Integrating Sustainability Into Engineering: Why, How, Risks and Rewards

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Several leading voices in the science and engineering communities have been calling for reform in engineering education since the 1990s. The initial urgency was to prepare graduates to be better prepared for life in industry with stronger teamwork skills and abilities to communicate.

Almost 20 years later, the stakes have increased dramatically, and now the emphasis has shifted from the health and welfare of industry to that of the very environment and social systems on which industry relies. Even the nonbelievers in the sustainability movement must concede that a collapse in the functionality of social or environmental systems will also destroy the economy.

Our training in the sciences, however, does not give us the luxury of disregarding the preponderance of evidence. Because our economy and challenges are now global, it is not an understatement to say that the human race is facing the potential collapse of the systems that enable the human race to thrive.

To answer the question of why we should integrate sustainability into engineering, we need only to remember our statement of professional ethics. It compels us to "dedicate [our] knowledge and skill to the advancement and betterment of human welfare" (National Society of Professional Engineers "Ethics Creed"). If this is not enough, we can consider the words of William Perry, former secretary of defense and chair of the recent National Academy of Engineering's grand challenges for engineering committee, "[An] engineer's job for the 21st century is to save the world ... in some cases, from the destruction that technology enabled" (www.engineeringchallenges.org).

Integrating concepts

But how are we to go about integrating these concepts into a curriculum that seems already packed with information? This was the question the California Polytechnic State University materials engineering faculty struggled with as it began a journey that would reform 80% of the courses taught to the school’s materials engineering majors. The hardest part of answering this question was directly evaluating all of the current curricular content, and honestly asking the question, "Is this really necessary for today's graduate?"

For engineers who have been educated in the deconstructivist practice of studying and appreciating the parts (versus the whole), questioning the value of our treasured technological minutia is taboo. Yet doing so is the first step in the journey of figuring out how to integrate sustainability into engineering curricula.

The second step involves understanding the cognitive, affective and social skills that must be strengthened if we, as a global society, are to design our way into a sustainable future. For the uninitiated, an excellent starting place is *The Necessary Revolution* by Peter Senge, Bryan Smith, Nina Kruschwitz, Joe Laur and Sara Schley. To see how this translates into new skills for the engineer, consult a presentation by Leah H. Jamieson, dean of engineering at Purdue University, that was delivered as the main plenary at the American Society for Engineering Education 2007 Annual Conference. In her presentation, available at the www.asee.org, she identifies a number of right-brained competencies, such as reflection, creativity, ethical development and holistic thinking.

At the same time, we must better understand the scientific evidence. The University of Michigan's Center for Sustainable Systems has made available an excellent set of fact sheets that outline evidentiary picture for sustainability (available at www.css.snre.umich.edu/).

Armed with a sense of the knowledge and skills that engineering graduates must have, we take the third step: redesigning the learning experiences for engineers to incorporate not only the right stuff, but also the right learning environment and the right learning activity. In essence, faculty must draw on educational psychology findings, designing learning experiences in a way that leverages what is learned through how it is learned. This is also the point of Jamieson's message: how you learn engineering is as important as what is being learned.

Because no effective design can be undertaken without an effective design methodology, the engineering education designer would be wise to adopt an appropriate design methodology guide. One that has worked for us has been the Fink Taxonomy of significant learning. In contrast to the more commonly used Bloom's Taxonomy of the Cognitive Domain, Fink's is cyclical, rather than hierarchical, and incorporates the range of skills that one needed for sustainability in engineering.

In practical terms, this redesign will involve simple changes to the way a classroom is experienced. For example, the data on learning show that traditional lectures should give way to active modes of learning if the goal is more effective understanding and retention of the material. It will also involve incorporating new perspectives, new mental models and new engineering tools (such as life-cycle analysis or the computation of environmental footprint). A proposed roadmap to integrating these concepts and tools into the engineering curriculum can be found at www.csine.calpoly.edu/curricular-resources.php.

Risks and rewards

At this point, the "how" may register as a daunting, insurmountable task. There most certainly is great risk in changing the educational status quo, especially in well-established, conservatively oriented fields, such as engineering. However, we have an imperative to integrate sustainability into engineering education. The risks of not doing so genuinely outweigh those of doing so.

After a five-year process of converting our program to one that integrates sustainability, we can happily report that the process has led to measurable improvements in all areas of our graduating students' performance, including the traditionally emphasized areas of engineering design and the application of science and math. The other metrics of health are greater levels of motivation, collaborative interaction with peers in the learning process and levels of moral reasoning exceeding that of professionals with a master's degree.

We have also experienced an increase in retention of our students, resulting in more than a 40% growth in our undergraduate materials engineering student body to roughly 175 undergraduates. External advisory board members report that the students are more strongly reflecting the qualities that they desire for those in a dynamic, global workforce.

Our choice to integrate sustainability into our materials engineering program is not over, and it has not been without trials (and errors). However, our investment has paid off manyfold, through the priceless reward of knowing that we have dedicated our professional knowledge and skill to the advancement and betterment of society.

Each of us will make a difference in the world by his or her choices. For some, the choice could be to transform their use of engineering education. For others, the choice could be to keep doing what has always been done. In the end, the question will be, "Is it the difference we want to make?"

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