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# Scholarship of Teaching and Learning in Psychology

Manuscript version of

Teaching Psychology to Future Engineers

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Funded by:

- National Science Foundation

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## **Abstract**

Human needs and goals are integral to engineering, but human-centered engineering requires understanding principles and methods from the social sciences. Instruction is needed to introduce engineering students to these concepts. This study explored (a) students' initial attitudes toward human systems engineering (HSE) and the bridging of psychology and engineering, and (b) how attitudes shifted over one semester. Undergraduate students responded to a survey of their attitudes and conceptions at the beginning ( $n = 215$ ) and end ( $n = 146$ ) of a semester. Students reported high perceived value for human-centered engineering, and these attitudes remained stable or increased. Students gained in their perceived understanding of psychological concepts and user-centered design, their ability to define HSE, and ability to articulate the value of human-centered engineering. Introductory coursework in Human Systems Engineering may thus help to prepare engineering students to appreciate the psychological underpinnings of their work and engage in human-centered engineering.

**Keywords:** Human Systems Engineering; human-centered engineering; teaching of psychology; engineering education; survey methods

## Teaching Psychology to Future Engineers

Human needs are integral to engineering (Oehlberg et al., 2012; Wickens et al., 2021). Engineers must consider who they are designing *for* and how engineered systems impact their users and clients (Mohedas et al., 2020; Oehlberg et al., 2012; Zoltowski et al., 2012). For example, insights from human-computer interaction (Jacko, 2012) and human systems integration (Boehm-Davis et al., 2015) inform designs that operate more effectively, efficiently, and safely for people. Second, engineering frequently occurs among multidisciplinary teams (Hall et al., 2018; Borrego et al., 2013), and engineering *with* other people necessitates interpersonal understanding and communication across disciplines (Cooke et al., 2012; McNeese et al., 2021). Team diversity (e.g., demographic and intellectual) can improve creativity and performance, but such benefits depend on constructive integration driven by shared understanding and values (Leroy et al., 2022; Salazar et al., 2012). Finally, engineers possess their *own* beliefs and attitudes (Sheu et al., 2018; Slaton, 2015; Stump et al., 2014). Engineers' personal preferences influence proposed solutions (Kinsey et al., 2020; Mohanani et al., 2020), and their beliefs influence how the needs of diverse users are included (e.g., designing technology for older adults; Harris et al., 2019) versus excluded during development (e.g., algorithmic bias in educational technology; Baker & Hawn, 2022).

Adopting and maintaining an authentic human-centered focus requires overcoming several hurdles. For example, engineers must contend with conceptions that promote societal disengagement (Cech, 2014; Slaton, 2015). Engineering culture commonly frames STEM pursuits as separate from emotions, politics, or systemic issues (e.g., racism), which fosters misconceptions that engineers can operate without acknowledging or addressing societal concerns. This ideology may be encouraged when the teaching of psychology and human factors

is disconnected from engineering (Roscoe, Becker, et al., 2019). Another obstacle is awareness—understanding how people think, feel, and act with engineered systems requires familiarity with psychology or related social sciences (Hynes & Swenson, 2013; Oehlberg et al., 2012, Pannasch et al., 2021; Wickens et al., 2021). How can future engineers account for the self-efficacy beliefs of users or themselves (Sheu et al., 2018) if they are unaware of that concept? How can engineers recognize their own cognitive biases (Kinsey et al., 2020; Mohanani et al., 2020) if they never learn about those topics?

