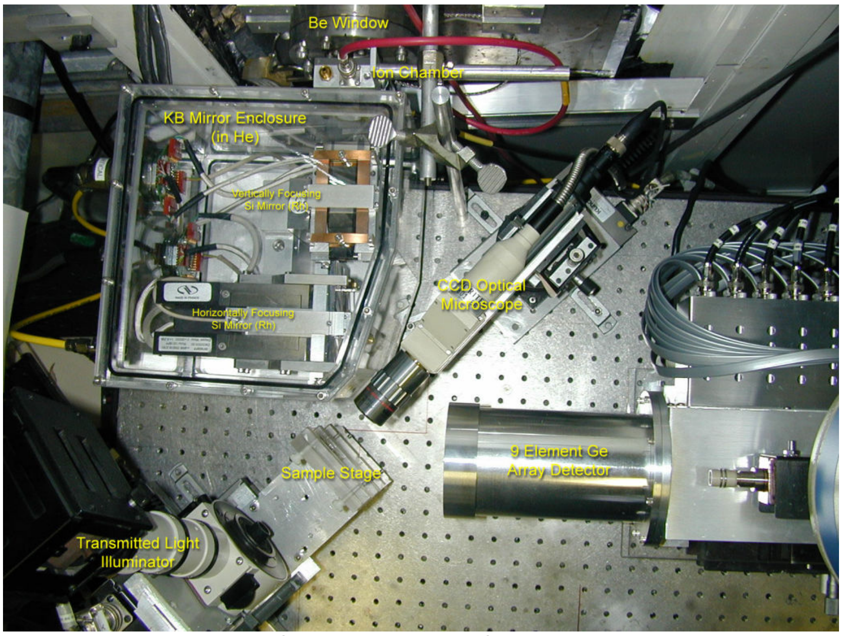

Figure 3. Aerial view of the components of the x-ray microscope system.

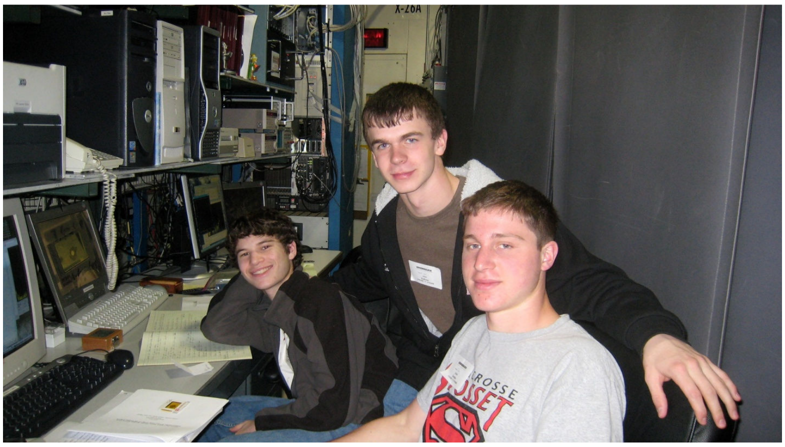

Figure 4. Students from Syosset High School at the NSLS are analyzing their samples at the NSLS.

7. Student Participation in NSLS Experiments

Students can come to the NLS and take control of experiments if they are over 16, and have qualified as users by taking the required web-based training courses. Students over 16 years of age also can attend as observers without becoming users. This system effectively overcomes the restrictions of time and distance. Web-based conferencing is an efficacious way to give virtual access to those under 16, to students too far away to make the trip, and to interact with small or large groups of students during classes scheduled for a particular time.

Many different web conferencing services are available for remote access:http://evo.caltech.edu/evoGate/index.jsp Skype (http://www.skype.com) Adobe Connect Now (https://acrobat.com/welcome.html#si=1), and http://research.seevogh.com/ (formerly http://evo.caltech.edu/evoGate/index.isp) are good examples that are free or low cost, but their features vary, and there might be a cyber-security issue depending on the individual school concerned. All three have proven very satisfactory for our work.

The most important features for CEES include the following: (a) Screen sharing so that participants can view samples at NSLS whilst capturing screen shots of the data output in real-time; (b) remote-control access wherein students can assume control of the desktop and take virtual tours through the NSLS, as well as manipulate the data from their classrooms; (c) video-conferencing for large- or small- group interactions; and. (d) audio options where using a microphone and speakers allow an entire class to interact directly with beam line scientists (Figures 5 and 6).

