Science • Technology • Engineering • Math
STEM PBL NEWS
Problem Based Learning for sustainable technology

A Project of the New England Board of Higher Education (NEBHE)

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STEM PBL is a project of the New England Board of Higher Education (NEBHE) and is funded in part by the Advanced Technological Education (ATE) program of the National Science Foundation (NSF).

Please visit our website:
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Program Staff:

Fenna Hanes
Project Principal Investigator
Sr. Director, Professional & Resource Development
617-357-9620 ext.129
fhanes@nebhe.org

Lisa M. Goldstein
Newsletter Editor & Program Coordinator
617-357-9620 ext.113
lgoldstein@nebhe.org

NEBHE
45 Temple Place
Boston, MA 02111 USA

NEBHE Launches STEM PBL Project

The New England Board of Higher Education (NEBHE) has launched a three-year, $900,000 grant from the National Science Foundation (NSF) for a new project titled ***Problem Based-Learning (PBL) for Sustainable Technology: Increasing the STEM Pipeline***. Funding is provided through the NSF's Advanced Technological Education (ATE) program to improve science, technology, engineering and math (STEM) education to help America develop sustainable technologies. PBL is a learning-centered rather than instructor-centered approach, in which the problem situation drives the learning (see page 2).

STEM PBL Principal Investigator Fenna Hanes of NEBHE said, "This project will develop two professional development courses, one for pre-service and one for in-service teachers. It will also meet the need for STEM instructional materials by developing six problem-based multimedia Challenges for use in college and high school classrooms. The topics will be in sustainable technology areas such as wind and solar power, sustainable agriculture, storm water remediation, lighting and green chemistry. The co-principal investigators (PIs) are all professors. They are: Michele Dischino from Central Connecticut State University in

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Summer Workshop at Boston University

A two and one-half day professional development workshop was held July 18 – 20, 2010 at Boston University's (BU) Photonics Center. Housing for the participants, STEM PBL team and guests was in BU's new air-conditioned high-rise dormitory overlooking Boston, Cambridge and the beautiful Charles River.

At the Sunday evening dinner, BU Associate Dean for Research and Graduate Programs Professor M. Selim Ünlü, welcomed the participants, project team and dinner guests to BU. Guest speaker John C. Warner, president and CEO of Warner-Babcock Institute for Green Chemistry, energized everyone with his presentation. Warner proposed teachers can lead a green chemistry revolution by making small changes in the way they teach chemistry. This includes testing current beliefs about chemical safety and teaching how to determine if a new chemical compound may be hazardous or not. Warner remained long after his speech to answer questions from teachers eager to speak with him.

A team of workshop participants present their solution to a Challenge. From L-R are JoAnne Flejszar, Christine Roberson, Aida Awad, Jennifer ElShakhs and Alexander Pancic.

On Monday morning, BU Professor of Electronic and Computer Engineering Michael Ruane, a member of the STEM PBL Advisory Committee, welcomed the participants to the Photonics Center where the workshop classes were held. On Monday and Tuesday, participants used three STEM PBL Challenges just as their students will when the Challenges are introduced in the classroom. The teachers

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Problem Based Learning: A Primer

By Nicholas Massa, PhD

Technicians are problem solvers - individuals who skillfully apply their knowledge of technologies to solving real-world problems. Working with engineers and scientists, technicians are the hands-on side of an engineering team. Technicians are responsible for designing experiments, building and trouble-shooting prototypes, analyzing and interpreting data and presenting experimental results to peers, supervisors and customers.

Given the broad scope of duties required of the technician, why do many technician educators continue to teach in a traditional instructor-centered manner that provides little opportunity for students to actively engage in real-world problem-solving? This approach to education too often results in graduates entering the workforce inadequately prepared to adapt to the complex and ever-changing demands of the 21st century high-tech workplace.

STEM PBL addresses this challenge through problem-based learning (PBL), an instructional method that challenges students to *learn how to learn* by collaboratively solving genuine real-world problems. Research shows that compared to traditional lecture-based instruction, PBL improves student understanding and retention of ideas, critical thinking, communication and problem-solving skills, as well as the ability to adapt learning to new situations - the cornerstone of lifelong learning.

