Chapter 7
Integrating Sustainable Design and Systems Thinking throughout an Engineering Curriculum

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ABSTRACT

The Madison Engineering Department was founded on the recognition that engineers are no longer constrained to disciplinary boundaries, and instead, must work across disciplines as members of global communities and multidisciplinary teams. The program offers a single undergraduate engineering degree that focuses on sustainable design and systems thinking. Since the inaugural class started in 2008, the faculty has been striving to integrate environmental, social, economic, and technical contexts of sustainable design and systems thinking as common curricular threads. This chapter discusses courses taken by students freshman through senior year to illustrate how content integration, developmental instruction, and a problem-based learning framework are used in Madison Engineering Department to purposefully transition students through Bloom's levels from knowing and thinking to simulating and doing to quantifying and applying with the goal of training students able to understand systems holistically, describe and analyze tradeoffs, understand resultant perturbations, and design effective, sustainable solutions.

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ORGANIZATION BACKGROUND

In order to prepare our engineering students to tackle the complex problems of sustainability, engineering programs must provide students with a holistic education that incorporates sustainability throughout the curriculum (Kagawa, 2007; McKeown, 2002; Moore, 2005; Pappas, 2012; Pappas & Kander, 2008a, 2008b; Thom, 1998). Academic disciplines are no longer discrete, and consequently, need to work together to integrate ideas to provide students with a holistic education. Students should be trained to think flexibly and to be adaptive; their education should prepare them to overcome the challenging multidimensional problems of sustainability. "Sustainability education needs to be incorporated into core curricula and courses in many disciplines" (Shriberg, 2002, p. 261). Students should be exposed to sustainability in a variety of contexts across a variety of classes. Their training should allow them to understand and assess tradeoffs, make decisions, and solve problems.

Arguably sustainable engineering and the future roles of engineers is not completely defined but there appears to be consensus that engineers trained in sustainable engineering will have the following skills (Allen et al., 2008; Allenby, Allen, & Davidson, 2007; Carew & Mitchell, 2008; Pawlowski, 2008; Segalàs-Coral, 2009).

- The ability to adopt systems level thinking/tools to define problems and propose solutions.
- The ability to identify the environmental, social, economic and technical considerations of a given problem scenario.
- The ability to assess the impacts associated with these considerations.
- The ability to identify the constraints these considerations place on functionality.
- The ability to propose solutions grounded in appropriate scientific data.
- The ability to make educated decisions using a holistic approach founded in the concepts of sustainability that are in alignment with ethics and values of the profession.

Beginning in December 2005, the Madison Engineering Department at James Madison University (JMU) was created to be an engineering program with a different approach to teaching engineering—one that trains students to have these abilities (Kander, 2008). James Madison University is a public regional university located in Harrisonburg, Virginia—the heart of the Shenandoah Valley. James Madison University has a total enrollment of approximately 20,000 students across all academic programs with approximately 1,700 of those students enrolled in a graduate program.

The Madison Engineering Department was founded on the recognition that engineers are no longer constrained to disciplinary boundaries, and instead, must work across disciplines as members of global communities and multidisciplinary teams (Pappas & Kander, 2008b). The engineer in question should recognize the world as a complex system of interconnected complex systems where a solution to one problem may (and likely will) precipitate whole new problems (Pappas, 2012). This engineer should be able to communicate their ideas and also listen to the ideas of others; they should embrace lifelong learning; and they should embody the ethics of a professional engineer. But also, this engineering should have the values and behaviors to match of an individual that not only cares to create solutions today but also strives to provide opportunities for future generations to create helpful and healthy solutions for themselves. In short, the Department of Engineering aims to train the engineering versatilist— a term invented by Garner, Inc. and popularized by Friedman (2005) which describes an individual who can "apply depth of skill to a progressively widening scope of situations and experiences, gaining new competences, building relationships, and assum-