Implementation stories from the PHOTON PBL project

Judith Donnelly[a], Nicholas M. Massa[b], Michele Dischino[c], Fenna Hanes[d]
[a] Three Rivers Community College, 574 New London Turnpike, Norwich, CT 06030
[b] Springfield Technical Community College, One Armory Square, Springfield, MA 01106
[c] Central Connecticut State University, 1615 Stanley Street, New Britain, CT 06050
[d] New England Board of Higher Education, 45 Temple Place, Boston, MA 02111

ABSTRACT

The PHOTON PBL project developed eight multimedia problem-based learning "Challenges" in optics/photonics in collaboration with industry and research university partners for use in technician education programs. More than fifty high school and college faculty from across the U. S. and Romania attended professional development workshops in 2007 and 2008 to become familiar with the PBL method and the Challenges. Teachers then field-tested the Challenges in their own classrooms. In this paper, we present the experiences and reactions of teachers and students who used the PBL Challenges to teach and learn optics/photonics.

Keywords: Problem-based learning, photonics education, community college, technician, inquiry, critical thinking

1. INTRODUCTION

Photonics technicians are problem solvers who use their knowledge of optics, lasers, electronics and related technologies to address real-world applications in the workplace. As the "hands-on" members of an engineering team, technicians design and carry out experiments, build and troubleshoot prototypes, analyze and interpret data and present results to supervisors, peers and customers. Despite the nature of the work they will be called upon to perform, technicians in two-year associate degree programs are usually taught by the traditional instructor-centered lecture method with cookbook laboratories and back of the chapter plug-in numerical problems. There is little in this instructional method to prepare students for the real world of business and industry.[1]

PHOTON PBL, a project of the New England Board of Higher Education (NEBHE) funded by the Advanced Technological Education program of the National Science Foundation (NSF/ATE), sought to address the challenge of educating twenty-first century technicians by developing multimedia problem-based learning "Challenges" in optics/photonics in collaboration with industry and research university partners. In problem-based learning, students learn the process of solving real-world ill-defined open-ended problems while they are learning course content. More than fifty high school and college faculty from across the U. S. and Romania attended professional development workshops in 2007 and 2008 to become familiar with the PBL method and the Challenges. Teachers then field-tested the Challenges in their own classrooms and reported their findings. In this paper, we present the experiences and reactions of students and teachers who used the PBL Challenges to learn optics/photonics.

1.1 The PHOTON PBL Challenges

The PHOTON PBL Challenges have been described elsewhere in detail; the following is a brief summary[2,3]

Each of the online multi-media PHOTON PBL Challenges consists of six main interlinked pages:

- The Challenge overview, a brief description of the problem, a list of photonics principles to be reinforced by the Challenge and prerequisite math and science knowledge
- A short video introduction to the main topic of the challenge to set the context
- An overview of the company or organization where the problem was encountered and solved
- Problem Statement – A re-enactment of the problem statement by the actual people who solved it
- Discussion – A re-enactment of a discussion with the actual people involved in solving the problem
- Solution – The problem solution presented by a member of the technical staff

For maximum flexibility, the Discussion and Solution pages are password protected, allowing the information to be revealed at the discretion of the instructor. For example, to introduce the PBL method to novice problem solvers, the Challenges may be presented in a *Structured* format with the instructor leading students through the Problem Statement, Discussion and Solution in one class period. Students who are more advanced in technical knowledge and/or problem solving skills may complete a *Guided* Challenge, where the Discussion page is withheld until students have spent time researching the problem. This format may take several class periods to complete. Finally, advanced students may be presented a Challenge in an *Open-ended* format, with the instructor acting as a consultant over the course of several weeks. In all cases, students are shown the organization's solution only after they have presented their own solutions for peer review. This provides an opportunity to compare and contrast students' solutions to the organization's solution. Often, students are surprised to learn that more technology is not the preferred solution to a given problem because of increased time or expense.