One prior investigation observed that psychological concepts were rarely referenced in engineering students' project documentation (Roscoe, Arnold, & Johnson, 2020). Researchers analyzed over 200 reports from an introductory engineering course wherein students redesigned “the future of being a passenger.” Overall, fewer than 10% of projects mentioned design thinking steps (e.g., empathy, problem-solving, and evaluation; see Dym et al., 2005; Razzouk & Shute, 2012), and fewer than 5% mentioned aspects of teamwork (e.g., consensus and delegation). Reports almost never mentioned psychosocial themes like “anxiety” (6%) or “frustration” (4%), and fewer than 2% mentioned “attention,” “interest,” “learning,” or “planning.” No other psychology concepts were reliably detected. Moreover, most psychological concepts were mentioned superficially—never defined nor explained. Finally, fewer than 10% of projects applied these concepts to *users* (e.g., user discomfort), but instead focused on students' *own* experiences (e.g., anxiety about teams). Although there was no expectation for engineering students to possess psychology expertise, these findings suggested enormous opportunities for teaching engineers about human-centered thinking.

At Arizona State University (ASU) the Human Systems Engineering (HSE) program addresses this gap via undergraduate and graduate coursework that bridges psychology and

engineering (Roscoe, Becker, et al., 2019). HSE majors typically seek careers (e.g., “Human Factors Engineer” and “User Experience Researcher”) in technology-related areas including personal computing, digital services, healthcare, aerospace, sporting goods, educational technology, and manufacturing. Importantly, HSE courses are also available and promoted to traditional engineering students through dual major, minor, and certificate programs. Thus, students who aim to become traditional engineers have access to credit-bearing, psychology-based instruction relevant to their work.

A foundational program component is “Introduction to Human Systems Engineering” (HSE 101). The literature on introductory STEM (i.e., science, technology, engineering, and math) courses has established their crucial role in building disciplinary knowledge, interest, and identities (Besterfield-Sacre et al., 1997; Gasiewski et al., 2012; Gurung & Neufeld, 2021; Medeiros et al., 2019; Pfund et al., 2018; Zieffler et al., 2008; Zoltowski et al., 2012). Meaders and colleagues have documented how such courses shape student expectations and concerns in their field (Meaders et al., 2019, 2020). Introductory psychology (or “PSY 101”) has received similar attention (Gurung et al., 2016; Gurung & Hackathorn, 2018; Gurung & Neufeld, 2021). For instance, Kowalski and Taylor (2009) explored how introductory psychology helps to refute common psychology misconceptions, and diverse studies have tested pedagogical approaches such as assignment modality (Riordan et al., 2020) and team-based learning (Travis et al., 2016).

The HSE 101 course catalog description (ASU, 2022) states that students will learn “basic principles, methods and theories of psychology and applications to engineering problems relevant to human systems” with “particular attention to the intersection of psychology and engineering.” Course topics span “brain anatomy and physiology, sensation and perception, cognition, social systems, and research methods” that engineers and others can “design systems

consistent with human capabilities and limitations.” HSE 101 also meets requirements for socio-behavioral general studies, which teach “methods of inquiry and empirical knowledge about human behavior, within society and individually” that are connected to “cultural, economic, geographic, historical, linguistic, political, psychological, or social” issues. Engineering students could meet this requirement via PSY 101, but HSE 101 offers an engineering lens. HSE 101 may thus have higher relevance to students who want to remain immersed in their field yet seek to bolster their expertise. For example, software engineers with human-centered design training are in demand, particularly in fields concerned with interface design or algorithmic bias.

Following calls for further research on introductory psychology-relevant coursework (Gurung & Neufeld, 2021), the current study surveys students’ conceptions of human systems engineering, attitudes toward bridging psychology and engineering, and how these factors shifted over one semester of HSE 101. Importantly, the aim was not to contrast HSE 101 versus alternatives (e.g., PSY 101) to determine the “best” for learning or engagement, nor was the intention to inform causal claims about course design. This investigation descriptively examined changes in attitudes to gain insight into the value of this unique course and to inform future iterations. The core methodology was a survey administered at the beginning and end of the semester, with sections on (a) attitudes toward topic areas, (b) conceptions of HSE, and (c) attitudes toward bridging psychology and engineering. This work was guided by two questions:

- **Research Question 1 (RQ1): What are students’ initial attitudes and conceptions of human systems engineering?** How do students perceive the bridging of psychology and engineering prior to HSE 101 instruction?
- **Research Question 2 (RQ2): How do students’ attitudes and conceptions of human systems engineering shift after one semester of HSE 101?** Do students perceive the

bridging of psychology and engineering more favorably, less favorably, or no differently over time?

