

Problem-Based Learning (PBL)

A Real-World Antidote to the Standards and Testing Regime

NICHOLAS M. MASSA

In 2005, a New Jersey man was arrested for shining a green laser pointer at an airplane on approach to Teterboro Airport, 12 miles west of midtown Manhattan, temporarily blinding the pilot. The man maintains he is innocent. You and your team of three other laser technology students are tasked with determining whether the man is innocent or guilty. Make your case.

Unlike traditional lecture-based instruction, where information is passively transferred from instructor to student, PBL students are active participants in their own learning, thrust into unknown learning situations where the parameters of the problem may not be well-defined and the task at hand ambiguous—just like in the real world.

Research shows PBL provides students with skills that are critical for lifelong learning, such as critical thinking, problem-solving, teamwork and the ability to apply their knowledge to new situations. Given the demands of the new global innovation economy for creative, teamwork-oriented problem-solvers capable of adapting to the ever-changing needs of business and industry, PBL may very well be the antidote to the prevalent standards and testing regime.

Developed in the 1970s for use in medical school education, PBL has since been adopted in other disciplines including business, education, law, nursing and engineering. PBL is a learner-centered rather than an instructor-centered approach, in which the problem situation drives the learning.

PBL is consistent with the recommendations outlined by John Bransford and his colleagues in their seminal publication, “How People Learn.” Based on more than three decades of research on effective educational principles and practices, Bransford *et al.* recommend that to be effective, educators must first draw out and engage students’ preconceptions regarding their understanding about how the world works. Second, in order for students to develop competence in a particular subject area, they must develop a deep foundation of factual knowledge, understand that knowledge in the context of a conceptual framework and organize it in a way that facilitates retrieval and application. Finally, instruction must facilitate the development of students’ metacognitive skills; skills needed to take responsibility for planning, monitoring and evaluating their own learning. With PBL, each of these steps is addressed through engagement in the problem-solving process.

PBL involves four basic stages: *problem analysis*, *self-directed learning*, *brainstorming* and *solution testing*. The process begins with students being presented with an authentic problem to be solved. The problem may be posed by an industry or business partner, or fabricated by an instructor based on real-world events and data. In either case, the first step in the process is *problem analysis*, in which teams of four to eight students collaboratively analyze and frame the problem. This process involves dissecting the problem to identify what is known, what is unknown, situational constraints and a clear understanding of the desired outcome. By identifying these factors, students learn how to frame the problem and develop a plan for action. At this point, preliminary hypotheses may also be developed to help guide the learning process.

The students gather around a whiteboard to analyze the problem. Given what they know about laser pointers, they are skeptical as to whether light from a laser pointer is bright enough to reach an airplane at such a distance, let alone penetrate the cockpit window and blind a pilot. They agree that to solve the problem, certain questions must be answered: How far away was the plane? How powerful was the laser? What were the weather conditions? How much laser light is required to blind a person? How much, if any, laser light entered the cockpit and how long must the pilot be exposed to the laser light to be temporarily blinded? To answer these questions, there is much they need to learn about the properties of laser light, laser safety and basic optics. They need a plan for action.

Self-directed learning involves students taking responsibility for acquiring the knowledge and skills identified as needed in the problem analysis phase. Self-directed learning involves setting specific learning goals, identifying the necessary resources (including human resources) to solve the problem, monitoring comprehension of the requisite knowledge and skills being acquired and evaluating the extent to which the newly acquired knowledge and skills apply in solving the problem at hand. One must be able to positively respond to the question, “Have I acquired the knowledge and skills necessary to solve the problem?”

Given the time constraints imposed by their instructor, the team decides to divvy up the learning tasks. They set a timeline and agree to reconvene in a week to report on what they have learned. Each team member is responsible for acquiring the knowledge required to evaluate a specific aspect of the problem and then sharing their newly acquired knowledge with the others to make the most effective use of their time and resources.

During the *brainstorming* stage, students reconvene to discuss what they have learned in the self-directed learning phase in hopes of converging on a possible solution to the problem. Individual contributions are presented without criticism or judgment. By expressing ideas and listening to what others say, students are able to gauge their own level of knowledge, absorb new information, increase their levels of understanding and awareness, and converge on a solution that represents the collective knowledge of the group. Brainstorming is the cornerstone of collaborative learning.

A week later, the students reconvene to share what they have learned with the other team members and brainstorm possible solutions. Their instructor is present to help guide the process and provide additional information if needed. After careful analysis and discussion, the team agrees that it is unlikely that the laser had enough power to penetrate the cockpit window long enough to blind the pilot under the given circumstances. To be sure, however, they decide to validate their solution by setting up a test to simulate the problem situation.

The final stage in the problem solving process is *solution testing*. Once a tentative solution has been agreed upon by the group, it must be evaluated to determine if it satisfies the desired outcome criteria established in the problem analysis phase. At this point, a formal test and evaluation procedure is developed with performance benchmarks. If the solution satisfies the desired outcome criteria and benchmarks, a formal presentation of the solution is presented in which peer review is used to validate the problem solution. If the problem solution does not meet the desired outcome criteria or performance benchmarks, the problem-solving process is repeated until an acceptable solution is reached.

Using what they have learned about how a laser spreads out after traveling a certain distance, how much light might be reflected by the cockpit window and how much laser light power is required to temporarily blind someone, the students design a test plan for validating their solution. They shine a green laser pointer onto a light detector mounted behind the windshield of a car parked at a distance estimated to be the same as that of the approaching aircraft and

measure the laser's power. They repeat the experiment several times at varying distances to obtain a range of values. They now have their answer. The results are ready to be presented to the class for peer review.

The PBL process may be repeated several times to solve a single problem. During this process, an instructor or tutor serves as a facilitator, guiding the students as they seek out resources and providing additional information upon request, which may include direct instruction. In summary, the nature of what is learned is dictated by the problem situation, and the responsibility for acquiring the knowledge and skills required to solve the problem is placed on the student.

Exactly how PBL is implemented depends on the context in which learning is to take place and the preparedness of the student. In its purist form, PBL involves presenting students with an authentic problem *prior* to any instruction of preparation. The idea is to use the problem to introduce the concepts and problem-solving skills necessary to solve the problem. Learning occurs in a small group facilitated by a tutor. Since its introduction in medical education at McMaster University in the 1970s, a number of adaptations have been developed.

For example, the New England Board of Higher Education (NEBHE) is developing a series of multimedia-based PBL instructional materials focused on photonics through the National Science Foundation (NSF)-funded *Photon PBL* project. Institutional modules, called *PBL challenges*, developed in partnership with the photonics industry and university research labs present authentic real-world photonics problems in the context in which they were developed. Examples of challenges posed to students include developing a safe method for testing high-powered lasers at maximum power unattended for a 100-hour period, evaluating optical filters appropriate for a UV photolithography system used to fabricate DNA microchips for genetic engineering research, and the use of high-powered lasers for cleanly and accurately stripping fine wires needed for diabetes testing devices. "The students believe that they learned a great deal more by solving a real-world problem than just by listening to a lecture or just reading about it," says Gary Beasley, an engineering technology faculty member at Central Carolina Community College using the Photon PBL instructional materials.

PBL is not another educational fad. It has been tried and tested, and it makes sense. If education institutions are to produce graduates capable of solving real-world problems, PBL is a no-brainer.

Nicholas M. Massa is a professor of engineering technologies at Springfield Technical Community College. Email: massa@stcc.edu.