To assist students' search for information, each Challenge page is accompanied by a link to Additional Resources, including scripts of the video dialog, links to the web site of the organization where the problem was solved, pdf documents with additional specifications and, for the solution, details on how the organization solved the problem. Navigation among the pages is accomplished by a set of buttons on each page. (See Figure 1.)

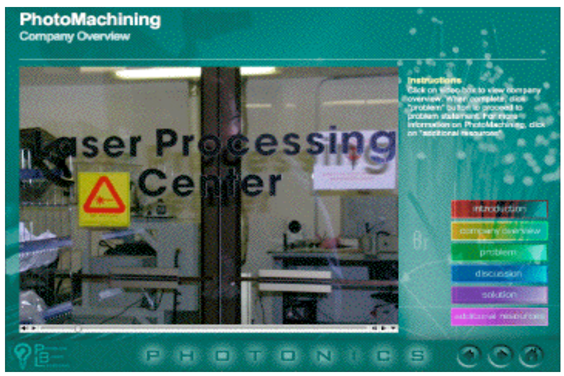

Figure 1. Typical page from an online PHOTON PBL Challenge showing navigation tools on the right side of the page.

1.2 Problem Solving Toolbox

Students accustomed to traditional lecture followed by back of the chapter problems can be truly stymied when confronted with open-ended problems. In order to scaffold the development of problem solving skills, each PHOTON PBL Challenge provides a link to a unique feature of the Challenges: the *Problem Solving Toolbox.* This tool guides students through a systematic approach to problem solving through use of *Whiteboards* that lead students to document each stage of the problem solving process:

- *Problem Analysis* – Identifying what is known, what needs to be learned, and any problem constraints to properly frame the problem.
- *Independent Research* – Setting specific learning goals, identifying necessary resources, and developing a timeline for achieving those goals.
- *Brainstorming* – Collaboratively generating and evaluating ideas and alternative solutions best suited for addressing the task at hand.
- *Test Your Idea* – Developing a plan to validate the solution based on specific performance criteria.

Figure 2 shows the Problem Solving Toolbox page; clicking on each of the four icon leads to a separate Whiteboard (Figure 3). The Whiteboards may be projected onto a classroom whiteboard for collaborative discussion or printed out for individual student use. Experience has shown that students will often skip steps in filling out the Whiteboards in their haste to get to a solution, leading to a solution that does not address all the problem criteria. Instructors implementing PBL Challenges need to stress the importance to students of documenting the problem solving process. By encouraging them to carefully document the problem parameters, criteria for success, required resources, and strategies for testing their designs, students are able to develop much more robust solutions.

Figure 2. Problem Solving Toolbox is accessed by a link from the Problem Statement and Discussion pages

