Strategic Engineering

1. Overview

The primary focus of my project is to increase awareness of environmental and sustainability concerns related to engineering work within the engineering community. My hope is that raising awareness of such concerns will ultimately influence the decisions of engineers. I have chosen the form of my final deliverable to be educational materials for an approximately 60 minute workshop, which will include a pre/post course activity (for evaluating workshop effectiveness) and presentation slides. Each slide will have notes associated with it (viewable under each slide in PowerPoint) describing the material that will be presented with the slide. The materials will be sufficiently high-level (generalized) to be applicable across a wide range of engineering fields. I will also submit a supplementary author's note (on the order of a few pages) which explains the decision-making behind the course content and presentation.

Essential project goals:

- Understand the typical worldview of practicing engineers
- Understand the social, environmental, and sustainability (SES) concerns that most practicing engineers are or are not aware of, and why
- Prepare educational materials which will raise awareness of social, environmental, and sustainability (SES) concerns, making the case for why they are important within the worldview of practicing engineers

2. Final Project Submission Components

My Complete Project Submission includes the following:

- This document (Final-Project-Submission.docx), which includes:
    - Project overview
    - Definition of workshop audience, learning goals, and learning needs
    - Author's note
    - Context
- A sample pre/post workshop activity (Pre-Post-Activity.docx). Conducting this activity will allow me to measure the ability of my audience against the defined learning goals of the workshop. There is both a pre-workshop activity which I can use for benchmarking and a post-workshop activity for evaluating the effectiveness of the workshop.
- A final version of my PowerPoint presentation for use in the workshop (Workshop-Presentation.pptx). Sources and citations not discussed in the Context section of the current document will be found in the "Notes" associated with each PowerPoint slide.
- A document outlining some of the lessons that I learned as a result of working on this project. (Lessons-Learned.pptx)

3. Workshop Audience, Learning Objectives, and Learning Needs

When designing educational materials, it is important to understand the audience and have clearly defined learning objectives. To accomplish this, I interviewed 10 practicing engineers in order to understand their awareness of social, environmental, and sustainability concerns and if said concerns at

all factor into their engineering decision-making. From the information gathered in the interviews, I was able to define an audience and my learning goals for the workshop.

Audience:

Practicing professionals who identify as engineers who are not consciously aware of the social, environmental, and sustainability impacts of engineering decisions.

Justification: The audience includes businesspeople trained as engineers, engineering managers, and engineers. Each of these groups of people plays a key role in the decision-making of any engineering project; increased awareness within these groups of the SES impacts associated with engineering decisions could lead to positive change. The audience also includes professionals in any industry and with any level of experience. Through my interviews, I found that neither of these factors correlated with awareness of SES issues. The course will not target professionals who are already conscious of the SES impacts of engineering decisions.

Each of the learning objectives iterated below is something that I would like to convey to my course participants. However, I have come to realize that it would be impossible to achieve all of said objectives in the form of a 60 minute workshop. It is sometimes difficult as a teacher to remember that information doesn't set in a learner's mind immediately. I have had several years to internalize the material that I will be presenting. I need to give my audience sufficient time to internalize the information. As such, I will indicate whether or not each learning objective will be addressed in the workshop.

Learning Objectives:

1. *Increase participants' awareness of the many impacts of engineering decisions on the world at large, some of which are social, environmental, and sustainability impacts.* [Workshop priority]

   Justification: Many interviewed engineers were not aware of the SES impacts of their engineering decisions. The first step in making more responsible decisions is to be aware of a broader range of considerations. Even if decision-making is not altered, a more informed decision can be made with greater awareness. At the least, awareness compels the participant to take personal responsibility for the impacts resulting from a conscious decision.

2. *Increase participants' ability to identify and articulate potential technical and business risks associated with causing negative social, environmental, and sustainability impacts.* [Workshop priority]

   Justification: Legitimate business risks are associated with negative SES impacts. Many interviewed engineers were not aware of the scope of these risks, though a few more experienced engineers were aware. An understanding of the business risks will justify awareness of SES considerations. These risks also provide a way for an engineer to justify SES-responsible engineering options to key decision-makers, such as managers and businesspeople.

