Extended Abstract – Engineers Make Life Better

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***Abstract* – Engineers have an ethical responsibility to contribute to the betterment of life. *Engineers make life better* is a more important and accurate message about engineering than the misconception that you have to excel at and love math and science. Students must learn and appreciate what leads to a good fulfilling life, and then incorporate those attributes into their work. Several initiatives are under way in the College of Engineering. One is the Engineering Ambassadors – sophomore and higher engineering students that through communication and leadership skills inspire pre-college and first-year students to challenge conventional ideas about science and engineering. Another is via design projects in *Introduction to Engineering Design*, a course that most first-year students must take. A third is a new one-credit first-year seminar, *Sustainable State*. This course leads students through an exploration of sustainability in four areas: transportation, waste, food and energy, and three dimensions: behavior, technology and projects on campus.**

Index Terms – ethics, sustainability, design, needs

INTRODUCTION

In 2008, the National Academy of Engineering published *Changing the Conversation: Messages for Improved Public Understanding of Engineering* [1]. Basically, this publication was a marketing study aimed at promoting engineering to the public and to potential students. This study reinforced initiatives already underway in higher education and led to additional efforts aimed at drawing more young people to engineering as a rewarding and socially relevant career. The number one marketing message that the study recommends is: "Engineers make a world of difference." Ironically, the study said that "a better understanding of engineering should encourage students to take higher level math and science courses in middle school, thus enabling them to pursue engineering education in the future." We agree with the marketing message, but think that the bigger problem is that people, including most engineering educators, think that you have to either love, or be really good at, math and science in order to be a good engineer. That misconception is the one that most impedes the flourishing of our profession by excluding people who don't love or excel at math and science. While proficiency at math and science is required for most engineering, it is not why we love engineering. For comparison, medical doctors must be proficient at math and science too, but that is not what motivates people to become doctors.

One analogy is that engineering is like riding a bicycle, and that math is like pedaling and science is like balancing. Sure you have to be able to pedal and balance in order to ride, but we don't ride a bike because we love to pedal and balance. We ride to go someplace. Similarly, we engineer to make life better and that is what motivates us.

WHAT IS A BETTER LIFE?

We get insight into this question in two fundamental places in engineering. First is the primary ethical canon in all engineering codes of ethics: Engineers shall hold paramount the health, safety and *welfare* of the public [2]. Second is the notion of sustainability: meeting the *needs* of the present without compromising the ability of future generations to meet their *needs* [3]. These ethical directives help us to understand why we engineer. They are the moral foundation that guides our technique. To use the bicycle analogy, they provide the destination for our bike ride.

So what are human needs? What contributes to welfare? Many scholars have investigated these rich and timeless questions. Three have been notable in recent years: David Braybrooke in *Meeting Needs* [4], Manfred Max-Neef in *Development and Human Needs* [5], and Martha Nussbaum in *Women and Human Development: The Capabilities Approach* [6]. These three scholars articulate that human welfare goes well beyond having the basic needs of food, shelter and clothing. Figure 1 summarizes what each of these sources identifies, while also grouping them to indicate possible common themes.

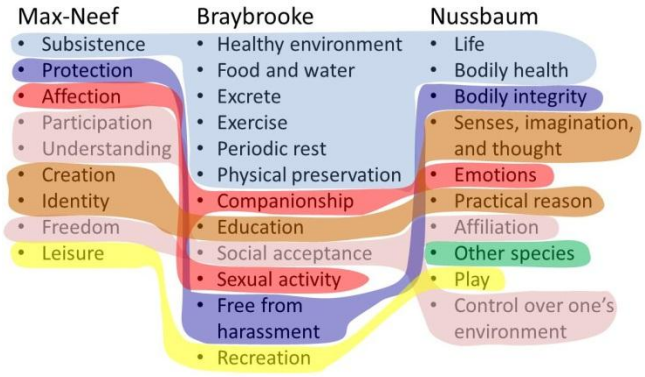

FIGURE 1
RECENT SCHOLARSHIP OF NEEDS AND HUMAN FULFILLMENT.