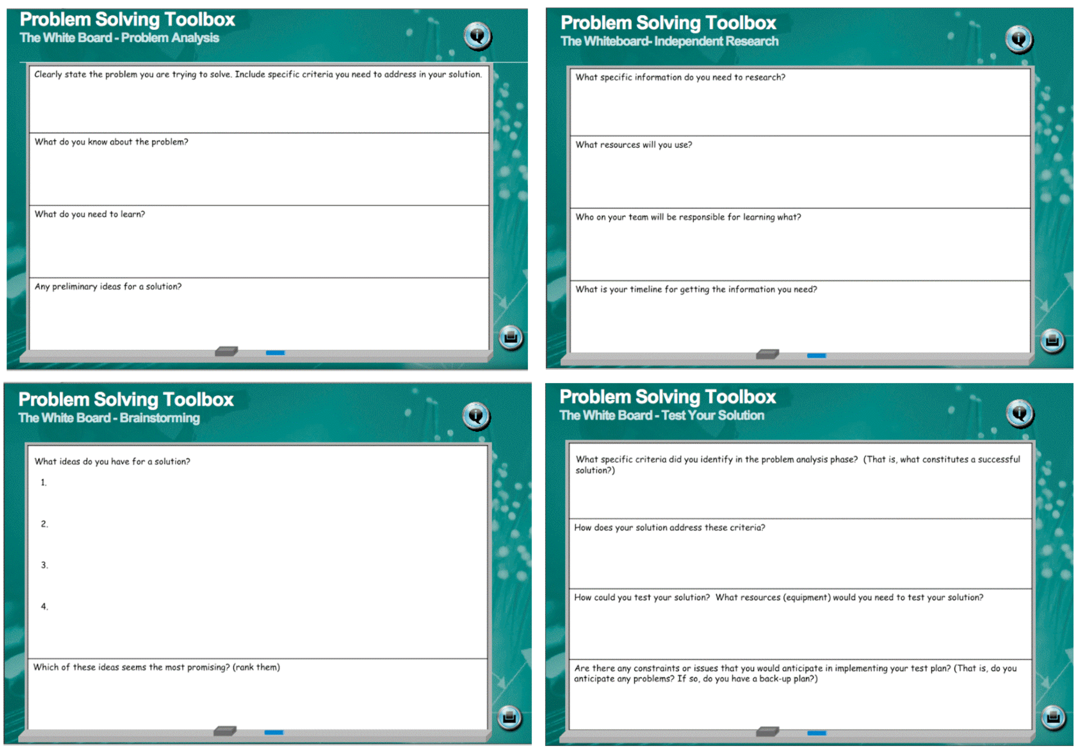

Figure 3. The Whiteboards lead students through the problem solving cycle and assist in developing robust solutions.

1.3 Resources for Teachers

Using PBL in the classroom can be as daunting and uncomfortable for instructors as it is for students. In PBL, the instructor is no longer the "sage on a stage", but assumes the role of consultant, offering suggestions but not answers to student questions. In addition, assessment of student learning is problematic since traditional tests and quizzes do not assess problem solving skills and often do not address deep conceptual knowledge. The PHOTON PBL Challenges provide teacher assistance both within the Challenges and on a separate web site, www.pblprojects.org.

Each Challenge includes a password-protected Teacher Resource page with links to detailed technical information about the problem and its solution, assessment strategies, implementation stories from other users of the Challenge, and a link to national standards alignment. The assessment strategies provide a means to assess three levels of learning:

- Content knowledge is assessed through tests and quizzes. Sample questions and problems are provided.
- Conceptual knowledge may be assessed through creation of a concept map, a graphical tool used to organize knowledge and show relationships between concepts. A sample concept map and a scoring rubric are included for the Challenge.
- Problem solving ability may be assessed through a report on the process used to solve the Challenge, as detailed in the completed Whiteboards. A final technical report form summarizing the Whiteboard information and a scoring rubric are included.

Additional teacher resources are available both for instructors who need a "PBL refresher" and those who would like to try the Challenges but have not attended any of our professional development workshops. A complete implementation guide, a "how-to" video, conference papers and presentations, and information on standards alignment are all available through www.pblprojects.org.

2. IMPLEMENTATION STORIES

2.1 Participant Field-Testing

Each participant in the PHOTON PBL project was asked to field-test at least two the eight Challenges in their classrooms during the 2007-2008 and 2008-2009 academic year. Teachers were asked to respond to five questions after field-testing:

1. Which PBL Challenge did you field-test and how was it presented? (Structured, Guided or Open-ended?)
2. Describe how the Challenge was introduced in your class. For example, was it presented as a supplemental activity in a traditional lecture course or was PBL the primary mode of instruction? How much time was allocated? What resources did the students have available to them? Did students work in teams? What was your role? How did you structure the student activities? Did the students solve the problem and present their solutions?
3. How did your students react to the PBL instructional method? Were they more engaged in the learning process? Was the experience stressful or enjoyable? Did students appear more or less motivated to learn using the PBL format? Did students feel they learned more or less using the PBL format?
4. What specific recommendations (if any) can you make to help us improve the PBL Challenges?
5. How did you use the teacher resources? Which resources did you find most useful?

Teachers responded by mail, email and in a threaded discussion set up for the purpose on the Springfield Technical Community College course management web site. In what follows, the authors have chosen one instructor report for each of the eight Challenges, attempting to balance secondary and post secondary classroom implementation. Additional implementation stories are available in the teacher resources of the Challenges and on the www.pblprojects.org web site.