3. *Increase participants' ability to identify and articulate find technical and business solutions which improve social, environmental, and sustainability conditions.* [Out of scope of workshop]

    Justification: It is sometimes difficult to recognize how the structure of the system one operates within affects one's decisions. By taking a step back, one can draw connections between a particular business model or business strategy and the resulting SES impacts. These structures can be modified to promote better decision-making that ultimately benefits both the company and the world at-large. (Note—this point draws heavily from the Sustainability and Entrepreneurship course taught by my mentor, Professor Brad George.)

Lastly, the audience has specific learning needs which were drawn from my interviews. All of the below learning needs apply to the workshop.

Audience Learning Needs:

1. *The audience must be respected as knowledgeable, experienced professionals.*

    Justification: The audience will be significantly less receptive to the course material if this condition is not satisfied. This is particularly important because I will likely be younger than all members of my audience, and will not be able to command authority beyond my content. I especially do not wish to be perceived as claiming superiority in any way (e.g. morally).

2. *Participants must be given the opportunity to apply the course content to their unique, individual engineering context.*

    Justification: Many interviewed engineers were unable to articulate the full societal role of their work. Without the ability to apply the course content to their own context, participants may not think that the course content applies to them and/or lose interest.

3. *Participants should feel optimistic about their ability to make better engineering decisions that account for SES constraints.*

    Justification: Many interviewed engineers were optimistic about the future and the ability of technology to solve many (but not all) societal and world problems. It is outside of the scope of my learning objectives to have participants realize that technological challenges are often the least difficult type to solve (and this can be a very discouraging realization, from personal experience).

4. *Justifications of SES concerns should be made from an anthropocentric, capitalist worldview.*

Justification: Most people (including engineers) have a strongly anthropocentric worldview. Though my worldview tends to be less anthropocentric than average, this is not something I can (or intend to) change in my course participants. Many interviewed engineers also felt strongly positive about the capitalist system (some even felt that engineers are one of the central drivers of capitalism). Participants should feel that my content fits within their likely anthropocentric, capitalist worldview so that they are receptive to it.

4. Author's Note

Ever since I was a kid, I have always loved tinkering. I love to build things. Becoming an engineer was never really a choice—I have been an engineer my whole life.

This is the origin story I hear most frequently when I talk to practicing engineers and my peers about why they decided to become engineers. Not me. This isn't to say that I wasn't curious (I started relentlessly asking my parents questions about how the world works from age 4), or that I didn't love math and science (which have always been my strongest academic subjects). I was no more of a tinkerer than my peers who have become scientists, businesspeople, historians, journalists, educators, etc. While my time at Olin has taught me the skills I would need to be a tinkerer, to this day, I am not one. I do not build for the sake of building. I am not an engineer by default. I consciously chose to be an engineer because of the problems it would enable me to solve. I am an engineer by *purpose*.

The oil crisis of the 2000s occurred while I was in high school. I realized for the first time the dangers posed by the finiteness of oil in a society that so completely depends upon its cheap, abundant availability. I thought that I might have something to contribute to solving this challenge and my mind started racing in an attempt to come up with an idea. I decided to enter the Seimens Westinghouse Competition in Math, Science, and Technology as a framework for creating and developing an idea. Inspiration struck on a solar energy idea. Unfortunately, I had few resources at my disposal (basically, what I could convince various companies to donate to me or what I could purchase at Home Depot). I cobbled something together without any mentorship and used equipment from my poorly supplied school physics lab to gather data. The experimental results were inconclusive, but something important came of my work nonetheless. I was now convinced that I needed to become an engineer to acquire the skills, contacts, and resources I needed to help solve this problem. Olin College of Engineering, with its focus on project-based engineering education, design, and entrepreneurship seemed like the place I needed to be.

Here I am four years later. It's amazing just how much your perspective can change in just four years. I entered college thinking that I could solve the energy crisis as an engineer; imagine my surprise when I realized that it was engineers who enabled and were perpetuating societal dependence on fossil fuels! This isn't to say that I don't value all of the benefits resulting from the usage of fossil fuels, but rather than I now recognize many of the associated human, environmental, and sustainability costs—costs that most of my engineering colleagues ignore. There are many other social, environmental, and sustainability problems besides fossil fuel dependence that I am now aware of (and, surely, many more that I am not aware of), and nearly all of these problems are at least-partially caused or enabled by technology created and supported by engineers. Why would engineers, whose job it is to solve problems, ignore the new problems created by their solutions?