While these lists represent human needs for fulfillment in differing ways, there are similarities. At the risk of oversimplifying and inaccuracy, we suggest this list of common themes that can be presented to engineering students:

1. Basic needs
2. Safety
3. Affection
4. Association
5. Expression
6. Recreation
7. More-than-human life

All but one of these themes is represented in at least one item in all three lists. Nussbaum is the only one though to identify "other species", represented here as "more-than-human life". She is also the most recent to speak to needs, bringing a feminist perspective and carrying on the capabilities approach to human welfare championed by Amartya Sen [7].

How can we use these in engineering? Well first we have to get students to understand them and appreciate that our efforts should at a minimum not interfere or diminish their fulfillment. More positively, we should work toward facilitating their fulfillment. The only way to do that is to place these attributes of a fulfilling life at the forefront of our designs, to build them in as design criteria and evaluate our designs as to the extent that they are improved.

FIRST-YEAR INITIATIVES

Much of the effort to convey and internalize the message that "engineers make life better" has found its place in initiatives in the first year. This is in part because there are common courses and programs that are college-wide, and in part because the upper-division curricula is focused on the how not the why. Certainly know-why should ideally pervade the curricula eventually.

I. Engineering Ambassadors

Established in May 2009, a main goal of our Engineering Ambassador program is to perform outreach to high schools and middle schools to help those students learn more about what it is that engineers do. By showing solutions that engineers have created for important societal problems, the program aims to persuade these students, especially females, to consider engineering as a profession. A secondary goal is to improve the presentation confidence and leadership skills of the ambassadors. A distinguishing factor of our program is the amount of formal communications training (6 credits) that the Engineering Ambassadors receive.

Due to the outstanding communication skills of the Ambassadors, the College of Engineering at Penn State began also using the ambassadors for on-campus events in 2010. Because of the additional use of ambassadors in some on-campus outreach to prospective students and families, the Engineering Ambassadors program expanded greatly in 2010-2011. The size of the program went from 12 female students to 36 students and included male students. Currently, the Engineering Ambassadors program is comprised of 50 engineering undergraduate students, both male and female, and the ambassadors participate in a variety of outreach activities both on and off campus. In 2011-2012, the Engineering Ambassadors spoke to over 6,500 people. It is important to note that the messages of *Changing the Conversation* are emphasized during every Ambassador interaction and presentation.

For first year students, four different opportunities were created for ambassadors to interact with engineering students in their first year seminar courses. Each section that participated in the project received the same series of events. The events were 1) a presentation of how the majors impacted different industries, 2) a presentation on the specific options within a major, 3) a presentation that focused on the cumulative experiences of one senior student, and 4) a panel discussion on how to be a successful engineering student. Following each event, there was much opportunity for students to ask questions about the content covered.

II. Introduction to Engineering Design

Another initiative is to develop and choose design projects in EDSGN 100, Introduction to Engineering Design, that reflect these three general goals (HSE):

1. Human fulfillment
2. Social responsibility
3. Environmental sustainability

Calling it an initiative may be misleading in that the goals are emerging from individual faculty endeavors. While more than half of the faculty use projects that reflect these goals, and it is a growing trend, there are still many faculty that are not yet on board.

Nearly all first-year engineering students at Penn State take EDSGN 100, with the exception of Computer Science, Computer Engineering and Architectural Engineering students. This amounts to nearly 1,800 students university-wide. The course is three-credits, and meets for six hours each week in a problem-based learning environment. Typically there are two half-semester projects, the first chosen by the faculty, and the second common to all sections for an outside client.

Welfare and needs surface in the Introduction to Engineering Design course in the first stage of the design process – defining the problem, and in particular, stakeholder needs assessment. We are working on a project this summer to develop curriculum that places more emphasis on stakeholder considerations. Based on the work by Carol Sanford published in *The Responsible* Business, a

symbol used to help students include all stakeholders is the pentad shown here [8]. Sanford emphasizes that a responsible business seeks to be value-adding in all of their interactions with these five stakeholder groups. Good responsible design emerges from a balanced consideration of these stakeholders' needs and then incorporating them into the design goals for the project.