In PBL, students learn the process of solving real-world, open-ended problems that may have a number of possible solutions. PBL involves a recursive problem-solving process that begins with a problem scenario presented in the context in which it is to be solved (see Figure 1). Student teams collaboratively analyze the problem by identifying relevant facts and learning issues, activating prior knowledge, generating hypotheses, reflecting on their beliefs about the problem and generating learning objectives needed to solve the problem. This phase is followed by a period of self-directed learning whereby each student engages in learning specific content identified as relevant in the initial problem analysis phase. During this process, the instructor serves as a consultant, guiding the students as they seek required resources and providing additional information as needed, thereby shifting the responsibility for learning onto the

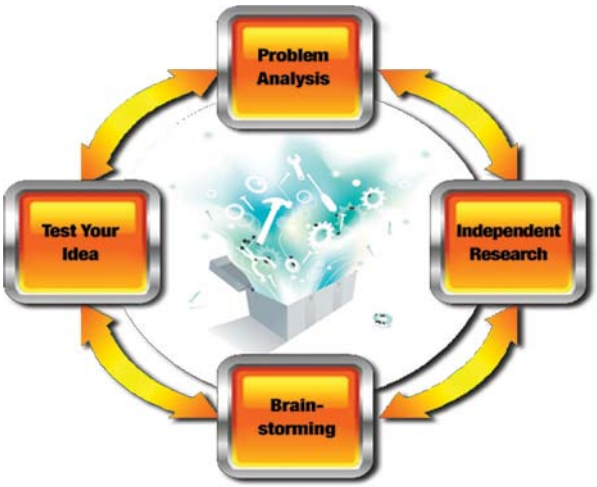


Figure 1 - The problem solving cycle

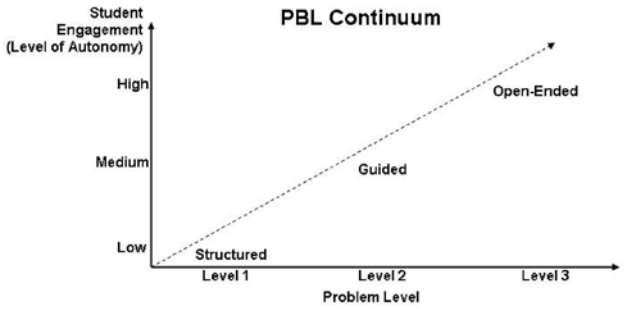


Figure 2 - The PBL continuum

student. Upon completion of the self-directed learning phase, students reconvene to brainstorm, assessing and evaluating their problem solutions based on their new understanding of the problem. Possible solutions are then tested and reformulated if needed. This process may repeat itself several times when solving a single problem. Student evaluation in PBL takes several forms, from a final patient diagnosis in medical education to the generation and presentation of a formal proposal, including cost/benefit analysis and/or feasibility analysis in an engineering education application. In either case, the final problem solution takes the form of what would be most appropriate in that particular context.

After years of learning from classroom lectures, many students have difficulty adjusting to PBL. A common complaint among those introduced to PBL for the first time is the stress and anxiety associated with solving open-ended problems and self-directed learning. PBL thrusts students into uncertain learning situations where problem parameters are not well defined and the task at hand may be ambiguous, just like in the real world. To ease this transition, the STEM PBL Challenges are designed so the instructor may chose from three levels of structure, depending on the technical nature of the problem and ability level of the students: *Level 1–Structured* (instructor led), *Level 2 –Guided* (instructor guided) and *Level 3–Open-Ended* (instructor as consultant). This format allows students and faculty to progress through the PBL Challenges along a continuum, from a low autonomy mode (structured) to high autonomy mode (open-ended) over time, improving the likelihood that both students and faculty will adopt and embrace this new mode of instruction and learning (see Figure 2). A video called *PBL How To* developed by the project instructional team explains how to implement PBL in the classroom. To view the video, go to **www.stempbl.org** and click on *PBL Resources*.

Given the practical nature of technology education where students must learn to apply their knowledge in solving complex, real-world problems, PBL appears well-suited for educating technicians capable of addressing the ever-changing needs of today's technological and multicultural society. ■

Dr. Massa teaches in the Laser Electro-Optics program at Springfield Technical Community College in Springfield, MA. He can be contacted at massa@stcc.edu.

What are Green Jobs?

There is a lot of talk about ***green jobs***, but what does it mean exactly? A simple definition is jobs related directly to improving energy conservation, such as insulating homes or building a wind turbine. But green jobs are more than just jobs requiring certain technical skills. They also include management and business practices that conserve materials, the environment and energy use in the first place. A number of colleges are starting to offer a variety of degrees in a wide range of related fields.