After years of thinking about this question and speaking to many engineers, I feel qualified to postulate my own answers. Many engineers simply do not recognize that their work has broader social, environmental, and sustainability implications beyond the creation of new technologies. This is simply an issue of awareness. Engineering work often involves the coordination of many people (e.g., engineers, businesspeople, suppliers, manufacturers, retailers/salespeople) spread across many locations, each with defined roles and responsibilities. An engineer is unlikely to become passively aware of all of the issues caused along the chain that he or she is a part of. Going a step further, some engineers only recognize the positive implications of their work without recognizing the negative. Once again, this is likely an issue of awareness. Further still, some engineers recognize the negative implications of their work but do not assign any responsibility to themselves. Generally, this is because the negative implications are somehow distant (e.g. spatially, temporally, emotionally) from the engineers involved. Because of the large number of people involved in the chain that ultimately creates the problems, it is easy to approximate one's own responsibility as negligible or to assign responsibility to another party (e.g., corporations, governments). Lastly, the few engineers who do assign themselves some level of responsibility for both the positive and negative broader implications of their work are frequently unable to justify more socially, environmentally, and sustainably responsible decisions. Decisions with broad implications may be made explicitly by a different person (e.g., business leader) or implicitly by a group of people (e.g., a group of engineers contributing to a design). Such decisions are difficult for a single individual to influence without a persuasive argument. Without the ability to affect socially, environmentally, and sustainably responsible decisions, the negative implications of decisions are psychologically distanced and ignored.

This project was inspired by my moral outrage at the realization that social, environmental, and sustainability damage would continue to occur at the hands of engineers. My goal was to find a way to push engineers towards recognizing and taking responsibility for both the positive and negative broader implications of their work and being able to justify more socially, environmentally, and sustainably responsible decisions. But how? If I can't find a successful way, won't I also become just another complacent member of the engineering community with regards to the negative implications of our work? This project is my attempt to understand the pressures and expectations that will be placed upon me as an engineer in the real world and to find ways to preserve my idealistic morals and sense of responsibility.

There are many courses of action I could take. Unfortunately, the ways in which I justify to myself the consideration of the negative broader implications of engineering work will not apply to most of my fellow engineers. My internal justifications are grounded in my own, non-standard worldview. For example, I do not believe in the exceptionalism of humanity or a sub-set of humanity (e.g., humanity is the highest form of life and is separate from nature, America is the shining city on the hill and better than all other countries). I view all of nature (including all other living beings) as intricately linked in ways that I will likely never fully understand or appreciate—and for this reason, I am morally opposed to actions which I perceive as damaging this web. If my arguments are grounded in a non-standard worldview, I can simply be dismissed as a "hippie, tree-hugging environmentalist", losing all credibly among my engineering peers. In order to have a chance of changing their minds, I need to instead ground my arguments in their (more standard) worldview, presenting my thoughts in a way that they are already included to agree with.

This is easier said than done. For starters, I talked to ten practicing engineers in order to understand their perspective with regards to how their work and the world interact. I then had a decent

understanding of the types of arguments that would be persuasive with my audience (engineers). But now, how best to frame my arguments?

The resources I reviewed in my search for a good framing (described in Context section below), combined with my past academic experiences and much thought, inspired me to frame the consideration of social, environmental, and sustainability concerns in engineering work as a strategic opportunity. Many engineers already are (or have the capacity to be) high-level systems thinkers—a necessary skill for recognizing and addressing the positive and negative implications of their work. Often, this thinking among engineers is restricted to technical, project management, or product development processes. But at the end of the day, engineering is a business; in order to be a great engineer, you have to understand business strategy. And you can, in fact, make the argument that being socially, environmentally, and sustainably responsible is an effective business strategy. I wish to extend business strategy as an additional plane of systems thinking which engineers will desire to occupy in order to be more effective—framed as "strategic engineering".

First, I need to convince engineers that "strategic engineering" is worth their time—that it directly matters to their work. Next, I need to increase the awareness of the engineers of the broader positive and negative implications of their work and demonstrate how these implications affect the success of a business (their work). Lastly, I need to give the engineers a framework for thinking about how to change the decisions that they can control or influence to increase positive implications and reduce negative implications in ways that are strategic for their business.

