

# PHOTON Problem Based Learning (PBL): Using “Real-World” Problems to Develop Optics/Photonics Challenges for Students

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**Abstract.** *Since 1995, the New England Board of Higher Education (NEBHE) has provided curriculum and professional development in optics/photonics to high school and college science and technology educators across the United States with support from the Advanced Technological Education (ATE) program of the National Science Foundation (NSF). NSF/ATE has funded four projects: Fiber Optic Technology Education Project (FOTEP, PHOTON, PHOTON2 and Problem Based Learning (PBL).*

*Project PHOTON PBL addresses the lack of “real-world” resources in photonics technology education by developing a curriculum of eight industry-based multimedia photonics Challenges and solutions to engage students in the process of solving open-ended problems.*

**Keywords.** Challenges, levels of structure, problem-based learning, professional development.

## 1. Introduction.

Photonics technicians are problem solvers – individuals who must skillfully apply their knowledge of lasers, optics, electronics, and

related technologies in solving real-world problems [1]. Working side-by-side with engineers and scientists, photonics technicians are the “hands-on” side of an engineering team, responsible for designing experiments, building and troubleshooting prototypes, analyzing and interpreting data, and presenting experimental results to peers, supervisors and customers. Given the broad scope of duties required of the photonics technician it is ironic that photonics technician education programs are most often taught in a traditional instructor-centered manner that provides little opportunity for students to actively engage in real-world problem solving. This approach to education often results in graduates who do not have a full range of important employability skills and competencies needed in business and industry, such as the ability to: (1) apply their knowledge in new and novel situations, (2) communicate effectively, (3) work as members of an interdisciplinary team, and (4) engage in lifelong learning – skills deemed critical by ABET EC2000 [2]. As a result, photonics technicians often enter the workforce inadequately prepared to adapt to the complex and ever-changing demands of the 21st century high-tech workplace [3]. The PHOTON

PBL project will address this challenge through the use of problem-based learning.

## 2. Problem Based 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 (see Fig. 1) that begins with a problem scenario presented in the context in which it is to be solved. 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 student as they seek required resources and providing additional information, as needed thereby shifting the responsibility for learning onto the 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 may take one of 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.

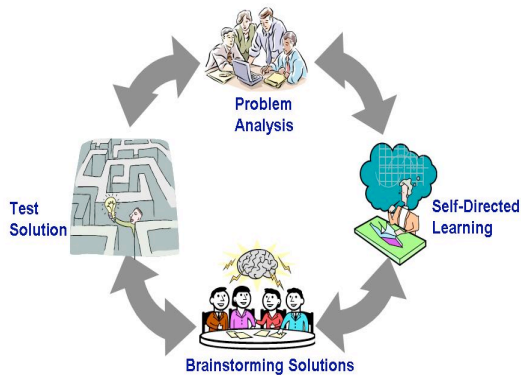


Figure 1. The problem solving cycle

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 the real world. To ease this transition, the PHOTON PBL Challenges are designed with three levels of structure: Level 1 (Instructor Led - Highly Structured), Level 2 (Instructor Guided - Moderately Structured) and Level 3 (Instructor as Consultant - Open-Ended) depending on the technical nature of the problem and ability level of the students. This format allows students (and faculty) to progress through the PBL Challenges along a continuum, from a low autonomy mode (highly 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. This design is illustrated in Fig. 2.

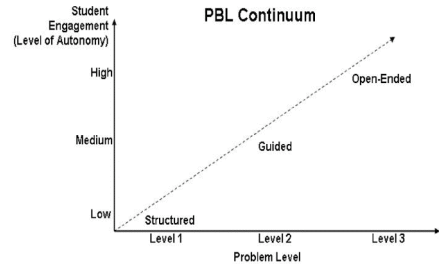


Figure 2. The Photon PBL continuum

Given the practical nature of photonics 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 [4].

## 3. PHOTON PBL Project

The PHOTON PBL project goals are to: **Create eight multimedia problem-based scenarios** and instructional resources in photonics technology to complement the highly successful PHOTON curriculum and laboratory materials. The materials

will be aligned to academic and industry skill standards.

**Recruit and train high school and community college photonics technology instructors** from 16 institutions to implement, assess and evaluate the problem-based scenarios in classrooms with their students.

Conduct **quantitative and qualitative research** on the efficacy of PBL in engineering technician education.

**Outreach and disseminate** the field-tested problem-based scenarios and research findings to high schools, community colleges and four-year colleges and universities that offer technology programs.

### 3.1 Multimedia Challenges

To address the lack of instructional resources for PBL in photonics technology education, the PHOTON PBL project, selected eight photonics industry and university research laboratories from across the US as Challenge partners to create a series of multimedia PBL Challenges (DVD) and instructional resource materials covering a broad range of photonics applications.

Unlike traditional case studies in which students passively study and critique problem situations encountered by others, the PHOTON PBL Challenges are designed to 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, thus emulating the actual workplace experience.

For each PHOTON PBL Challenge, both a student version and an instructor version will be developed. The student version will contain a multimedia introduction to the specific company or university research lab to set the context for the problem challenge followed by a re-enactment of the problem statement by actual industry/university personnel, the problem-solving process engaged in by actual engineers and technicians, and a detailed presentation of the problem solution. A problem solving “toolbox” will be incorporated into each PHOTON PBL Challenge to provide students with the learning resources needed to successfully guide them through the problem-solving process.