2.2 Blinded by the Light – A Laser Safety Challenge

Developed in collaboration with the International Laser Display Association, this Challenge was designed to serve as an introduction to the PBL method. The students pictured in the video segments solving the Challenge use the Whiteboards and model good problem solving technique. The problem involves a green laser pointer targeting a small private plane on landing approach. Students must determine if the pilot's claims of permanent injury are reasonable.

The Challenge was field-tested at a community college in the Northeast in the Structured format in an introductory physics course, Introduction to Light and Lasers. Students in the course were from several engineering technology disciplines a well as General Studies. The Challenge was used to teach laser safety during the first laboratory session of the semester. Students were allowed one 3-hour lab session to complete the Challenge.

Twenty-four students worked in six self-selected groups of four students each. At the beginning of the lab session, students were presented with the Introduction, Organization Overview, and Problem Statement videos. Students were also provided with an introduction to the Problem Solving Toolbox, the Whiteboards, and Additional Resource sections to get them started. Students were then instructed to work through the Whiteboards starting with the Problem Analysis Whiteboard to the best of their ability to begin the problem solving process. They were given approximately 45 minutes and had access to classroom whiteboards, computers, and optics lab equipment (laser pointers, optical power meters, safety goggles, etc).

As students worked through the Whiteboards, the instructor moved between groups to provide guidance and address students' questions, but without providing specific answers. Students were strongly encouraged to fill out the Whiteboards as completely as possible. After 45 minutes, students were presented with the Discussion video to provide them with additional information. Students continued working in their groups for another hour. Once again, the instructor moved between groups to provide guidance and assistance. Some students experimented with the laser pointers in a long hallway outside the laboratory to measure the laser's divergence to simulate the problem scenario.

During the final hour of the lab session, each team presented their solution to the class in an informal five-minute presentation. As part of their solution presentation, students were required to describe the thought process used in developing their solutions. The Challenge solution was then presented to the class and a discussion took place in which the groups compared their solutions to the Challenge solution. As a homework assignment after the completion of the Challenge, students were required to complete the problem set provided in the Challenge and complete (individually) the final technical report. Students were given one week to complete the assignments and were quizzed on the problem set.

Overall, students enjoyed the Challenge and thought solving a real world problem was definitely a worthwhile experience. The problem forced them to consider things that would not normally be found in the textbook. One issue that students complained about, but later found valuable, was completing the Whiteboards. Their immediate instinct was to jump directly to a solution without carefully considering all of the problem parameters and constraints. By requiring students to carefully and thoughtfully complete the Whiteboard data, they were better able to properly frame the problem and their problem solving approach in a way that produced more accurate solutions.

2.3 DNA Microarray Fabrication

Developed with the assistance of the Boston University Photonics Center, this Challenge requires students to determine exposure time for a maskless DNA fabrication process given specifications for the optical system and the photochemistry involved. The PBL Challenges were introduced as a supplemental activity in two traditional lecture classes in a four-year college in New York, College Physics II and University Physics II, which included students from different engineering fields. Students were allowed to select two Challenges most closely related to their major, and several chose the Boston University Challenge. The Challenges were delivered to both classes as in the Open-ended format by presenting the Introduction, Organization Overview, and Problem Statement videos. Additional Resources were introduced along with the Problem Solving Toolbox. The Whiteboards were explained as a means of properly framing the problem.

Students were allowed to work individually or in teams for about three months on their two selected Challenges. Each student or team was required to submit a progress report every two weeks and the instructor held a 20-minute meeting with each group once every two weeks. Key concepts for the Challenges and instructions on how to find reliable information online were posted on Angel, a web-based course management tool for course materials and communication. The instructor's role was to answer questions concerning the logistics of Challenges and to make sure that deadlines were met. Each student or team developed, documented, and presented solutions to two Challenges. Since the Challenges were worth 20% of students' overall grade, students put a lot of effort and time into them. Students took full advantage of Whiteboards, Additional Resources, and key concepts involved in the Challenges. Each student or team was required to submit a hardcopy report of the solution proposal.

