Engineering Design & Society: A First-Year Course Teaching Human-Centered Design

Pamela Dickrell and Lilianny Virguez
Institute for Excellence in Engineering Education
Herbert Wertheim College of Engineering
University of Florida
Gainesville, FL, USA
pld@ufl.edu , lilianny.virguez@ufl.edu

***Abstract*—How do you get first-year engineering students to stay in engineering? Get them to care! A first-year multidisciplinary engineering design course was developed and that emphasizes the human-centered design process. Students learn hands-on maker tools and software to fully design and build a prototype based on a societal need. An open-ended design challenge is presented to students to help humanity in a way that tells the story of engineering as a field to help the world through thoughtful human-centered design.**

***This work presents the story of the formation of a human-centered design course, outlining the structure of the course, goals, maker-tools covered, and flipped-classroom format for active-learning delivery of the first-year engineering design experience. Examples of human-centered topics considered for first-year design prototypes include food stability (self-watering planters), sustainable energy (non-traditional power generation), tools for disabilities (toys for children with prosthetics), etc.**

The Engineering Design & Society human-centered course aims to inspire engineering students to become makers to help humanity. Students are empowered through the impact their inventions can make to serve society and improve the lives of others through engineering.

Keywords—society; design; maker; human-centered; first-year

I. Introduction

Often engineering students get a great idea, and start designing and building right away. While innovation and inspiration in students in encouraged, there is a need to promote higher-level design thinking within engineering students to consider the human or societal nature of what they are creating and why they are making it. One of the benefits of the human-centered design process is that it promotes engineers to consider both individual end-user and larger societal needs throughout the design process for a greater impact of engineering skills on humanity and keeping in mind the people affected by the design [1].

A first-year multidisciplinary course, Engineering Design & Society, was created to inspire first-year engineering students to be the makers in the world to help society through their engineering skills by considering not only the users but also the social and environmental context of their designs. In this way, we expect to help students make connections between engineering and society early, within the first-year of their engineering studies [2]. Students learn about human-centered design, obtain maker-skills needed to build prototypes (solid modeling, 3D-printing, sensors/actuators, microcontrollers, programming), and professional skills such as teamwork, communication, critical thinking, and self-directed learning. Students then use those competences to actively design, create, build, document, and showcase a functional prototype of their human-centered design solutions.

II. Course Goals

A team of faculty with technical backgrounds representing seven different engineering majors as well as engineering education collaborated over a year to map out the Engineering Design & Society course content and structure. Part way through the process, the faculty team was supported by the university teaching center that provided a two-day guided course mapping training using a Bloom's Taxonomy based method for outlining student-centered course goals, learning objectives, and course content. The engineering faculty team followed the course mapping process to systematically outline a full semester of content for Engineering Design & Society.

The overall course goals were based on building skills in first-year engineering students that would encourage early consideration of the impact of engineering on society as well as build critical technical and professional skills engineering students need in subsequent courses in their various majors and careers in general.

The eight larger course goals the multidisciplinary faculty team arrived at were:

1. Understand and practice the human-centered engineering design process for a societal based project
2. Learn techniques to solve open-ended engineering challenges

3. Promote a culture of making by introducing solid modeling, programming, sensors, data acquisition, 3D printing, and other maker tools
4. Build teamwork and cooperative learning skills through participation in multidisciplinary teams and active engineering project management
5. Build professional skills in background research and written, pictorial, and oral communication methods
6. Raise awareness of ethics and contemporary issues in engineering design related to a global society
7. Introduce engineering students to the various engineering majors and their roles within society
8. Inform students of opportunities for experiential learning related to their majors throughout the college of engineering and university community

III. Human-Centered Design Process

The first two goals of the Engineering Design & Society Course are for students to *"Understand and practice the human-centered engineering design process for a societal based project"* and to *"Learn techniques to solve open-ended engineering challenges"*. These two goals involve students learning and practicing the human-centered design process created by the faculty in support of the Engineering Design & Society course, Fig. 1. We acknowledge and emphasize in class that design is an iterative process and Fig. 1 doesn't mean to be a rigid plan, but rather the framework that serves to guide the overall human-centered design approach in the class.

