Best Practices

Problem-Based Learning
Problem-Based Learning (PBL) is a non-traditional teaching technique where “the problem drives the learning” (Tse & Chan, 2003). First, a problem is presented. Students must then search for the information needed to help them solve it (Salas, Segundo, Álvarez, Arellano & Pérez, 2014). In PBL, “learning is student-centered” (Tse & Chan, 2003) and the instructor’s role is not lecturing, as in the traditional style of teaching that has dominated engineering and science education, but coaching the students to acquire knowledge and to become “self-directed learners” (Forcael et al., 2015, Stanford University Center for Teaching and Learning, 2001).

Why Use Problem-Based Learning?

Problem-based learning promotes a better understanding of course concepts and improves the problem-solving skills of the students as well as their communication, presentation and teamwork skills. Research has shown that students find PBL to be a very “motivating and effective means for learning” (McLoone, Lawlor & Meehan, 2016; Forcael et al., 2015). Students are more engaged in class because they recognize that they are acquiring important skills which will help them succeed in their future careers (Stanford University Center for Teaching and Learning, 2001). The combination of problem-based learning with traditional teaching in engineering and science “strengthens the teaching-learning process” (Salas, Segundo, Álvarez, Arellano & Pérez, 2014).

In this issue of Best Practices, we will explore different problem-based learning strategies, with a focus on teaching in STEM.

Problem-Based Learning Strategies

Case-Based Learning

- To get students interested in the lesson, the instructor presents a real-life example of an open-ended problem for them to solve
- Students brainstorm in small groups for a few minutes to formulate their ideas
- Through online simulations or interactive discussions, students understand that as yet unknown fundamental principles are needed to solve the problem
- The instructor then introduces the fundamental concepts needed to solve the problem. This can be done through case studies, scenarios, field trips and online tours

Example: Case-Based Learning

Nasr and Ramadan describe how case-based learning was used to teach the laws of thermodynamics (2005). To explain the first law of thermodynamics, the instructor began by presenting an online simulation showing a car piston-cylinder system where the law applies. The students brainstormed in small groups for five minutes to formulate the problem. Through discussion, students discovered the need for an energy principle to understand the process by which the car piston-cylinder system worked. This led to the introduction of the first law of thermodynamics (Nasr & Ramadan, 2005).
In a subsequent lesson on the first law of thermodynamics, the instructor started with an online tour of a coal-fueled steam power plant. The students then brainstormed trying to understand how the water turned into steam. They concluded that the 1st law of thermodynamics as it was first applied to closed systems (the car piston-cylinder system) needs to be changed when working with open systems, i.e. steam power plants (Nasr & Ramadan, 2005).

**Inquiry-Based Learning**

- The instructor poses a problem to students without giving any background information
- The students attempt to solve the problem in small groups based on what they already know from the course
- The instructor then explains the fundamental concepts needed to solve the problem
- After the explanation, the instructor dedicates time to review the problem with the students and to address their questions
- Another problem can then be presented to the students which they must solve using what they just learned

**Example: Inquiry-Based Learning**

Students in a civil engineering class were divided into groups of four. The instructor presented an engineering project scheduling problem to students without explaining the concept of the critical path project modeling method. The students were then asked to attempt to solve it using the scheduling methods taught previously in the course. Once students completed this exercise, the instructor explained the critical path method and reviewed the problem with them. Then, the instructor opened the floor for questions. After the review, the instructor gave a second problem to the students and asked them to solve it in groups using the critical path method (Forcael et al., 2015).

**Design-Based Learning**

- Students are divided in groups and required to work on a design project through the semester
- The instructor works as a facilitator and provides criteria for the project
- The instructor sets the deadlines for reports, presentations, etc. and provides clear rubrics for the assessment of the project
- Based on the fundamental concepts that students have learned in previous courses and through their progressive research, the students will develop a design project and present their model at the end of the semester
- Throughout the semester, workshops about ethics, technical report writing and presentation skills help students acquire the skills needed to finish their projects successfully (McLoone, Lawlor & Meehan, 2016)

**Example: Design-Based Learning**

Students were given the task of designing a scientific calculator using microcontrollers (Tse & Chan, 2003). Two major criteria were set: the calculator should (1) perform operations in the right sequence and (2) have the ability to check for errors in case of wrong user input. The instructor set the milestones for the project and the areas that will be assessed, including functionality of the calculator, hardware design,
the interface between the software modules, presentation/report and built-in programming capability. The project was divided into four major components: hardware design, software development for the keyboard and the display interfaces and finally the mathematical algorithm. During the lectures, students were provided with the technical information needed for their design. In addition, they had to gather more information on their own from different sources to strengthen their ideas.
Work Cited