There are many green degree and certificate programs offered through NEBHE's Tuition Break program at New England public colleges and universities. Tuition Break enables thousands of New England residents to enroll at out-of-state New England public colleges and universities at a discount. Eligible majors are those not offered by a public college or university in the student's home-state. For more information, visit **www.nebhe.org/tuitionbreak**. ■

A Partial List of Green Majors in New England Public Colleges & Universities

CERTIFICATE PROGRAMS

Environmental Technology Certificate with concentration in:
- Coastal Zone Management
- Site Assessment
- Photovoltaic Technology
- Small Wind Technology
- Solar Thermal Technology
- Wastewater Management
- Water Supply

Cape Cod Community College, MA

Organic Agriculture Technician
Bristol Community College, MA

Sustainable Building Advisor
Gateway Community College, CT

Sustainable Facilities Management
Three Rivers Community College, CT

ASSOCIATE'S DEGREES

Construction Management Technology
Three Rivers Community College, CT

Energy Services and Technology
Lakes Region Community College, NH

Environmental Technology
Naugatuck Valley Community College, CT
Cape Cod Community College, MA
Holyoke Community College, MA
White Mountains Community College, NH

Environmental Engineering Technology
Three Rivers Community College, CT

Environmental Science and Safety
Massachusetts Bay Community College

Wind Power Technology
Northern Maine Community College

GRADUATE DEGREES

Biodiversity and Conservation Biology (MS)
University of Connecticut

Environmental Education (MS)
University of New Hampshire

Green Chemistry (PhD)
University of Massachusetts Boston

Wildlife and Fisheries Conservation (PhD)
University of Massachusetts Amherst

Wildlife Ecology (PhD)
University of Maine

BACHELOR'S DEGREES

Coastal Studies
University of Connecticut

Community and Environmental Planning
University of New Hampshire

Diversified Agriculture
Vermont Technical College

Ecogastronomy
University of New Hampshire

Environmental Engineering
University of New Hampshire

Environmental Horticulture
University of Maine
University of New Hampshire

Environmental Safety and Health
University of Southern Maine

Forest Ecosystem Science
University of Maine

Sustainability Studies
Lyndon State College (VT)

Sustainable Product Design and Innovation
Keene State College (NH)

Challenge Partners Collaborate to Develop Challenges

The STEM PBL project is developing six multimedia Challenges in collaborations with industry partners. The Challenges are based on authentic real-world problems that are similar to a case study. They are designed to develop students' problem-solving and critical thinking skills to prepare them for today's high technology workplace.

Through video re-enactment of problem situations recorded on location in industry and research labs, the STEM PBL Challenges will actively engage students in the problem-solving process by virtually inserting them into the context and environment in which the problem is to be solved. This is a significant departure from traditional lecture-based instruction where end-of-chapter problems with well-defined parameters often produce artificial and uninteresting solutions.

Each Challenge has the following segments:
1) A general overview of the STEM area of the Challenge to set the context for the problem.

2) An introduction to the industry or research partner(s) where the problem was solved.

3) A presentation of the problem being posed at a company morning meeting or as a customer request.

4) A brainstorming discussion session by engineers, scientists and technicians at the organization's site that provides technical hints for the problem's solution.

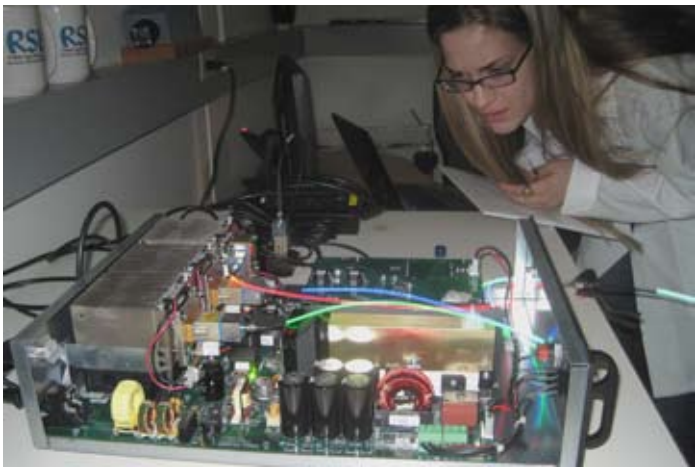
5) The organization's own solution, which students can compare and contrast to their own.