The first few weeks of the course emphasize the human-centered design process and various active-learning sessions for students to practice the process both individually and with peers. Faculty-led discussions during these hands-on activities highlight the human-centered nature of engineering as a field where students can use their technical skills to support humanity.

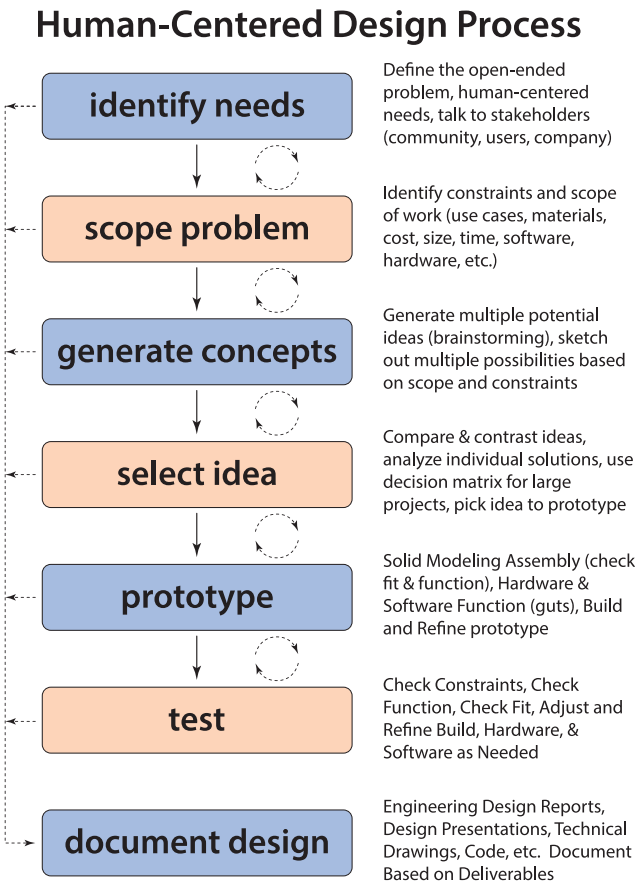

Fig. 1. Engineering Design & Society Human-Centered Design Process

IV. Course Flow

Fig. 2 shows the general course flow for a 14 week semester.

