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Work-in-Progress - Emphasizing Human-Centered Design in the Freshman Year through an Interactive Engineering Design Process Experience

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***Abstract* – Let's start with the basic idea of the engineering discipline: problem-solving. At the base of all problems, there is a human with a need seeking a solution. At Lipscomb University, the engineering faculty have found that upper-level students lack experience in the human element of design. Specifically, students need improvement with client interactions, decision-making processes, holistic critical-thinking, and sustainable design. In the past, our college's engineering courses have generally focused on the analysis of a system rather than designing a solution to fit a human need. In order to address this concern, the college will redesign a freshman engineering course to better focus on the concepts in human-centered design. The students will be introduced to a five-step design process originally developed by Engineering for Change. A fundamental aspect of this design process is its iterative nature and its inherent focus on the human at the center of the problem-solving experience. The design process will be presented to the students through three interactive experiences.**

Index Terms – FYEE course, Human-centered design, Interactive design, Sustainable design, Engineering design process

INTRODUCTION

While engineering problem-solving utilizes concepts from mathematics and physical sciences, sometimes the hardest part of a solution is including the human element. Around the world, engineering programs emphasize problem-solving using math, science, and engineering concepts, but many understate the importance of humanities or social science topics that are imperative to understanding the human element of design. Various accreditation agencies like ABET require that programs cover design and analysis under the considerations of global, economic, environmental, and societal contexts [1], but many programs expect these topics to be covered in other courses rather than creating a curriculum focused on holistic problem-solving. Other researchers have found that problem-based teaching can lead to ineffective learning patterns such as an inability to adapt to unknown constraints or variable conditions [2]-[3]. As Felder and Silverman discuss in their 1988 paper, most engineering courses are taught using a model that does not match or address their students' learning-style models [4]. Though published in 1988, the conclusions drawn by Felder and Silverman seem to hold true even in recent years. In response to these concerns, many programs have shifted toward active learning and focus more heavily on design thinking [5]-[6]. Based on student responses in a course, there also seems to be a lack of understanding as to what kind of problem-solving is required of working engineers [7]. Workplace engineering problems are rarely stated in a simple and easy-to-understand format. Rather, problems that working engineers encounter are very complex and have conflicting goals, variable constraints, and a variety of non-technical considerations [8]. From the literature presented here, it seems that current engineering curricula lacks the ability to prepare their students for the following:

- human-elements of design
- real-world problem-solving

This paper outlines an initial attempt to address these two main concerns in the engineering curriculum at Lipscomb University. By introducing these concepts in the freshman year, students will be able to apply the skills they develop in future projects throughout their tenure as an undergraduate student and into their career as an engineer.

OBJECTIVES

To improve student outcomes at the Raymond B. Jones College of Engineering at Lipscomb University, the faculty have decided to redesign a freshman engineering course to focus more heavily on an engineering design process. The course to be redesigned originally concentrated on providing hands-on lab activities for students to experience different disciplines within engineering in order to aid students in their major selection. While the faculty in the college see value in these experiences, there was a major lack of design experience in the course. Faculty perceptions of senior design projects show a need to improve client interactions, decision-making processes, holistic critical thinking, and sustainable design. A quick examination of the current curriculum shows that many engineering courses at Lipscomb generally focus too heavily on the technical analysis of systems rather than the design-analysis relationship. Additionally, students do not seem to gain experience in the human element of design that is critical for successful design. This revamped course aims to integrate an engineering design process with human-centered design to improve student outcomes.

By partnering with The Peugeot Center for Engineering Service in Developing Communities, the redesigned course will utilize skills and knowledge from previous projects to construct an immersive and interactive design process experience emphasizing the human element of design. Students in the course will be introduced to a five-step design process originally developed by Engineering for Change (E4C) [9]. The steps are: a plan stage for team formation, budgeting, and management; a learn stage for research and interviews with a client; a design phase for brainstorming and prototyping; a realize stage for analyzing producibility and manufacturing techniques; and a sustain stage for ensuring long-term success. One critical aspect of this design is its iterative nature that encourages students to view failure as a feedback loop for improvement. The design process presented by E4C is also inherently focused on the human at the center of the problem-solving experience. The Peugeot Center, an entity within the college, has a wealth of expertise in humanitarian engineering applications with nearly fifty completed projects over twelve years. A partnership between the college and The Peugeot Center will allow students and professors to utilize the knowledge, data, and skills obtained during past projects for the course.

COURSE FORMAT

The freshman course will be based on E4C's design process as shown in Figure 1. Students will be exposed to this design process in three phases, each delving deeper in understanding of the full design process. The first phase is a short 90-minute activity introducing students to the idea of designing a product for another person. Students begin by finding a partner. Each student then designs a wallet for their partner [10]. Students are given time to ask questions and interview their partner before prototyping a wallet with materials like duct tape, cardboard, and markers. At the end of the activity, students provide feedback to each other and talk about lessons learned from this initial human-centered design experience.