The majority of students really enjoyed working on the real life problems. More importantly, students were impressed by the Whiteboards and found them to be very helpful and a very effective way to work on the Challenges. Several students reported they were going to keep the Whiteboards for the projects in future courses. In addition, they enjoyed the videos because they made it easier to understand problem. The students felt they learned a great deal of optics by solving real world problems. The instructor reported that students did not seem to be stressed but enjoyed doing Challenges. The instructor commented that in his Physics courses he cannot cover optics in depth simply because there is not enough time to do so. The PHOTON PBL Challenges appear to be the solution to this problem. Using the PBL approach, students learned a great deal of optics outside of the regular classroom, freeing eight lecture hours for other topcis.

2.4 Watt's My Light? – A Lighting Challenge

This Challenge was developed in collaboration with the Center for Lighting Education and Research at California State Polytechnic Institute at Pomona. Students were asked to test the advertising claim that a given CFL is as "bright" as a certain incandescent bulb. This Challenge was field-tested in many classrooms, and in at least three schools students built their own integrating spheres to further test their solutions. We choose to highlight the implementation by a high school in Boston where the Challenge was used in an elective course in Photonics.

The Photonics course was centered on the PHOTON PBL Challenges, using only PBL for instruction. The teacher acted as a resource for the students but gave them little formal instruction. The high school is associated with a major university and was fortunate to have a university professor also serve as a resource for the students. The class spent six weeks on the Challenge, meeting for two hours a week (two meetings, one hour each). This was the second Challenge done by the class.

The solution presented in the Challenge involved the use of an integrating sphere to compare the luminous output of the two lamps. The high school students did not come up with the idea of an integrating sphere right away, but investigated a variety of other ideas. They considered the idea of a photosensor and an enclosure, and their main concern was blocking out room light. Initially, the three groups used the same sensor to take readings of the CFL bulb from a distance of 50 cm. The power readings differed among groups and students hypothesized the problem was that the light coming from the bulb was not spatially uniform. To test this idea, the class built and experimented with an integrating sphere, constructed with a 30" diameter hollow styrofoam sphere. A single sheet piece of paper held in place by balsa wood acted as a baffle (Figure 4).

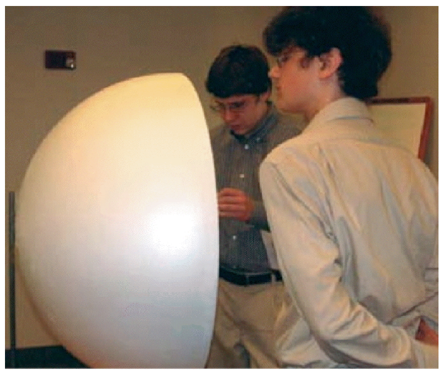

Figure 4. High school students experiment with a home-made Styrofoam integrating sphere.

The instructor reports that highly self motivated students were more successful at PBL than less motivated students. In general, students wanted to develop ideas from first physics principles, and refused to accept the idea that maybe someone in the world had already solved the problem. He indicated that open-ended PBL is probably not as successful in his classroom as a more guided format. Younger students may need more structure to steer them in the right direction.

2.5 High Power Laser Burn-in Testing

This Challenge was developed with IPG Photonics in Oxford, MA and asks students to design a safe and inexpensive enclosure for burn-in testing of a 2 kW fiber laser. The Challenge was field-tested by high school students in Romania, in a "Physics by Experiment" course. The course instructor attended a PHOTON PBL workshop held in 2008, funded by grants from SPIE and OSA and was an active participant in the project. The students worked in both English and Romanian and as part of their PBL experience participated in an online discussion forum with laser specialists in the U.S. Since the classroom had blackboards rather than whiteboards, the teacher created a blackboard version of the Whiteboards (Figure 5).

