A Multi-scale Chemical Engineering Product Design: Design of a Transdermal Delivery System

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It has been suggested that the future of chemical engineering is in product design rather than traditional process design. Chemical engineering research has become more molecular and biological in scope. Therefore, design at different scales, from the macroscopic scale to the atomic and sub-atomic scales is also becoming more important. Similarly, biology is joining chemistry and physics as an enabling science for chemical engineering. Therefore, it is imperative for chemical engineering educators to develop educational modules to address this change in educational paradigm. Design of a transdermal delivery system is an excellent design case study to expose students to the principles of product design, to the principles of multi-scale design, and to a problem involving applications of the biological sciences. This assignment was given to the senior class in chemical engineering at West Virginia University for the 2003-04 academic year.

The class was assigned the task of investigating all drug delivery systems, but told to focus on transdermal systems. A framework for chemical product design was followed. In the fall 2003 semester, they identified the **need** for transdermal delivery systems by learning their advantages over traditional drug delivery systems. The students generated **ideas** for different products by identifying the characteristics of drugs that are suitable for transdermal delivery systems. Then, they **screened** the ideas to rank potential drugs for such a system. In the spring 2004 semester, the assignment was to design and determine how to **manufacture** the transdermal delivery system.

In terms of multi-scale design, a transdermal delivery system illustrates design from the macroscopic scale through the molecular scale, though the present design stopped at the nano scale. At the macroscopic scale, the transdermal delivery system must be assembled and be customer friendly. At the mesoscopic scale (between macroscopic and microscopic), the pharmacokinetics of the drug can be modeled. At the colloidal scale, adhesion must be understood in order to facilitate selection of a suitable adhesive. At the microscopic scale, the mechanism of transport of the drug through the skin must be understood. At the nano scale, the drug is usually mixed with enhancers and/or excipients. The former may alter the permeability of the stratum corneum, the external layer of skin most often acting as the limiting resistance, to facilitate delivery. The latter are pharmaceutically inactive ingredients such as skin moisturizers usually found in transdermal patches. One example of a molecular-scale design would be to design the drug based on an understanding of the desired pharmacology; however, this was beyond the scope of the current project.

A summary of the final student project will be presented. An assessment of the project based on departmental rubrics will be discussed. Finally, suggestions for similar projects will be enumerated.