

Problem-Based Learning (PBL) Implementation Strategies for STEM Courses

Background

Industry is increasingly looking to high schools, community colleges, and four-year universities to graduate problem solvers—individuals who skillfully communicate and apply their knowledge of science, technology, engineering, and mathematics (STEM) and other disciplines to solve real-world problems. Yet instructor-centered pedagogical methods paired with text-based exercises often do not address the interdisciplinary, ill-defined, and ambiguous problems graduates will face when entering the 21st century workforce. Since 2006, the New England Board of Higher Education (NEBHE) has been funded by the National Science Foundation's (NSF) Advanced Technological Education (ATE) program to develop a series of curriculum and professional development projects using PBL in collaboration with industry.

Curriculum Development. Each project has created a series of instructional materials: authentic real-world multimedia case studies called Challenges in the fields of optics and photonics (PHOTON PBL), sustainable technologies (STEM PBL), and advanced manufacturing (AM PBL). The PHOTON PBL and STEM PBL materials have been field tested in high school and college classrooms and are being pilot tested in middle schools. The AM PBL Challenges are currently under development. Project participants have been recruited in partnerships called an Alliance in order to promote pathways to higher education and careers in STEM. Access to the Challenges is free of charge at http://www.pblprojects.org/?page_id=884.

Professional Development. The projects' instructional materials have been disseminated through multi-day professional development workshops, a distance learning course, short *Introduction to PBL* workshops, and conference presentations across the country. In addition, two teacher education courses have been developed and delivered at Central Connecticut State University: an undergraduate course designed to teach pre-service STEM teachers how to introduce PBL into the classroom and a graduate course designed to prepare in-service teachers for PBL.

Based on requests for assistance in developing PBL curricula from schools that were not part of the ATE projects but are interested in introducing PBL to their students, NEBHE has begun to offer consulting services that prepare instructors to develop their own Challenges based on topics of their own choosing.

Documented Results

Fourteen PBL multimedia materials—eight PHOTON PBL and six STEM PBL Challenges—have been field tested in secondary and postsecondary institutions across the country. Our research shows that PBL engages students in inquiry-based real-world problem solving, teaching students “how to learn” by collaboratively solving authentic real-world problems. The research shows that compared with traditional lecture-based instruction, PBL improves student understanding and retention of ideas, critical thinking and problem-solving skills, motivation and learning engagement, the ability to work in teams, and the ability to transfer skills and knowledge to new situations.

Comments from teachers and students who have used the Challenges include:

- "PBL was a very rewarding experience for me. I felt like an actual scientist instead of a student in high school. When you are just sitting at a desk and teachers are giving you information it's really boring, but when I have to find the information on my own it sticks with me." —Taft Union High School student, California.
- "PBL teaches you what to do when you don't know what to do. First, by process of elimination, you learn what you do know and then it gives you clear steps on how to go about researching the parts that you don't know." —Springfield Technical Community College student, Massachusetts.

All of the Challenges have been developed in collaboration with industry. Follow-up with the PBL industry partners verifies that employers are eager to engage with education institutions in order to increase the number of graduates who have problem-solving, critical-thinking, and teamwork skills. Dale Miller, semiconductor manufacturing and operations director at IBM Microelectronics Division in Vermont, an AM PBL industry partner explained, "IBM's future depends on highly skilled workers, including both technicians and engineers. We fully support programs like AM PBL and are eager to do our part to ensure a well-prepared workforce."

Potential Applications

The projects' team of experienced PBL practitioners trains instructors in "learn by doing" workshops in which instructors experience the PBL process as a student. Participating instructors gain access to a library of teachers' resources, become versed in implementation and assessment strategies for PBL, and are prepared to develop their own PBL Challenges based on industry problems using the project's *Challenge Design Guide*.

NEBHE's PBL projects' instructional materials have been aligned to the science, mathematics, and technological literacy standards, as well as the English language arts and mathematics components of the new *Common Core State Standards* (CCSS) and will be aligned to the science and engineering components of the *Next Generation Science Standards* (NGSS). Instructors are introduced to a template and set of curriculum-mapping tools to align their own PBL curriculum materials to national academic standards and accreditation criteria.

NEBHE is currently in the second year of a consulting project with Kennebec Valley Community College in Maine to help faculty incorporate PBL into a new ATE-funded Energy Services Technology degree program. This initiative was featured in ATE@20 and can be viewed at <http://www.atecentral.net/ate20>.

For More Information

Visit <http://www.pblprojects.org> to access NEBHE's PBL Projects, the PBL Challenges, and supporting teacher and student resources. Contact Fenna Hanes, NEBHE's senior director of professional and resource development, at fhanes@nebhe.org or call 617-357-9620 x129 to learn more about these initiatives.

Research papers presented at regional, national, and international conferences can be found under each of the PBL projects at http://www.pblprojects.org/?page_id=215.