The Challenge was completed in a structured format using a *Socratic Seminar* with the instructor as leader. Students were divided into two groups: an "inner" circle (10 students) who participated in the discussion of the problem and an "outer" circle (13 students) who observed the two-hour seminar. The seminar began with the distribution of the Company Overview and Problem Statement scripts, presented in English. All participants were asked the opening question, "What do you think are the key terms in this text?" Once begun, the seminar (conducted in Romanian) was driven by questions from the instructor and the participants. Students from the inner circle were asked to compile lists of what they did and did not know and what needed to be learned. These students then presented the lists to the entire class.

The students from the outer circle were required to make specific observations, for example:

- Observe the seminar participant directly across from you. Make note of what he/she is doing during the seminar.
- How many times did each person speak?
- What were the ideas discussed?
- Was there any evidence that a participant changed his or her opinion during the seminar?

At the end of the seminar, the members of the outer circle reported their findings and it was agreed that next time the participants would switch circles.

Students were given a post-seminar writing assignment to complete and were asked to improve the final scheme of the solution. Students also received the URL for the Challenge so they could view the videos. At the next class meeting, students presented new or improved drawings of the solution, answers for the outer circle translated from Romanian into English, their conclusions and some notes from the Internet about this topic. The instructor reported there were active students who asked a lot of questions, responded, made drawings, had ideas and, on the other hand, there were passive students who did not contribute. Teacher and students agreed that solving the Challenge was fun.

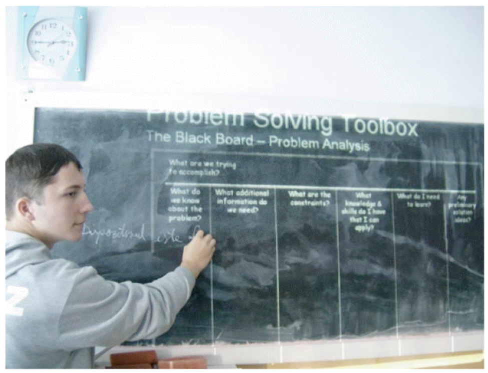

Figure 5. Romanian student works on a PHOTON PBL Challenge using a version of the Whiteboards designed to be used with a black chalkboard.

2.6 Hiking 911 – the Lost Hikers

Hiking 911 was developed with the assistance of the Electro-Optic Center (EOC) at the Pennsylvania State University (Penn State). The main focus of the Challenge is infrared imaging, but in solving the problem (and rescuing two lost hikers in rugged terrain in western Pennsylvania) students must also consider pixel size, resolution, view angle, terrain and aerial surveillance technology. From participant reports, this is one of the most often used Challenges.

An interesting classroom implementation of this Challenge was as a supplemental activity in a high school Advanced Placement (AP) Chemistry class in Texas. Photonics was introduced to students during the two weeks following the AP Chemistry Exam. These students knew essentially nothing about photonics, although all had completed a brief introductory optics unit in their physics classes. After background reading assignments on laser safety and types of lasers, there was a brief lecture and discussion on how lasers operate. PBL was introduced by projecting the IPG Challenge on a screen while the class as a whole went step by step through the presentation of the Introduction, Organization Overview, Problem Statement and Discussion, completing the Challenge in a Structured format. The Problem Analysis Whiteboard was projected and the class contributed to filling in the columns. After this brainstorming activity, the class suggested some ideas for solutions.

Once introduced to the PBL method, the fifteen students in the class were divided into four teams and each team chose either the Hiking 911 Challenge or the Infant Jaundice Challenge (see Section 2.9). The Challenges were completed in the Open-ended format. Students were shown the problem introduction for their choice of Challenge and after that worked mostly unassisted by the instructor. The Challenge took 2 days, that is, four 90-minute class periods. The resources available to students included the text, *LIGHT – Introduction to Optics and Photonics*[4] and Internet access in a computer lab. Students worked independently in groups and within groups where they were assigned roles. The instructor provided little guidance after the PBL concept was introduced and was mostly an observer

The students learned a significant amount about the technology of their chosen Challenge topic as well as new problem solving strategies. The instructor reports he did not assess what was learned in terms of a photonics curriculum but that the goal of the using the Challenge was to introduce problem solving rather than photonics. Students were assessed upon completion of the Challenge through

- completed Whiteboards presenting the outcomes of their brainstorming.
- statement of a possible solution to the problem. (Students did not present their solutions to the class.)
- discussion of what they learned in the process of solving the Challenge.

