Chapter 4
A Guide to the Art of Crafting Engineering Problems for Problem–Based Learning (PBL)

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ABSTRACT
An effective problem is the heart of problem-based learning (PBL). Problems play an important role in achieving learning outcomes, assessing learning process, providing a learning context, stimulating thinking skills, and catering for teaching and learning activities. Although a number of criteria that characterize effective PBL problems have been identified in the literature, crafting problems according to the criteria is a challenging task for these problem crafters in most disciplines, especially engineering. The aim of this chapter is to propose a PBL problem crafting framework and describe techniques to craft engineering problems. The problem crafting framework consists of five interrelated principles representing the characteristics of effective problems which have been identified and extracted from literature articles. These principles are aligned with the objectives of how to use problems as the basis for learning. As a guide, a sample problem is included to demonstrate the technique, and how the problem has been mapped to the five principles of effective engineering problems. Feedbacks from students are included to put forth their perspectives on the effectiveness of these engineering problems.

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INTRODUCTION

Problem-Based Learning (PBL) is a student-centred teaching and learning methodology in which the problem is the basis from where new knowledge is constructed using the prior knowledge as the foundation. PBL lies in the constructivist learning framework as its learning environment is designed and executed to be inductive and cooperative (Savery & Duffy, 1995; Mohd-Yusof, Helmi, Jamaludin, Harun, 2010). Unlike conventional transmission teaching approaches, PBL enables students to become producers, rather than consumers of knowledge. Unstructured case studies that are real or emulate real life problems would help students develop cognitive and metacognitive skills besides empowering them to become self-directed and lifelong learners. As far as the course learning outcomes in engineering are concerned, PBL would equip students with essential technical skills before entering the actual workplace. In this approach, particular emphases are placed on critical thinking, problem solving and team working skills.

The idea of using problems as the driving force for learning in PBL has been discussed by Duffy and Cunningham (1996), and Weiss (2003) as follows:

- **Deliver the intended learning outcomes.** Problems are the instruments used to achieve the intended learning outcomes. Students are not left on their own without being guided during the PBL experience.
- **Assess learning process and the achievement of learning outcomes.** Problems function as tests to assess the level of student learning, whether they were able to reach deep understanding or only at surface understanding. This will in turn provide feedback for facilitators to give support as part of formative assessment so that students may improve themselves as learners.
- **Provide context for learning as well as replication of professional practices.** Problems provide learning contexts in which the intended learning outcomes are embedded into the problems. Applications of certain concepts, principles or procedures are required in order to solve the problems. The uniqueness of using problems is due to its portrayal of job specifications, illustration of the working scenarios, and simulation of challenges that students may face in their professional practices. Hence, students are trained to meet the needs in the actual working environments.
- **Stimulate and train thinking skills.** Problems serve as tools to stimulate and train thinking skills, beyond solving the problems. Problems that are designed at a certain degree of complexity have the potential to promote higher-order thinking and enhance meta-cognitive skills.
- **Cater for teaching and learning activities.** Problems provide platforms for learning activities and activate learning process to support the design and implementation of effective learning environments. Student participation in learning activities is essential to help them develop certain skills, for instance, self-directed learning, lifelong learning, problem solving, critical thinking and communication skills.

In PBL, problems serve as the backbone of learning to deliver the intended learning outcomes that include acquisition of knowledge through deep learning, and development of skills through participation in learning activities. Problems should motivate students to learn and prepare them for the real world by ensuring that the intended learning outcomes are achieved after they solve the problems. Since problems act as stimulus for learning in PBL, crafting the problems by itself is a challenging task in most disciplines, including engineering. Unlike its use in medical studies,
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