## **Method**

### **Introduction to Human Systems Engineering (HSE 101)**

The research occurred within multiple sections of HSE 101, all of which taught introductory psychology content (e.g., Cacioppo & Freberg, 2016) infused with relevant examples from engineering and design (e.g., Cooke & Durso, 2007; McLaughlin, 2022; Norman, 2013). Naturally, there were variations across instructors with regard to topics and sequencing, but the overarching learning objectives were highly comparable. For instance, learning objectives in one section spanned (a) research methods, (b) body and behavior, (c) sensation and perception, (d) consciousness, (e) learning and conditioning, (f) thinking and memory, (g) motivation and emotion, (h) human development, (i) personality, (j) stress, (k) group behavior, and (l) applications to real-world problems. Similarly, learning objectives from a different section included (a) research methods, (b) applying psychology to engineering problems, (c) body and behavior, (d) sensation and perception, (e) consciousness, (f) learning and condition, (g) thinking and memory, (h) motivation and emotion, (i) cognitive processes and interactions with the environment, (j) stress, (k) health psychology, (l) group behavior, (m) language and communication, and (n) applications to real-world situations. These foundational psychology themes were typically taught in connection with applied examples, such as how product designs afford or constrain usage based on principles of human perception and behavior (Norman, 2013), or how motor vehicle design interacts with human development and aging (Cooke & Durso, 2007). In sum, HSE 101 course fundamentally seeks to teach psychology to future engineers—HSE 101 is a psychology course tailored to engineering audiences rather than an engineering course with superficial appeals to psychology.

## **Participants**

The research was approved by the ASU Institutional Review Board (IRB), and all participants provided informed consent before participating. This process communicated that the purpose was “to understand students’ attitudes about engineering-related courses,” and explained that the survey included “a few questions about your personal background and goals,” “questions about Human Systems Engineering,” and ratings about “your attitudes toward a variety of topics.” The consent process also communicated that data would “be used for research purposes and to help us improve students’ educational experience.” Immediate course credit or financial incentives were not offered, but participants were informed that they would be entered into a raffle for one of five \$20 rewards. All participation was voluntary.

**Beginning of the Semester.** All students enrolled in five in-person sections of HSE 101 (taught by three independent instructors) were invited to participate. From this population of about 250 students, 216 students provided informed consent and took the survey at the beginning of the semester. One participant did not provide complete data and was excluded from analyses, resulting in an initial sample of 215 students (Table 1). As expected in an introductory course, the majority were first year students (83.7%). The sample was demographically limited to those enrolled in the course. As is typical of undergraduate engineering populations in the United States, the sample was largely male, White, and English-speaking. A variety of majors were reported, including engineering fields (e.g., mechanical, software, and robotics) and other STEM fields (e.g., biology and information technology). We recorded student majors as given, and thus there was ambiguity. For instance, both manufacturing engineering or electrical engineering majors who specialized in robotics may have listed “robotics engineering.”

Participants were further characterized by their aspirations (Table 1). Participants ( $n = 215$ ) expressed strongly positive aspirations for learning about engineering, solving problems, being creative and innovative, being ethical and compassionate, working with variety of people, and improving career opportunities. Students were also somewhat positive toward learning about psychology and combining areas of expertise. Reported aspirations for learning about engineering were higher than goals of learning about psychology,  $t(214) = 10.91$ ,  $p < .001$ ,  $d = 0.74$ . Indeed, goals of learning about psychology were significantly lower than all other aspirations (all  $t > 9.00$ , all  $p < .001$ , and  $d > -0.62$ ). The most strongly endorsed goal was to improve career prospects. Students agreed with this goal significantly more than any other goal (all  $t > 4.0$ , all  $p < .001$ , and all  $d > 0.30$ ). Overall, the main observation is that students positively endorsed all goals, on average, including intentions to solve authentic problems while being creative, ethical, and interdisciplinary. Thus, a variety of students may be drawn to HSE 101 and possess openness toward human-centered engineering.