Each Challenge includes video segments, Internet links to additional resources, and other technical and problem-solving resources such as an innovative *Problem Solver's Toolbox* and *Teacher Resources* package.

Partners with whom Challenges have been developed include:

RSL Fiber Systems, LLC

RSL Fiber Systems in East Hartford, CT, worked with the United States Navy to develop a fiber optic illumination system called Remote Source Lighting (RSL). This technology involves generating light in one location and then transporting the light through fiber optic cable to another location up to 250 meters away. Applications include navigation, area illumination, security and signaling lights. This allows the Navy to lower maintenance costs, reduce system down time, increase system ruggedness and improve safety. RSL Fiber Systems has also been involved in a number of innovative lighting projects to replace conventional lights with light emitting diodes (LEDs) for U.S. Navy ships.



Samantha Bullard, a student at Springfield Technical Community College, views a novel laser lighting system with fiber optic delivery at RSL Fiber Systems.

Discussing how to revive a bog sustainably, from L-R: Brian Wick, Director, Cape Cod Cranberry Growers' Association; Linda Rinta, Conservation Farm Planner for the Plymouth County Conservation District; Len Reno, District Conservationist at the U.S. Department of Agriculture; Gary Randall, cranberry bog owner.

THE CHALLENGE

The Navy asked RSL Fiber Systems to design a new lighting system for submarines that is both ergonomic and energy efficient. Research shows that sailors working in an environment without natural sunlight suffer greater stress and are less alert, so more mistakes may occur. The Challenge is how to create a lighting system that mimics natural sunlight, helps the sailors adjust to an 18-hour circadian rhythm, and is energy efficient.

Cape Cod Cranberry Challenge Partners

The U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) was established by Congress in 1935 to protect the nation's farm land. Since that time, NRCS has expanded to become a conservation leader for all natural resources, ensuring private lands are conserved, restored and made more resilient to environmental challenges. Experts from many science and technology disciplines work together with landowners to benefit local soil, water, air, plants and animals.

The Plymouth County Conservation District in Plymouth, MA, was established by state legislation more than 50 years ago. It is a local environmental agency dedicated to wise land use and conservation of natural resources. The district provides leadership to set priorities for local conservation activities and works hand-in-hand with NRCS to achieve them.

The third partner is the Cape Cod Cranberry Growers' Association. Established in 1888, it is one of the oldest farmer organizations in the country. The goal of the Association is to

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"enhance the economic viability of the Massachusetts cranberry grower" by supporting and promoting the cranberry growers of Massachusetts.

THE CHALLENGE

Traditional cranberry farming is very water intensive. It also uses a large amount of chemical fertilizers and pesticides that can run off into the local water table. The Challenge is how to revive an old fallow cranberry bog and make it water efficient, while reducing the amount of chemical fertilizers and pesticides needed.

Tookany/Tacony-Frankford Watershed Partnership

In 2000, the Philadelphia Water Department initiated the Tookany/Tacony-Frankford Watershed Partnership (TTF) with a mission to enhance the health and vitality of the Tookany/Tacony-Frankford Creek and its watershed. TTF was incorporated in 2005 as a non-profit organization that acts as the crucial link connecting residents, businesses and government as neighbors and stewards of this impaired but critically important watershed. Through educational programming, community outreach, networking services and project coordination, the partnership both supports and initiates efforts to restore the health of the watershed and to mobilize its communities as watershed stewards.

THE CHALLENGE

Before people built houses, roads, factories, playgrounds and parking lots, the rain that fell onto the earth soaked into the ground to be absorbed by plant and tree roots. The large impervious surfaces of a modern urban environment prevent rain from seeping into the ground. In many parts of Philadelphia there are combined sewer systems where stormwater and sewage share the same pipes. This allows a combination of sewage and stormwater to flow untreated into local streams, including those eventually used for drinking water. How can the amount of stormwater entering a sewer system be reduced? Can urban streams and their habitats be repaired without massive and expensive construction projects?

The staff of the TTF Watershed Partnership from L-R: Sarah RobbGrieco, Executive Director; Ashley Schmid, Model Neighborhood Liaison; and Katie Donnelly, Associate Director.

FloDesign, Inc.

FloDesign, located in Wilbraham, MA, is a research and development company using state-of-the-art aerospace technologies to develop, prototype, patent and market new products for other companies such as Rolls Royce and Sikorsky Aircraft. FloDesign Wind Turbine Corp. is a spin-off from its parent company, focusing on wind power technology.