The instructor reports that the students were very receptive to the PBL Challenges. This group of students was highly self-motivated and the majority enthusiastically participated. They needed very little encouragement to get to work each day. Because the students got to choose from two Challenges, they worked on topics in which they had an interest. The chemistry curriculum just completed was mostly direct instruction from the teacher and PBL provided a change in format that the students enjoyed.

2.7 Stripping with Light, Fantastic! – Laser Wire Stripping

Photomachining in Pelham, NH was the industry partner for *Stripping with Light, Fantastic!* The Challenge tasks students with the design of a laser wire stripping system for 50 micron copper wire. The system must also cut the wire to a specified length. The Challenge was field-tested in a four-year engineering technology program in the Northeast in a Principles of Photonics course. The sixteen students in the course were divided into four groups for this Open-ended Challenge.

The Challenge was presented as a component of the class assignments with 15% of their class grade assigned to this aspect of the course. There were four two-and-a-half hour class sessions devoted to the Challenge for a total of 10 hours over a two-week period. Students were instructed to use the class time to work on the problem. Some classroom time included discussions about the problem solving process. Students worked in teams and had computers available in the classroom. Several students used the library for reference. The instructor's role was that of facilitator, explaining the desired outcome and encouraging students to work together as a group to find solutions. Students were required to presents their solutions in a formal oral presentation to the class with peer assessment.

The instructor reported that students liked the fact they could apply what they learned to the solution of a real life problem. They were very engaged, deliberative, and highly motivated using PBL. Students commented that the problem could have been assigned over an entire semester as a "really big project". The instructor noted that the PBL method is now a permanent part of the curriculum for this course

2.8 Of Mice and Penn – Measuring Mouse Tendons

This Challenge was based on the doctoral research of one of the authors (M.D.) and asks students to develop a method of quickly measuring the cross sectional area of mouse tendons. The Challenge was field-tested by a high school in Missouri and a community college in Iowa, two institutions participating in the PHOTON PBL projects as "alliance partners". A model piloted in earlier NSF/ATE projects of NEBHE, alliance partnerships consist of high school STEM instructors, community college technology faculty, and in some instances engineering faculty from 4-year institutions who collaborate to promote career-based learning within each school, foster photonics education "pipelines" linking secondary and post-secondary schools, and build linkages to local industries that employ photonics technicians.[5]

Using grant funding, the seventeen high school students and their instructor traveled to the community college where they worked with twenty-two college students and their instructors on a two-day joint field-testing experience that provided an opportunity for students to interact in a real-world learning experience. The instructors used the Open-ended format; only the Introduction and Problem Statement videos were provided to the students to reflect the real-world situation encountered in industry. The high school and college students then worked together in teams to research the problem and propose solutions. At the end of the process, each team presented their solution, responded to questions and comments from other teams and defended their solution before the entire group.

The students reacted very positively to the Challenge and were very engaged. The high school instructor reported the experience was stressful at first, but in the end students really enjoyed it. Not only did the students feel that they learned more than in a traditional lecture, they were more motivated and driven to finish the problem. The only disappointment was that that they did not have a chance to try to model their solutions with a hands-on exercise.

2.9 *Shining Light on Infant Jaundice*

The *Shining Light on Infant Jaundice* Challenge was introduced to students using the Open-ended format in a Senior Projects course at a Community College in New England. The course was team taught by two instructors. Students in the class were familiar with the Challenge format and Problem Solving Toolbox through experience with a previous PBL Challenge. In *Shining Light on Infant Jaundice*, students are asked to develop a portable, safe and effective home therapy for infant jaundice. The Challenge was developed in collaboration with partners from Drexel University (Philadelphia, PA), Photodigm (Richardson, TX), and Onsite Neonatal Partners (New Jersey).