The instructor version will contain all of the information contained in the student version plus additional instructional resources including an instructor’s “toolbox” containing instructional

strategies, assessment and evaluation tools, industry standards related to the problem challenge, a solution guide detailing alternative problem solutions, and information regarding alignment with national science, math, language arts and technological literacy standards. The instructor version will also contain a generic PBL template and instructions to help them develop their own PBL Challenges.

Each PHOTON PBL Challenge is designed to be completed by students in a one- to four-week time frame and can be customized by the instructor for complexity allowing for multiple problems to be presented within a typical 15-week semester [5].

As a first step in developing the Challenges, NEBHE convened the eight Challenge Partners at a two-day workshop at Central Connecticut State University in New Britain in January 2007. The aim of the workshop was to introduce the PHOTON PBL partners to problem-based learning (PBL) and to work together to begin to design the eight case-study-like “challenges” encountered in “real world” optics and photonics applications.

Participating challenge partners include: Boston University, California State Polytechnic University Pomona, Fleming Tinker, LLC (Conn.), IPG Photonics Corp. (Mass.), Penn State Electro-Optics Center, Photodigm, Inc. (TX), Photomachining, Inc. (NH), and PVI Systems (Conn.).

Visits for developing the first three problem-based challenges were held at during spring 2007 at Photomachining, Boston University and IPG see Fig.3. The additional five Challenges will be developed during fall 2007 and spring 2008.



Figure 3. Visit to IPG Photonics, Inc.

### 3.2 Project PHOTON PBL participants

Twenty-six instructors from across the US (Alabama, Arizona, California, Connecticut, Florida, Hawaii, Michigan, New Hampshire, New York, North Carolina, South Carolina, Texas and Vermont) have been selected to field-test the curriculum between the fall 2007 and spring 2009 semesters. As in NEBHE's previous optics/photonics professional development workshop, the instructors were either science, math or technology instructors. Most of the science instructors teach physics but there are also a couple of chemistry and mathematics teachers. In addition to the interdisciplinary composition of the cohort, the instructors come from both secondary and postsecondary institutions. Project applicants were asked to apply as teams, called "Alliances," composed of at least one high school and one college instructor who teach in the same geographic area. This strategy has proven to be very effective in helping to build educational pathways for students. The participating instructors have found numerous opportunities to work with their alliance partner and develop a mutual support system that leads to productive collaborations.

### 3.3 Project Professional Development Workshop

In order to introduce the participants to problem-based learning and the first three PHOTON PBL Challenges, a one-week professional development workshop was held at Roger Williams University (RWU) in Bristol, Rhode Island.

The goals of the workshop were to:

- Introduce the project participants to the first three PHOTON PBL Challenges.
- Gain feedback from the participants to guide the project principal investigators (PI) in editing the first three and developing the remaining five Challenges.
- Create a community between the secondary and postsecondary partners who will be working together to implement the PBL Challenges in their home institutions.
- Build a network of educators who will become resources to one another as they introduce their students to the PBL Challenges.
- Provide the educators with the tools to build their own PBL Challenges.
- Provide a stimulating professional development experience in an attractive higher education learning environment.

On Monday, Co-PI Richard Audet introduced participants to a scientist's notebook that each participant would maintain throughout the workshop to track his/her learning experiences. This was followed by interactive activities that modeled PBL. Co-PI Judy Donnelly, and Co-PI Nick Massa then described the methodologies employed in developing the three PHOTON PBL Challenges to be examined during the workshop. Participants first examined the Challenge developed in collaboration with PhotoMachining, Inc., located in Pelham, NH. The following day, the Boston University (BU) Electrical & Computer Engineering Department and Photonics Center's Challenge was presented.

Wednesday morning and most of the afternoon was spent viewing and analyzing the IPG Photonics Challenge. On Wednesday afternoon the project PIs held an open discussion with the participants to discuss the field-testing process. Thursday and Friday were reserved for questions and discussions of how participants would implement the challenges they had worked with over the previous three days. On Friday morning, PHOTON PBL media consultant and Central Connecticut State University professor Michele Dischino presented the electronic template used to create the Challenges. The long-term goal of the project is that each participant will be able to develop his/her own PBL Challenges using the prepared template.

### 3.4 Challenge Field-testing

All of the PHOTON PBL participants are expected to field-test two of the eight PBL Challenges. The purpose for field-testing the PBL Challenges is to gather data on implementation strategies, student reaction, student learning outcomes, and to provide suggestions for the design and development of the PBL Teacher's Guide that will ultimately accompany each Challenge.

The instructors will answer questions that are presented on a BlackBoard® website hosted by Springfield Technical Community College. Questions include: which PBL Challenges were field test and which level of complexity was used; structured, guided or open-ended; how the Challenge was introduced to the class; how students reacted to the PBL instructional method; and what specific recommendations could improve the Challenges. Instructors will receive a stipend upon completion of their field-testing activities.

#### 4. PHOTON PBL Research

To address the need for more research on PBL in technology education, the PHOTON PBL project will conduct quantitative and qualitative research on the effectiveness of PBL as compared to traditional lecture-based methods with regard to learning outcomes, problem-solving and critical thinking skills, metacognitive development, self-efficacy, and motivation. Researchers will also examine the extent to which specific professional development activities contribute to changes in teaching practices (i.e., transfer of training) among participating faculty. Data sources will include instructor and student questionnaires, classroom observations, personal interviews, anecdotal data, documents and other artifacts. The research will result in a series of published articles and conference presentations.

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