The second phase of the course includes a brief introduction to the E4C design process and the examination of a case study. The instructor spends about five lab periods explaining the E4C design process to students. Rather than giving a passive lecture based on content only, the instructor is expected to actively interact with students throughout the presentation of the design process through a case study. At the beginning of this phase, the instructor gives students the opportunity to briefly read through a case study. Throughout the presentation of the design process, the instructor references the case study and invites students to critique the project with respect to the E4C design process. Utilizing a real-world example while explaining the design process gives students a better idea of how the iterative nature of design and analysis actually works in the field.

The third phase of the course employs the students to complete a project in small groups with the aid of the design process. To begin this phase, students are placed in or choose groups to work with for the entirety of the project. The instructor then presents a scenario to the students that depicts a client or community that has a need. To encourage creativity and imagination, the instructor could use a form of role-play to provide a realistic experience for the students. Once the instructor introduces the client and the scenario, students are given the opportunity to ask questions and make an initial assessment. Following this introduction, student groups then follow the design process to find a suitable, sustainable solution for the client's need.

For example, the scenario may involve a family in Guatemala who is experiencing coughing, red eyes, and wheezing. The instructor or a teaching assistant could role-play as a Guatemalan family member (i.e. the client) and answer questions from the students. Through the initial assessment of engaging and observing the client and their family, the students may find that the family currently cooks and heats their home using an open-fire causing lung and eye problems. The student groups then follow the design process and may decide to design and prototype a wood-burning stove with a chimney to reduce smoke inhalation for the family. Continuing along the design process, the student groups plan for manufacturing and sustainability of their design by including maintenance instructions, for example. Upon completion of the project, students are given the opportunity to present their product to the client and receive feedback.

Finally, the fourth phase of the course provides an opportunity for each student group to present their findings to fellow students in the course. For the presentation, student groups present their design, prototypes, and final product along with client reactions. Additionally, each group also gives a brief discussion on lessons learned and recommendations for future designers.

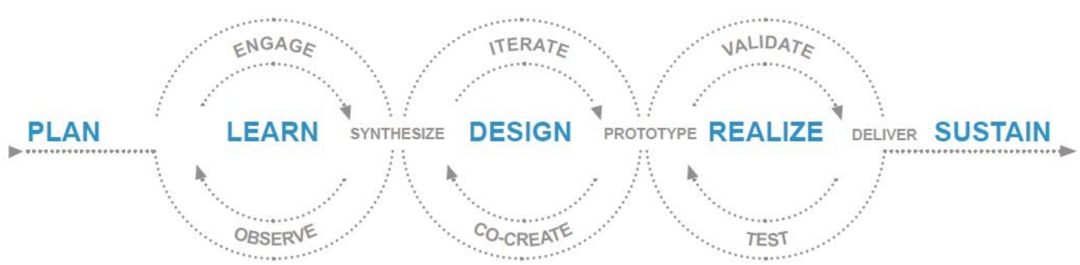

FIGURE 1 DESIGN PROCESS DEVELOPED BY E4C [7]

An example timeline of the course is shown in Figure 2. Note that this course will be taught in fall 2017 as lab sections that meet on Tuesdays and Thursdays in 100 minute periods for fourteen weeks. Currently, the four lab sections are taught by different faculty and are divided by disciplines within the college: two mechanical, one civil/environmental, and one electrical/computer. While the formatting and design process content for the course will be fairly uniform across all lab sections, the scenario, project, schedule, assignments, and activities may be customized by each instructor to better suit the students and the discipline. Examples of projects may include a clean wood-burning stove for mechanical, a pedestrian bridge over a river for civil/environmental, and the development of a health systems phone application for electrical/computer.

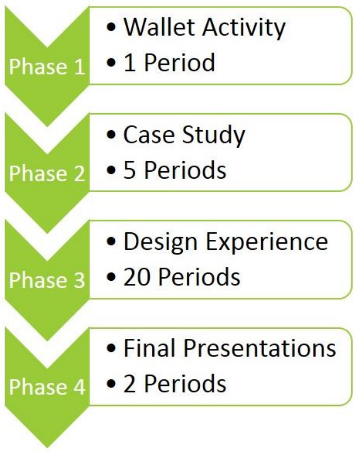

FIGURE 2 EXAMPLE 28-WEEK COURSE TIMELINE

FUTURE WORK

Students that participate in this class are expected to achieve the following ABET outcomes [1]:

- an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- a knowledge of contemporary issues

These outcomes will be delivered through lab sessions, discussions, lab sheets, reports, and presentations throughout the course. These outcomes will be assessed in a qualitative manner by the instructor. Assessment methods will include a pre- and post-questionnaire as well as observations and focus groups.

While the results of the assessments are immediate indicators of a basic understanding of human-centered design and a full design process, long-term indicators will be vital to investigating the success of the course. In addition to validating this course as an improvement upon the curriculum, other changes may also be made to ensure that students graduate with the skills and tools necessary for a career in engineering. Long-term indicators and future curriculum changes are yet to be explored and developed, but are viewed as necessary steps to refining the college curricula.

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