THE CHALLENGE

Although the idea of wind power has overwhelming public support, many people do not want huge unsightly towers located near their homes and businesses. Excessive noise and danger to flying birds are also concerns. FloDesign Wind Turbine Corp. wants to design, develop, fabricate and test a new wind turbine that is smaller, quieter and more efficient. This new design concept can potentially generate over three to four times the useful energy compared to a similarly sized conventional wind turbine. How do you translate this new design concept into a working model to test the theory and see if it delivers on its promise? ■

A Peek Inside a Multimedia Challenge

A Challenge is a multimedia presentation that provides the basis for problem-based learning. Below are three of the five segments plus the Teacher Resource webpage. The screen shots are from the FloDesign Challenge. ■

The industry partner introduction provides context to the real-world problem. This is followed by the problem statement.

The problem discussion is a brainstorming session showing the FloDesign technicians analyzing the problem.

In the problem solution, the technicians explain their solution and the reason why they chose it.

The Teacher Resources page contains both technical and pedagogical support materials.

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New Britain, CT; Judith Donnelly from Three Rivers Community College in Norwich, CT; and Nicholas Massa from Springfield Technical Community College in Springfield, MA.

Applications were accepted during fall 2009. Out of nearly 90 applicants, 26 were accepted. Thanks to additional funding received from the Connecticut Regional Center for Next Generation Manufacturing, also funded by the NSF/ATE program, an additional six educators were selected from the waiting list.

Applicants were requested to apply as an Alliance team with a nearby school. Each Alliance has a high school and a college partner. Benefits include creating educational pathways for students, building students' higher education aspirations, providing opportunities for high school and college students to work together, and increasing networking and professional support for educators.

A total of 32 high school and college instructors were accepted. Of the 21 men and 11 women, 17 were from New England and 15 were from seven other states. In all, 58% are from secondary schools, while 44% are from postsecondary institutions. Instructors came from various disciplines: 11 from science, 20 from technology/engineering technology and one from English. The cohort teachers have various levels of teaching experience: 56% have over a decade and 16% have less than five years.

Applications were encouraged from both instructors with some experience with PBL as well as those with none. Forty-seven percent have a little experience with PBL, 13% are at an intermediate level, 27% consider themselves experienced, while another 13% stated that they have no experience at all.

The NSF focuses on assisting students underserved in STEM education, and significant efforts were made to reach out to these populations. As a result, participants' schools have a broad demographic spread: 38% are urban, 31% are rural and 31% are suburban; 40% of the participating student bodies are from African American, Hispanic, Asian, Native American or other ethnic groups, while 60% are Caucasian. ■

Summer Workshop continued from page 1

worked in teams to learn about each Challenge's problem statement, brainstormed together to discuss options for solving the problem and agreed upon the best solution given the problem's parameters. The three STEM PBL Challenges used were the wind power, lighting and cranberry Challenges (see pages 4–5). Representatives from each of the Challenge partners' organizations, as well as several members of the STEM PBL Advisory Committee, also attended and participated in the workshop.

At the end of the workshop, all the participants, STEM PBL project staff and workshop guests enjoyed a boat tour of the Charles River and Boston Harbor. The tour gave participants a chance to network, relax, and see a beautiful clean harbor, once one of the worst polluted in the nation. ■

Group photo of STEM PBL project participants, Challenge partner guests and project staff at the summer workshop.

STEM PBL Particpating Schools

California
Taft College
Taft Union High School

Connecticut
Windham High School

Illinois
Maine East High School
Oakton Community College

Louisiana
Grambling State University
Jonesboro-Hodge High School

Massachusetts
Boston Latin Academy (HS)
Doherty Memorial High School
Springfield High School of Science and Technology

Massachusetts, cont.
Norton High School
Odyssey High School
Quinsigamond Community College
Stonehill College
Wentworth Institute of Technology

Maryland
Anne Arundel Community College
Baltimore Polytechnic Institute (HS)
South River High School
University of Maryland - Eastern Shore

Maine
George Stevens Academy (HS)
Maine Maritime Academy

Michigan
Oakridge High School

Missouri
Central Methodist University
Columbia Area Career Center

New Hampshire
Great Bay Community College
Kingswood Regional High School/Region 9
University of New Hampshire

Rhode Island
Ponaganset High School

Texas
LeTourneau University
Longview High School

Vermont
South Burlington High School
Vermont Technical College

STEM PBL Holds First Annual Advisory Committee Meeting

On May 6 – 7, 2010, the STEM PBL Advisory Committee held its first annual meeting at the New England Board of Higher Education (NEBHE) in Boston. The committee has16 representatives from industry, education and government who:

- provide guidance for skill sets and curriculum requirements needed by technicians in industry.
- advise on strategies for incorporating problem based learning principles in the Challenges.