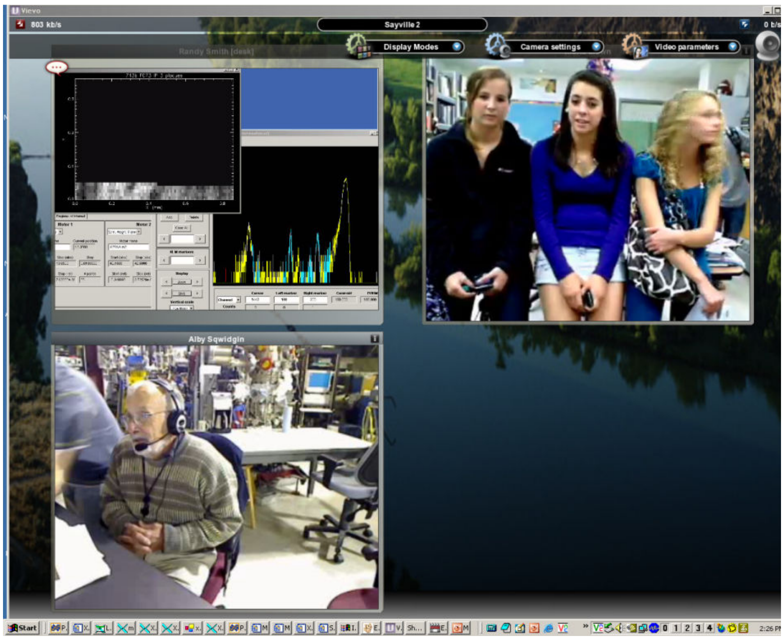

Figure 5a and 5b. Interactive remote conference between NSLS and Sayville High School Students. The group discusses the experimental data being acquired in real time on the upper left. The students can control the experiment from the classroom. The top photograph (5a) shows the computer screen seen by the participants and the bottom photograph shows the students and teacher at the high school (bottom) (5b).

Figure 5b.

Figure 6a and 6b. Internet conferencing with larger classes is shown at the William Floyd High School (top) and the Southampton High School (bottom).

Figure 6b.

8. Initial Demonstrations at Sayville- and Riverhead-High Schools

Students from Sayville- and Riverhead-High Schools collected oysters and sediment samples from the Great South- and Peconic-Bays, Long Island, New York. They prepared the samples at their high school before analyzing them at the NSLS facility. Preparations included tissue, shell, and sediment as described in the Methods section. Samples of tissue, shell, and sediment were probed at the NSLS x-ray microprobes while students and teachers observed through the cyber-enabled remote access to the NSLS. The most valuable part of these sessions was when BNL scientists displayed and explained the real-time data to the participating students. Typically, this led to a discussion session between the scientists, students, and teachers from the different high schools. BNL scientists instructed students how to interpret the x-ray energy levels, and associated elemental maps. Students asked questions via a microphone, while viewing the data output through a videocam. This communication platform also enabled the scientists to familiarize students with the basic physics involved in synchrotron storage rings used to generate x-rays; there were some valuable discussions about the interaction of x-rays with matter in terms of the Bohr model of the atom. This gave the students the necessary background for analyzing and interpreting the data.

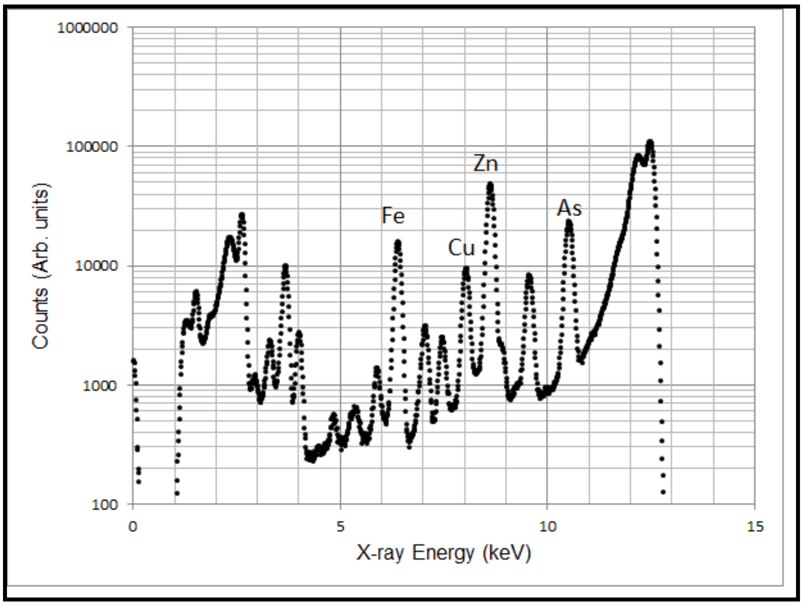

Figure 7. Typical x-ray spectrum found for soft tissue from an oyster. Peaks corresponding to detection of specific elements are labeled in the plot. The concentration of the element is proportional to the peak height.

