WIP: Towards Human-Centered Engineering: Integrating Engineering Psychology Early in the Engineering Curriculum through General Education

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***Abstract*—This work in progress innovative practice paper describes a new course, *Introduction to Engineering Psychology*, designed to introduce engineering students to concepts of human factors and human-centered design early in the curriculum through a general education course. Conceived as an alternative to Introduction to Psychology (a staple of general education programs), the course focuses on human perception, cognition, and action applied to the design of technology. This paper expands upon the motivation for the course, the curriculum, and the preliminary outcomes. It concludes with a discussion of how general education curricula might be re-designed to better complement engineering and computing, helping students to draw connections between courses in the social sciences, humanities, and arts with their own discipline to more effectively address the problems facing society in a technology-enhanced world.**

Keywords—human centered design, design thinking, course assessment

I. INTRODUCTION

To design inclusive technology that works for all people requires the incorporation of human-centered design practices throughout the design cycle. Usability-engineered products and systems improve productivity, operational efficiency, and customer satisfaction while reducing training costs and human errors [1]. Notably, considering human factors (or human-systems integration) early in the design process is associated with faster time to delivery [2] and reduced cost over the product lifecycle [3,4]. However, in both industry and student engineering projects, human factors and human-systems integration are often not sufficiently considered early in the design process. System modification to improve safety and efficiency or to address usability problems can cost over sixty times more after the system design has been finalized [5]. Changing this practice requires a change in how we introduce engineering students to these concepts.

Although systems thinking is foundational to engineering training, the human part of the system is often under-emphasized in the standard engineering curriculum with little coursework dedicated to understanding humans or human-technology interaction. When present in the curriculum, specialized coursework related to human factors, engineering psychology, or human-systems integration tends to appear near the end of the engineering curriculum or as choice points in technical electives. Positioning this coursework late in the curriculum may implicitly send a message to students that human factors, human-systems integration, and usability concerns are unimportant or simply cosmetic.

What if we could leverage general education to introduce students to the science and practice of human factors early in their undergraduate curriculum so that they could bring a human-centered design lens with them into their engineering classes? This question underpinned the design, development, and implementation of a novel curriculum for an *Introduction to Engineering Psychology* course, a new general education offering designed to address these issues. Engineering psychology is typically offered at universities as an upper division or graduate level course, focusing on human factors "from the neck up". Here, *Introduction to Engineering Psychology* was conceived as an alternative to Introduction to Psychology (a staple of general education programs), focusing on human perception, cognition, and action applied to the design of technology. The course introduces students to the theory, design principles, mindsets, and

practices of human factors and human centered-design through exposure to human factors research, usability testing, design thinking, case studies, and design standards (e.g., [6]).

II. Course Design

A. Course Description/Overview

Engineering psychology is the science of human performance applied to the design of technology. Engineering psychologists study the capabilities and limitations of humans from the perspective of perception, cognition, and action, with a specific focus on the interactions between people and technological systems. This course provides an introduction to the theories, principles, and concepts of engineering psychology and how they can be applied to create human-technology systems that are safer, more efficient, and easier to learn and use.

B. Course Learning Objectives

By the end of this course, students will be able to:

- describe theories and principles of human perception, cognition, and action.
- explain how mental workload, stress, and individual differences contribute to human performance.
- cite real-world examples of how engineering psychology is applied to the design of displays and controls.
- evaluate case studies, identifying sources of human error and proposing opportunities for applying psychology to design.
- discuss how principles of engineering psychology can be applied in their own field of study and future career.

C. Readings

The course relies on readings from two open source e-textbooks (*Perception and Cognition in Engineering Psychology* [7] and *Engineering Psychology* [8]) and Dr. Anne McLaughlin's *All Too Human* [9]. *All Too Human* provides a well written and engaging introduction to human factors psychology, using a combination of stories that are ripped from the headlines and ones that are relevant to student's experiences (e.g., using online dating to introduce concepts from signal detection theory).

D. Assessments and Activities

The course includes five types of assessments: post-class reflections, short assignments, summative tests, a case study, and a final project.

Class reflections are included to help students consolidate their knowledge. After each class, students are asked to spend a few minutes considering what they have learned using the PAW framework for reflection: Present, Analyze, What's Next? In short, this framework prompts them to describe what they have learned, analyze and connect it to other things, and then queue up future action. The reflections also allow the instructor to rapidly identify places where students may be struggling or misunderstanding key concepts.

Short assignments include reading quizzes based on textbook chapters as well as short homework assignments (<30 minutes) or extended reflections. Materials from in class activities are submitted for participation credit.

Two *summative tests* cover material from the readings and class sessions. They include a combination of multiple choice and short answer questions.