Committee activities include an annual meeting, conference calls discussing technical/scientific curriculum content, commenting on the pedagogical soundness of the Challenges, assistance in disseminating the Challenges and instructional materials, and possible assistance with obtaining additional funding (cash or in-kind) for the project and/or participating schools.

Committee members are able to influence curricula and the education of the future workforce, meet and work with other professionals interested in building America's sustainable industry employee pipeline, and have opportunities to bring their organizations' products and services to the attention of STEM PBL educators and their students. ■

Committee Members

Karen Wosczyna-Birch
Connecticut Community Colleges

Kevin Doyle
Green Economy

Robert Douglas
Zygo Corporation

Wes Golomb
Lakes Region Community College

G. Groot Gregory
Optical Research Associates

Mark Kahan
Optical Research Associates

Marijke Kehrhahn
University of Connecticut

Stanley Kowalski III
FloDesign Wind Turbine Corp.

Jake Mendelssohn
Greater Hartford Academy of Math and Science

Daniel K. Moon
Environmental Business Council of New England

Michael Ruane
Boston University

Scott J. Soares
Massachusetts Department of Agricultural Resources

Sheryl K. Rosner
U.S. Environmental Protection Agency

Michele Wakin, PhD
Bridgewater State College

Douglas Webster
Vermont Department of Education

Eitan C. Zeira
Konarka Technologies

Advisory Committee members and Project PIs at the first annual meeting.

Top row, L-R: *Sheryl Rosner, Michael Ruane, Wes Golomb, Kevin Doyle, Mark Kahan, Marijke Kehrhahn, Judy Donnelly (Co-PI), Daniel Moon, Douglas Webster, Fenna Hanes (PI).*

Middle row, L-R: *Robert Douglas, Michele Wakin, Barbara Darnell substituting for G. Groot Gregory.*

Bottom row, L-R: *Richard Estes substituting for Eitan Zeira, Jake Mendelssohn, Stanley Kowalski, Nick Massa (Co-PI), Karen Wosczyna-Birch.*

college ready new england
a nebhe initiative

Continuing with the work of NEBHE's College Ready New England (CRNE) program, the New England 2025 initiative, in conjunction with the Lumina Foundation, employs a systematic and data-driven examination of postsecondary degree production in each of the New England states. Its goal is to achieve a significant increase in college attainment by the year 2025.

- Identify realistic, contextualized state goals for increased degree production.
- Provide support and assistance for state-based work on policies, programs and other change levers.
- Help states implement advanced data-mining and analysis techniques.

For more information, contact:
Matthew Crellin, Director of Policy and Research
mcrellin@nebhe.org • 617-357-9620 ext. 130

NEBHE
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STEM PBL Dissemination Activities

The STEM PBL PI team has already started disseminating project plans and activities. PI Nick Massa presented at two conferences; the project team of Michele Dischino, Judith Donnelly and Fenna Hanes co-authored.

The presentations focused on how the STEM PBL project team is partnering with industry and related organizations that are breaking new ground in sustainable green technologies. Massa described and demonstrated how the project is developing a comprehensive series of multimedia STEM PBL instructional materials designed to engage secondary and postsecondary students in real world problem solving.

Massa described how the professional development component of the project is preparing STEM high school teachers and college faculty to introduce PBL instructional methods using STEM PBL materials. To this end, the project is developing two courses. One is an online course, *Introduction to STEM Problem Based Learning,* for in-service STEM teachers who attended the professional development workshops in Boston this summer (see page 1). The other course is a classroom-based course for pre-service STEM teachers, offered at Central Connecticut State University during the 2010-2011 school year. ■

PRESENTATIONS

Using Problem-Based Learning in Sustainable Technologies to Increase the STEM Pipeline
Workshop
National Association for Workforce Improvement (NAWI)
April 21–23, 2010 in Old Town Alexandria, Virginia

Problem Based Learning for Sustainable Technologies: Increasing the STEM Pipeline
Paper
American Society for Engineering Education (ASEE)
June 20–23, 2010 in Louisville, Kentucky

Visit **www.stempbl.org** and click on *Conference Papers*.