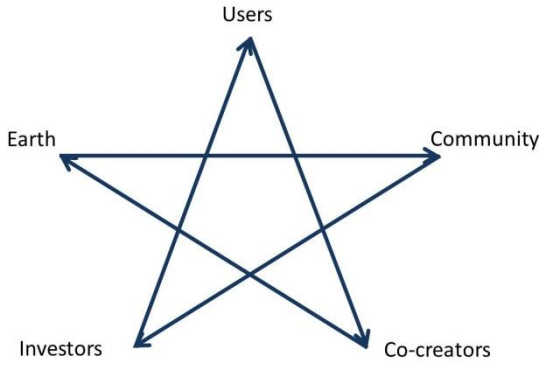

FIGURE 2
STAKEHOLDER PENTAD [8]

One of the faculty-developed projects that reflects the three HSE goals above is the Zero Energy Home. Student teams take their common dreams about their future homes and create a concept that fulfills their dreams and provides its own energy from the sun and wind. The skills and abilities they learn and apply are always in the context of the project. They focus on where the bicycle is taking them and develop the necessary techniques along the way. Thus far, five faculty have used this project for their first design experience. More information on this project is in a 2012 ASEE paper [9].

Another recently developed project for EDSGN 100 is Design for Emerging Markets (DEM) [9]. Student teams focus on a need in the developing world, especially for people and communities in the bottom of the economic pyramid, The student teams create prototypes that are tested and evaluated, leading to a second prototype. There are three goals for this project:

1. Do activities to comprehend design issues for the other 90%
2. Do multiple design iterations: learn from success and failure
3. Develop understanding of frugal and appropriate design, importance of understanding societal factors/context, local customs, and triple bottom line (people, planet and profit).

In Fall 2011 the DEM design project was to design/test/build solar cookers (Figure 3). In Spring 2012 students worked to come up with solutions to various design challenges including bike shelves, bike power generation, filter press redesign, and food preservation through drying. A common design element for many of these projects was using universal connectors (Figure 4).

FIGURE 3
STUDENT TESTING SOLAR COOKER

FIGURE 4
UNIVERSAL CONNECTOR PROTOTYPE

One goal for the DEM project was to involve other faculty and increase the number of students exposed to this type of design project. In Fall 2011 three faculty used the DEM project in four sections of EDSGN 100 reaching approximately 130 students. The project expanded in Spring 2012 to four faculty and seven sections of EDSGN 100 reaching approximately 200 students. Assessment data has been collected and is being analyzed and will likely be available at the conference. This student comment is indicative of the goals being achieved:

> "To sum it all up, this is a great activity to allow someone to realize all the aspects that go into engineering a new product and how important it is to gather all the information you can on the target consumer before jumping into the project."

In addition to these faculty-developed projects in the first half of the course, the client-driven design projects are frequently aligned with the three goals above (Table 1).

III. First-Year Seminars (FYS)

Another initiative is new first-year seminars, notably Sustainable State. All first-year students must complete a

TABLE 1
CLIENT-DRIVEN PROJECTS REFLECTING HSE GOALS

Semester	Sponsor	Project
Fall 2007	Shell	Sustainable Village
Fall 2008	Borton Lawson	2009 Solar Decathlon
Fall 2009	Shell	Rural Cooker
Fall 2010	GE	Autonomous Cell Tower
Spring 2011	Air Products	Hydrogen City
Spring 2012	Arcelor Mittal	Advanced High Strength Steel Recycling

one-credit seminar taught by regular faculty. There are about 60 different seminars reflecting the variety of faculty interests and student needs. Sustainable State was co-developed with an environmental educator and first offered to two sections in Fall 2011 and again in Spring 2012. Students are introduced to sustainability with four themes: food, waste, transportation and energy. Behavior and technology are considered for each theme, along with a field trip to research and operations at Penn State in that thematic area. Students pair up to create a one-minute video about some important concept or lesson.

Other FYS faculty and sections reflect the HSE goals as well, including Humanitarian Engineering, Engineering Projects in Community Service, Biomimetic Design, Engineering Entrepreneurship and Health, Happiness and Safety: Research in Mechanical Engineering. And as mentioned previously, many of the FYS sections invite the Engineering Ambassadors to make presentations related to *Changing the Conversation*.

CONCLUSION

Through various initiatives in the first-year engineering experience, students are learning that *engineers make life better*. As these programs evolve and expand, assessments will be undertaken to understand the extent that the lessons are being learned.

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