5. Context

Many of the sources below will not be referenced directly in the course content and presentation, but have greatly shaped my work on the project:

> The ADDIE Instructional Design Model. Student Auxiliary Services, Bringham Young University. < http://sas.byu.edu/training/documents/TheADDIEInstructionalDesignModel.pdf> Accessed March 8, 2013.
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> > The ADDIE instructional design model provides a framework for the development of training courses. ADDIE is an acronym for Analysis, Design, Development, Implementation, and Evaluation—the five stages of the ADDIE framework. I have used this framework as a guide for the development of my training course.
> >
> > The analysis phase involves understanding the audience of the training course, identifying the learning goals for the course, and identifying the needs of the audience towards achieving the learning goals. For my project, this involved interviewing practicing engineers in order to understand the factors which weigh on their decisions. In particular, I was interested in ascertaining the awareness of practicing engineers of the full impacts of their decisions beyond the direct effects on time, cost, and technical performance. In order for the educational materials to be effective, I must not present material which is already known by the audience or incorrectly assumes prior knowledge (to the fullest extent possible). After processing the interview responses, I created learning objectives describing what learners should be able to do following the workshop.

The Design phase of the project focuses on the creation of a high-level course structure that will accomplish the learning objective defined in the Analysis phase. The high-level structure, called the instructional design document, defines how content should be organized and presented to learners, the method of delivering content, and how to measure the achievement of learning objectives. For now, I intend to work towards the production of a 60 minute workshop. Thus, the Design phase of my project will focus on structuring this 60 minute workshop session to achieve my learning objective with an audience of practicing engineers. Though the scope of material I can cover in 60 minutes will be limited, I would like to have some measure of whether or not the workshop was successful at achieving my learning goals. For example, this could be accomplished by a pre and post-workshop activity where improvements in responses are indicative of learning. The instructional design document can be presented to my mentor, peers, and possible participants in a course for feedback. Obtaining feedback will be critical in producing a course that is effective at achieving my defined learning objectives with my target audience.

The Development phase of the project involves creating course materials that fill in the details of the high-level course structure set by the instructional design document. Prototypes of course materials should be produced when possible in order to receive feedback for further iteration. For my project, the number of iterations I can perform will be limited given time constraints, but even a low-fidelity prototype which doesn't take a lot of time to create can provide valuable insights before spending time polishing a set of materials. If time permits, I may choose to pilot a course with Olin students; though Olin students are not typical of my audience (general practicing engineers), they are the most available audience I have for running a pilot.

The final two phases—Implementation and Evaluation—involve actually running the course and measuring its effectiveness. I may not get to this point in my project, as implementation is dependent on securing interested participants in such a workshop. I chose not to proceed with these final phases of the ADDIE process in the context of this project.

Strategy and Society: The Link Between Competitive Advantage and Corporate Social Responsibility. Porter, Michael E. and Kramer, Mark R. Harvard Business Review. December 1, 2006.

The wide availability of information from sources such as the internet are empowering governments, activists, and the media to hold companies accountable for their actions. For this reason, corporate social responsibility (CSR) is becoming an increasing important priority for businesses. However, most CSR activities carried out by companies do not fall within their area of expertise or value-creation, limiting the ability of the company to produce a positive impact. A better approach for the company and for society is for the company to fold CSR activities into its strategy, called strategic CSR. One example of strategic CSR is Toyota's production of the Prius—developing new automotive technologies that have the potential to reduce the environmental impact of transportation. Toyota has been able to exercise one of its core strengths (development of automotive technology) while producing a societal benefit and becoming a recognized leader in hybrid vehicle technologies. A second example of strategic CSR is

Nestle's development of its supply chain in Moga, India. Many poor farmers in the area were producing variable quality milk with low yield due to a lack of refrigeration. Nestle invested money in these farmers and the local community; the community now has a much higher standard of living and Nestle now has a high quality supply of milk from a distributed range of small suppliers (with no middlemen, reducing cost). The potential for impact is much greater if a company finds a way to incorporate CSR activities into its value-chain, producing benefits for the company and for society.

