Chapter 1
Bridging Product Design with Materials Properties and Processing:
An Innovative Capstone Course

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ABSTRACT

Innovative products improve the quality of our life and are important for the prosperity of the chemical and materials industries. This chapter introduces a product design capstone course for chemical engineering seniors at the University at Buffalo (SUNY), USA. The course encompassed the following themes: a general framework for product design and development (identify customer needs, convert needs to specifications, create ideas/concepts, select concept, formulate/test/manufacture product, intellectual property, safety, environmental, marketing and financial considerations); and (nano)structure-property relations that guide the search for materials (typically mixtures, blends, or composites) with particular properties. These two main themes are reinforced by case studies of successful products. The course material is integrated into nanostructured product design projects that are drawn from real-world problems. This chapter discusses the course organization, learning outcomes, teaching techniques, assignments, assessment, and student feedback. Throughout this product design course, students received significant exposure to real materials development problems and strategies.

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INTRODUCTION

In addition to addressing the question "How should we make it?" (process engineering), several practicing chemical and materials engineers are concerned nowadays with the question "What should we make?" (product engineering). Chemical and materials engineers and the companies that employ them have traditionally focused in the efficient production of commodity and specialty chemicals and materials, but are increasingly active in the development and production of

1. Formulated products;
2. Consumer goods;
3. Bio-based concepts; and
4. Devices.

Formulated products are multi-component systems that have been designed and manufactured to meet end-use requirements. They are often multifunctional (i.e., they accomplish more than one function of value to the customer) and nano/micro-structured (i.e., their function and perceived value derives significantly from their internal structure at a lengthscale of 0.01–100 μm). Formulated products, which include bulk and shaped solids, semisolids, liquids, and gases, are also known as structured products, engineered products, dispersed systems, or chemical-based consumer products. Consumer goods of interest to chemical and materials engineers offer functionality that is based on chemical/physical technology. Bio-based concepts include biomaterials, drugs, and technologies based on metabolic, cell, or tissue engineering. Devices include in their function physical or chemical transformations (Costa, Moggridge, & Saraiva, 2006).

The various chemical and materials-based products may have little in common in terms of appearance or performance. However, they share common principles and practices in terms of development and manufacturing. Thus there is a need and the opportunity for introducing a chemical/materials product design course. Asking engineering undergraduate students to view technology development and product innovation through the lens of customer needs is an altogether different approach than what they are usually exposed to in their core engineering courses. This not only compels them to consider technology from the viewpoint of its prospective users and financiers, but also allows students to synthesize and apply fundamental technical lessons from their other courses towards real-world, everyday applications.

This chapter sets out to highlight themes which guide the Product Design course and the manner in which such a course exposes students to the principles of product design. A description of the course organization leads into a review of the deliverables that students are tasked with, and culminates in examples of student work. The examples demonstrate how students practice design principles and techniques, and implement chemical and materials-based technical knowledge, accrued throughout their degree program, in order to pursue solutions to real-world challenges.

New pressures facing industry, namely increased competition and tighter budgets, are driving emphasis towards product innovation. Consumer demands continue to become more specialized, and nanostructured products present an opportunity to economically address these demands. This forms the case for preparing chemical and materials engineers for their evolving job responsibilities, by exposing them to new design techniques and perspectives, and also technical materials knowledge. Students should also become accustomed to interpreting market pull and needs into products with desirable attributes. Companies currently value these skill sets, as they can translate into higher productivity and less employee training.