The Challenge was presented over a three-week period as a supplemental activity during a weekly 3-hour laboratory class. During the first lab class, students were presented with the Challenge Introduction, Organization Overview, and Problem Statement. Groups of four students then worked through the problem analysis and independent research Whiteboards. They were given one week to engage in independent research and to hold a brainstorming session with their group to discuss initial solution ideas. Students were encouraged to use any and all resources available to them including the embedded Challenge resources, the Internet, books and journals available in the library, and advice from other students and faculty. During the second lab class, initial ideas were presented to the class in a mock "staff meeting" held in a conference room. Students were encouraged to use the peer and instructor feedback received to refine their solutions and generate a detailed test plan, which would be presented as part of a formal classroom PowerPoint presentation the following week.

Once the classroom discussion was complete, students groups were presented with a list of photonics concepts addressed in the PBL Challenge and instructed to create a concept on the whiteboard in the classroom. Students were given approximately one hour to complete the concept map and were asked to explain their concept maps to the rest of the class. In addition to the concept map, students were instructed to complete the Photon PBL final technical report form to summarize their problem solving process. In the end, student performance was evaluated using multiple measures that included their Challenge solution and presentation, conceptual knowledge, and problem solving process captured in the technical report.

Student reaction to the PBL Challenge was extremely positive. They appeared to be thoroughly engaged in the problem analysis stage of the Challenge and put forth a concerted team effort in framing the problem and developing hypothetical solutions. Although students initially complained about the requirement to fill in all of the Whiteboards, after completing the Challenge they were enthusiastic about their use as a systematic approach to problem solving. In fact, one student was overheard telling a student in another class "You should really try this Whiteboard method. It takes more time but it really helps you organize your thoughts so you don't miss anything."

Overall, the instructors found the students much more interested, engaged and motivated than with traditional laboratory experiments. Interestingly, two students found the "Shining Light on Infant Jaundice" Challenge so fascinating that they decided to use the topic as the basis for their senior design project (Figure 6).

Figure 7. Community college students work in the lab on improving the solution to the infant jaundice Challenge.

3. CONCLUSION

The PHOTON PBL Challenges were field-tested in high school and two- and four-year colleges to introduce optics/photonics topics as well as to teach the process of problem solving. The use of the Challenges ranged from supplemental material at the end of a course to replacement for traditional lectures during a course. Instructors who field-tested the Challenges were generally pleased with student learning and attitudes toward the Challenges, reporting that students were highly engaged and motivated to solve the problem and they enjoyed working on "real world" problems. High school teachers indicated the need for additional structure when introducing the PBL method to a younger audience. Several instructors commented that student proficiency in solving open-ended problems has improved in other contexts as well and that they are continuing to use the Challenges in their courses. The Challenges are currently being revised based on field-testing feedback.

4. ACKNOWLEDGEMENTS

PHOTON PBL funded in part by the Advanced Technological Education program of the National Science Foundation (ATE #ATE 0603143) Principal Investigator, Fenna Hanes (Project Manager), New England Board of Higher Education; Co-Principal Investigators Judith Donnelly, Three Rivers Community College; Nicholas Massa Springfield Technical Community College. Website: www.pblprojects.org.

REFERENCES

[1] Massa, N. M., Masciadrelli, G. J., & Mullett, G. J., "Re-Engineering Engineering Technician Education for the New Millennium", Paper presented at the ASEE Annual Conference,Portland Oregon, June 2005.

[2] Donnelly, J., Dischino, M., Hanes, F., and Massa, N., "Creating and using industry-based problem-based learning challenges in photonics: Lessons learned," Proc. ETOP (2009).

[3] Massa, N., Donnelly, J., Dischino, M., and Hanes, F., "Problem-based learning in photonics technology education: Assessing student learning," Proc. ETOP (2009).

[4] Donnelly, J. and Massa, N. [LIGHT-Introduction to Optics and Photonics], Lulu.com, Raleigh, NC (2010).

[5] Hanes, F., "Photon2 is launched with NSF Funding", PHOTON2 Newsletter, NEBHE (2003).