This particular reading inspired me to find ways to work within the worldview of practicing engineers in framing my material for the workshop. In retrospect, the term "Strategic CSR", coined in the article, was likely my inspiration for the term "Strategic Engineering", the theme of my workshop.

Collapse: How Societies Choose to Fail or Succeed. Jared Diamond. Penguin Books. 2nd ed. 2011.

This particular book has greatly influenced my perspective on the world in general. It takes a look at the long-term trajectory of societies and their interactions with the environment. In many cases, the surrounding environment and a society's interactions with said environment have a profound effect on the historical trajectory of the society. In many cases, negative interactions with the environment lead to societal collapse on multigenerational timescales.

In addition to looking at historical examples, the author draws connections with examples in the modern world in an attempt to draw lessons from history. Several of these examples are referenced in my presentation slides (cited in the notes section).

Sustainability Reporting Guidelines. Global Reporting Initiative. Version 3.0. <https://www.globalreporting.org/resourcelibrary/G3-Guidelines-Incl-Technical-Protocol.pdf> Accessed on March 8, 2013.

The Sustainability Reporting Guidelines present a standardized framework for companies to report the responsibilities of their corporate actions. I found the framework useful as a reference when thinking about the broader implications of engineering work. The framework includes the following categories:

- Economic: including financial risk, government subsidies, employee benefits and wage disparity.
- Environmental: including materials; energy; water; biodiversity; emissions, effluents, and waste; products and services; compliance; and transport concerns.
- Labor Practices: including occupational health and safety; training and education; diversity and equal opportunity; and labor/management relations.
- Human Rights: including non-discrimination; prevention of forced or compulsory labor; indigenous rights; and investment and procurement practices.
- Society: including community; corruption; public policy; anti-competitive behavior; and compliance.
- Product Responsibility: including customer health and safety; product and service labeling; marketing communications; customer privacy; and compliance.

Environmental Ethics: What Really Matters, What Really Works. OUP USA. 2nd Ed. pp. 556-566. July 5, 2012.

> In a section within this book titled "Taking Environmental Ethics Public," Andrew Light claims that the field of environmental ethics has become disconnected from its formative origins. Environmental ethics formed out of a desire to find moral motivation for people to support more environmentally-sensitive views. Traditional ethics has no established mechanisms for determining ethical standards between humans and non-humans, as is the case when dealing with questions of the appropriate relationship between humans and the rest of nature. Unfortunately, in the search for an ethical framework appropriate for environmental considerations, the discussion has largely become abstract and focused on defining non-anthropocentric judgments of the value of nature. Unfortunately, because the majority of modern cultures will not accept non-anthropocentric judgments of the value of nature, the utility of such an environmental ethics for motivating people to support environmentally-sensitive views is highly limited. Light argues that environmental ethics should take a more practical approach, in which issues that the environmental community agrees upon (for whatever reasons) are justified on philosophical grounds and conveyed to the public. He argues for a "strategic anthropocentrism", in which statements are justified from an anthropocentric framework wherever possible to appeal to the broadest possible audience. I will adopt this philosophy in my approach to my project—my goal is to work within the framework of my audience to raise awareness of SES concerns and, hopefully, result in positive behavioral change.

Ethical Decision Making through Organizational Structure. James, Harvey S., Jr. Journal of Business Ethics. Vol. 28, No. 1, pp. 43-58. Nov. 2000. <http://www.jstor.org/stable/25074399> Accessed on February 11, 2013.

> "[F]rom a managerial perspective, efforts directed at an appeal to the ethical sensitivity of the individual, such as corporate training and codes of ethics, are neither necessary nor sufficient in fostering ethical behavior within the corporation. Rather, managerial efforts should first build on an examination of the organization's formal structure because of the direct affect it has on employee behaviors and because it is directly controllable by business managers. That is, an examination of the ethical impact of the formal structure of organizations is necessary and, when combined with an appropriate corporate culture, will generally be sufficient in promoting the ethical behavior of workers." (pp. 44)
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> It is important for me to convey in my materials that the incentives of any structure (e.g. company, community, society) have a large influence on individual choices, often superseding personal ethics. An engineer must be aware of the influence of incentive structures on his or her choices in order to make informed, responsible decisions.