Throughout the semester, class sessions engage students in discussion and evaluation of several *case studies* featuring real-world accidents and incidents that involved human error and poor design. Example cases include the death of Elaine Herzberg, the first recorded pedestrian fatality involving a self-driving car [10], and the death of Charlene Murphy at Vanderbilt University Medical Center in a fatal medication accident [11]. Students independently complete a case study based on a chapter from *Set Phasers on Stun* [12] that details the death of a patient receiving radiation treatment using the radiotherapy accelerator, Therac-25.

As a final project, students curate their own collection of design principles aimed at professionals in their field (or another specific target audience). Throughout the class, as each aspect of human perception, cognition, and action is introduced, they are immediately translated into concrete design principles that can be applied in a range of industries and settings. For their final project, students are asked to select some of these principles (or write their own), define them, motivate them based on theory, and provide concrete examples of the principle in action

or the consequences of failure to apply it. Students can choose the format of their collection (which must be approved). Common project formats have included websites, YouTube channels, social media accounts, e-books, and graphic novels.

The course also includes two experiences outside of the classroom. For one, students tour the campus power plant, focusing on the control of the power plant and on recent upgrades to the control room and human-machine interfaces. Students have the opportunity to meet one of the powerplant operators and ask questions about their job, training, and experiences. This tour is the basis for one of the extended reflections that asks students to identify examples of design principles and other concepts that they've learned about throughout the semester.

The other experience is a design thinking workshop, modeled after the classic Wallet Project from the Stanford d.School [13]. This two-class workshop is held in our campus makerspace and introduces students to mindsets and processes of design thinking.

III. Preliminary Results

The course has been piloted over three semesters at Michigan Technological University, a mid-sized, public engineering university within the United States, with increasing course enrollment (N_{2021}=13, N_{2022}=17, N_{2023}=37) and positive student evaluations (N_{2021}=4.62/5, N_{2022}=4.75/5, N_{2023}=4.44/5). As this course has grown, so too has the visibility of human factors programs on campus, as well as enrollment in upper division human factors courses (especially those that have been added to the general education list). Our 3000-level human factors class has sufficient enrollment to begin offering it every year (instead of on an every other year rotation) and has been added as a required course in the mechatronics program. Enrollment in our 4000-level cognitive task analysis course has doubled each year. Both classes have since been added as technical elective choice points in other majors.

IV. Discussion

The development of this course occurred in parallel with a number of other changes on our campus, including the launch of a new bachelor's degree in Human Factors and the redesign of Michigan Tech's general education program. The latter, in particular, afforded a unique opportunity to introduce more students to human factors and human-centered design. Prior to our general education reform, adding courses to the general education program was possible, but certain categories of courses were tightly controlled. Students also had a tendency to choose their general education courses based on what fit in their schedule rather than based on courses that might complement their major or serve them in their career.

Upon the arrival of a new university president, the campus community was charged with reimagining education for the 21st century. Over four years, more than 100 faculty, staff, and students collaborated to develop a new general education program from the ground up, considering the skillsets and mindsets that Michigan Tech's (predominantly) engineering and computing students need to thrive in a rapidly changing technological world. The resulting Essential Education program infuses the AACU's high impact practices [14] into the general education curriculum, emphasizes 21st century skillsets and mindsets, and helps students select a more cohesive set of general education courses and make connections between these courses and their major program of study.

Introduction to Engineering Psychology is included at a required choice point, Foundations in the Human World, that most students will take during their first year of college. This will ensure that all engineering students have the option to take the class without adding additional credit requirements to their program. Additionally, beginning in fall 2025, students can opt to complete one of fifteen interdisciplinary minors in partial fulfillment of the Essential Education requirements. Human-centered design has been identified as one of the interdisciplinary themes and the minor (currently in development) will feature *Introduction to Engineering Psychology* as its foundational course. As a result, some aspects of the current class (e.g., assessment formats) will likely need to be adapted to allow for larger sections. The overall structure and content, however, are expected to remain the same

The combination of adding *Introduction to Engineering Psychology* to the general education program and introducing a human-centered design themed minor as one way to satisfy general education

requirements will provide all engineering students with the opportunity to learn about human factors early in their engineering degree program, hopefully increasing the likelihood that students will adopt human-centered design practices and consider human-systems integration early in the design process in their senior design projects and as they enter the workplace. To assess the benefits of the new course and the new minor, we plan to conduct follow-up surveys with students who have taken the *Introduction to Engineering Psychology* class and a matched sample of those who have not. In addition to assessing knowledge about human factors and human-centered design practices, assessments will include measures of attitudes associated with human-centered design, for example, the validated Systems Engineering and Design Thinking Scale[15].

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