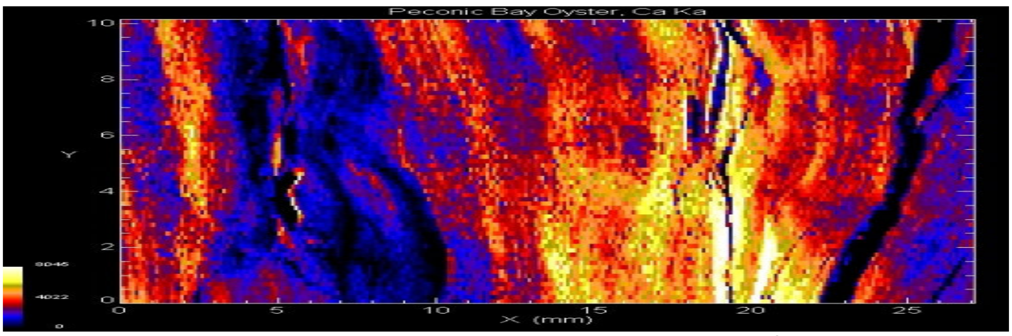

Figure 8. The map shows changes in calcium concentrations over a length of the shell. The color scale runs from black for the lowest concentration and white for the highest concentration.

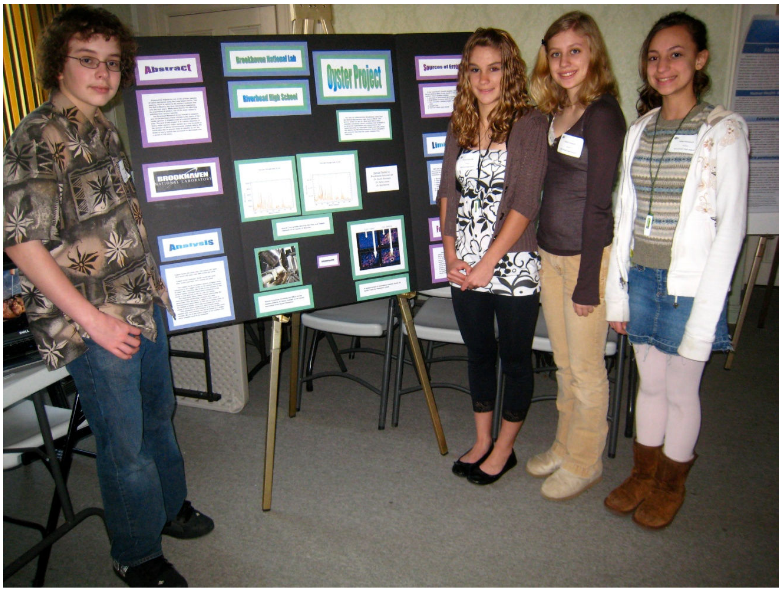

Figure 9. Riverhead High School Students presentation at the NY/NJ Baykeeper sponsored conference on “Restoring the Urban Oyster”, held at Pershing Hall, Governors Island, New York, NY on April 24, 2009.

Preliminary Findings

The x-ray data obtained by the x-ray analysis yields the relative concentrations of each element by plotting a spectrum of events as a function of their energy. Figure 7 is a spectrum obtained from the soft tissue of an oyster taken in the Great South Bay. A striking result is the observation of arsenic, a very toxic element that probably reflects contamination from anthropogenic sources, such as fertilizers and pesticides. Students can analyze the data at different levels of sophistication to identify the elements and their concentrations beginning with the use of a ruler to measure peaks and positions on a plot of the data. A more refined method imports the data into a spreadsheet for manipulation. Finally, the most sophisticated one uses freeware to run software designed for the specific task.

Maps can also be made of elemental concentrations in selected areas of a shell. Figure 8 shows an example of changes in calcium (Ca) concentration in an oyster shell over time. This information is important and can relate the growth of the bivalve to environmental conditions in the marine environment. When conditions are optimal for growth, the Ca concentrations will peak. The map shows measurements made at many points over the shell’s surface. The map covers a total area of the shell that was 27 mm in the horizontal and 10.0 mm in the vertical directions along the X-ray beam The horizontal distance covers about 1year in the life of the oyster, and the color scale reflects changes in the oyster’s metabolism that dictates the changes in the Ca concentration in the shell over that period.

9. Assessment

Students were assessed through a grading rubric at various checkpoints throughout the year. Project assessments include literature searches, experimental design, final report, scholarly writing, PowerPoint presentation, poster board, and formal presentation at local-, regional-, and/or national-science competitions, as well as presentations at BNL.

As an example, Riverhead students presenting their project results at a conference are shown in Figure 9.

In conclusion, bivalves and their environment have proven an excellent interdisciplinary study model organism that captures the interest of the target spectrum of students, teachers, and scientists to foster inquiry-based science, while introducing the skills and technology to promote secondary students into STEM career paths. BNL's Office of Educational Programs (OEP) and Environmental Sciences Department thus have successfully demonstrated that they can bring the resources of BNL to students and teachers anywhere in the country (or world) with an Internet connection.