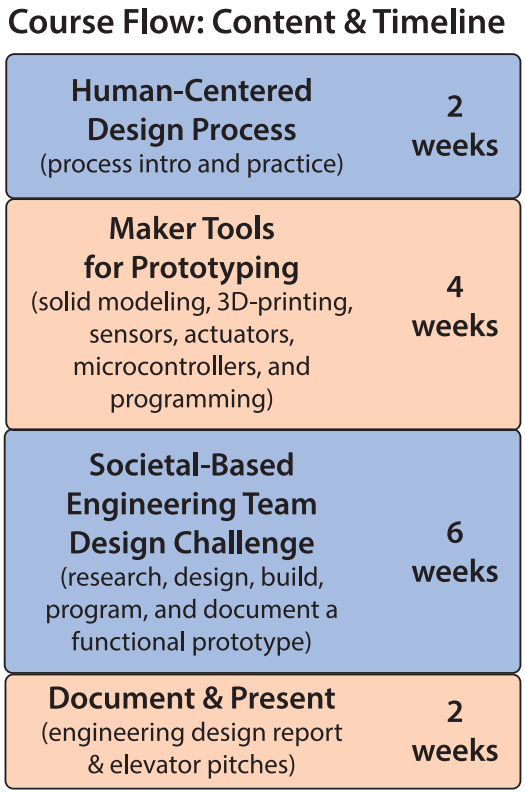

Fig. 2. General flow for a 14 week semester of Engineering Design & Society

While the course content is not directly linear in nature, Fig. 2 illustrates the general flow of student content and timeline within the course. The Human-Centered Design Process is emphasized and practiced both individually and with small groups first. Students are then equipped with various maker-skills to help them create their human-centered prototypes, and they practice those skills both individually and in teams. The grand reveal of the larger societal-based team open-ended challenge occurs, and student teams are given six weeks to research, design, build, program, and document their functional prototypes. In these open-ended societal design challenges student teams are required to both design AND build a physical prototype that involves structural, mechanical, electrical, and programmed components. While documenting is done throughout the design & build process, there are two weeks at the end of the semester for finalizing a formal engineering design report on their created prototype and presenting their functional physical design to publicly in a 3-5 minute elevator pitch presentation.

Additional topics that are instructed and practiced throughout the semester include new-to-campus skills (library research, engineering and other general student organizations, maker resources on campus), professional technical communication (engineering design notebooks, engineering memos, engineering drawings, engineering design reports), working in teams (creating team charters, peer communication, peer evaluations), engineering majors and the multidisciplinary nature of design (learn about various engineering majors through uses of maker tools across disciplines, how most technologies are systems of multiple specialties working together).

V. Makerspace & Flipped Classroom Format

Engineering Design & Society is a 2 credit hour course structured in a flipped-classroom format. Students watch a number of short (~15 minute) lecture videos at home (for a total of ~1 hour a week of online video content) in preparation for a single 2-3 hour session per week of active learning with the professor and peer mentors in a makerspace classroom. Online lecture videos each week are structured to build the skills that will be practiced live in-class. This flipped classroom format is utilized for optimizing makerspace classroom time for active-learning and to allow the flexibility of students to watch and re-watch the online videos as many times as needed to be comfortable with the content prior to hands-on activities.

The makerspace classroom for the initial pilot of the course seats 20 students in teams of 4 students per worktable. Each worktable is outfitted with a rolling tool chest containing various hand tools and small power tools useful in the making process. Students are instructed on safety and the use of any tools before they are utilized. No prior tool, solid modeling, 3-D printing, or programming knowledge is assumed or required for the course. The basics of these maker tools and skills are part of the instruction of the course, with the goal of promoting a culture of making and confidence in first-year students to seed their continued participation in prating societal based engineering design through hands-on projects, internships, and student organizations.

VI. Societal-Based Projects for First Year Students

The general characteristics sought in course project topics for Engineering Design & Society include:

- Human-centered topic that students can research and document impact on society and/or end-users
- Multidisciplinary in nature, all engineering majors
- Representable by a physical functional prototype that fits within 0.5m by 0.5m by 0.5m workspace
- Functional physical prototype can be created using a combination of solid modeling, 3-D printing, microcontroller-based electronics (engineering sensors, actuators, and low level of programing), and a limited number of purchased or recycled materials.

Based on these general characteristics sought in course project topics, the pilot project is for student teams to research, design, and build a self-watering windowsill planter to promote food sustainability and air purification. Student teams are challenged to use sensors and actuators to automate plant watering for a small scale windowsill sized prototype.

VII. Conclusions and Future Work

As described, the Engineering Design and Society course has been created in collaboration with faculty members from

different engineering disciplines and the center for instruction and learning in the university. The overall goal of this course is to provide students a broad outline of the engineering design process with a high emphasis in human-centered design including relevant practices that take into account students' interests and goals. The opportunity to learn and use software and tools such solid modeling, 3D printers, and microcontrollers to make design solutions to open-ended problems has been one of the aspects that keep students more motivated in this class according to feedback received from students in the pilot of the course. The flipped classroom and active learning format has also been cited as one of the features that helped students learn certain skills quickly since they could easily access videos with foundational information and class time was mostly devoted to put in practice hands-on skills.

Student feedback and data analysis, along with departmental feedback across the college will be folded into an evolved version of the first pilot curriculum to refine Engineering Design & Society to make it a more effective tool for students to consider social impacts of design, while learning and practicing the maker skills needed to prototype and create across multidisciplinary teams of engineering freshmen.

REFERENCES

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