We have shown that:

1. Our program brought about a close relationship between high school teachers and students at different locations to investigate a topic of mutual interest. The result was a large database that can be used as a foundation for continuing investigations. The collective results make a contribution to management of particular environmental resources and make possible evaluation of multi-year changes in the environment.

2. Our project comprises three collaborating groups: teachers and students, BNL educators, and BNL scientists. Schools can get involved in the project by direct contact with either of the BNL components or through school-to-school connections. Teachers need to understand that the program content is flexible and can be adjusted to the situation in particular schools or to the needs of particular students. We have an open program and expect that schools will opt out or in as time goes on. We add schools through word-of-mouth contacts, participation in conferences and environmental projects, and through the core BNL Office of Education teacher and student programs.

3. We plan to develop similar programs based on other subjects and facilities at BNL. This can be done by networking with the teachers and BNL scientists. We want to have topics that are important from a scientific standpoint and are suitable for multi-year participation by teachers and schools.

4. Teachers should be aware that the Department of Energy operates 10 National Laboratories around the United States. All of them run education programs similar to the one in operation at BNL. Teachers need to be aggressive in working with them to develop new interactive programs.

This program significantly expanded the participation of high- school students and teachers at a large National Laboratory research facility. It removes many barriers to participating in research during the academic day, viz., economic (busing), safety, and time away from school (missed course work). Potential shortcomings of this project include the unreliability of the Internet and Internet connectivity. However, cyber infrastructure, and technical support continues to improve in the participating schools. We note that it is vital for teachers and technology administrators to become familiar with web-conferencing technology before they undertake cyber-enabled science experiments with students. Several students who were co-authors on a scientific, peer-reviewed paper on the work conducted in association with the Pilot Program[2] provided feedback about their experiences with CEES as follows:

Some typical student feedback about experiences with CEES, is outlined below:

Kala - grade 9- "I've seen a new world- the ability to work on this project is one of the most exciting things to happen at my school."

Alycia - grade 9- "I feel as though I am more in contact with the rest of the world."

Nina - grade 9- “I have never learned so much in such a short time.”

Andrew - grade 9- “Face to face contact with a scientist is much more valuable than reading a publication- EVO and our web cam has opened our classroom to web 2.0 and the rest of the world. We can travel great distances and never leave our classroom”

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Biographical statements

Scott Bronson is the manager of K-12 Programs for Brookhaven National Laboratory's (BNL) Office of Educational Programs (OEP). Before coming to BNL, Mr. Bronson was the Education Coordinator of Cold Spring Harbor Laboratory's Dolan DNA Learning Center. He has a strong background in developing and commercializing laboratory science, technology, engineering and mathematics (STEM) curriculum for middle school, high school, and undergraduate faculty and students. E-mail: sbronson@bnl.gov

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Maria Brown received a Master of Science in Environmental Science from Long Island University. She received a BS in Geology and a BA in Biology from CUNY – Queens College. She worked as an Environmental Scientist and Certified Professional Wetland Scientist for 10 years in local engineering and consulting firms before becoming a science teacher at Sayville High School in 1999. She is certified in general science, biology and Earth science (7-12), and has taught Advanced Placement Environmental Science for 8 years and Research in Science and Engineering for 5 years. E-mail: zostera2@gmail.com

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Yerel Çevre Sorunları ile Mücadele Etmek için "Büyük Bilim" Araçlarını Devreye Sokmak

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Özet

Bu çalışmada, Brookhaven Ulusal Laboratuvarı'nda bulunan gelişmiş laboratuar olanaklarını, bir ya da daha fazla yıl sürecek lise düzeyindeki bilim projeleri için erişilebilir kılan, etkileşimli ve işbirlikçi bir çevre eğitimi projesi açıklanmaktadır. Bilgisayar İçerikli Çevre Bilimi, (BİÇB) katılmak isteyen ilgililer için çok disiplinli araştırmaya dayalı fırsatları sağlamak için web tabanlı konferans yazılımı kullanır. BİÇB, uzaktan öğrenme ve deneyi heyecan verici bir şekilde bütünleştiren, öğrencilerin gelecekteki Bilim, Teknoloji, Mühendislik ve Matematik (BTMM) kariyer becerilerini geliştirmek için hizmet veren bir modeldir. BİÇB aracılığıyla yapılan lise araştırmaları, New York Eyalet Standartlarının matematik, fen ve teknoloji (MFT) alanındaki yedi ve Ulusal Coğrafya Standartları'nın 12'sini destekler.

Anahtar Kelimeler: Eğitim, bilim, çevre, senkrotron, Internet

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