**End of the semester.** At the end of the semester, we returned to the same HSE 101 sections and offered the survey to all students who were present. Students who had not completed the initial survey were invited to participate although their data were not analyzed. Two predictable challenges related to absenteeism (Golding, 2011; Oldfield et al., 2018) and course withdrawal (Hudson et al., 2014, 2015). Researchers have reported pervasive problems of student attendance and declines in attendance throughout any semester. Likewise, students may withdrawal from courses for reasons spanning finances, health, time constraints, or interest. Both of these factors contributed to attrition; a number of students who had completed the initial survey were absent or no longer enrolled in the course for the second survey. One student did not finish the survey.

We refer to the subset of participants who fully responded to both rounds of the survey as the “Complete” sample ( $n = 146$ ). Table 1 characterizes this subset with respect to demographics and aspirations. One consideration was whether attrition was systematically driven by subsets of students (e.g., first-generation students, Goldman et al., 2020). In this study, the students who completed both survey rounds were demographically similar to (a) the entire initial sample and (b) students who took only the first survey. ANOVA (i.e., for age) and chi-square tests (i.e., for sex, ethnicity, language, year in school, and academic major) showed no significant differences between students who completed both rounds of the survey ( $n = 146$ ) versus only the first round ( $n = 69$ ). There was a small effect of language;  $X^2 = 4.01$ ,  $p = .045$ . Among the 146 participants who completed both rounds, 32 (21.9%) self-identified as multilingual. However, of the 69 participants who completed only the initial survey, 24 (34.8%) self-identified as multilingual. Thus, English language proficiency may have contributed to attrition for a few participants. However, we cannot know if these participants were absent, had withdrawn, or chose not to participate for the second survey. Finally, mean aspiration ratings from the Initial and Complete samples were nearly identical and demonstrated the same patterns (Table 1). Aspirations for learning about psychology were significantly lower than all others (all  $t > 7.00$ , all  $p < .001$ , and  $d > -0.60$ ), and aspirations for improving career prospects were significantly higher than all others (all  $t > 4.00$ , all  $p < .001$ , and  $d > -0.34$ ).

Given the similarity between the Initial and Complete samples, and given the study purposes, analyses focus only on the Complete sample ( $n = 146$ ). Responses from the beginning and end of the semester are referred to as “Round 1” and “Round 2,” respectively.

Table 1. Characterizing participants across the initial sample and complete subset.

| <b>Demographic Background</b>                         | <b>Initial (n = 215)</b> | <b>Complete (n = 146)</b> |
|-------------------------------------------------------|--------------------------|---------------------------|
| <b>Age, Mean (SD)</b>                                 | 19.0 (2.0)               | 19.1 (2.3)                |
| <b>Sex, Frequency (%)</b>                             |                          |                           |
| Female                                                | 37 (17.2%)               | 24 (16.4%)                |
| Male                                                  | 178 (82.8%)              | 122 (83.6%)               |
| <b>Race/Ethnicity, Frequency (%)</b>                  |                          |                           |
| Asian                                                 | 21 (9.8%)                | 17 (11.6%)                |
| Black                                                 | 7 (3.4%)                 | 4 (2.7%)                  |
| Hispanic/Latinx                                       | 41 (19.1%)               | 23 (15.8%)                |
| Indian                                                | 5 (2.3%)                 | 5 (3.4%)                  |
| Middle Eastern                                        | 4 (1.9%)                 | 3 (2.1%)                  |
| Multiracial                                           | 24 (11.2%)               | 16 (11.0%)                |
| Native American                                       | 6 (2.8%)                 | 3 (2.1%)                  |
| White                                                 | 104 (48.4%)              | 74 (50.7%)                |
| Unreported                                            | 3 (1.4%)                 | 1 (0.7%)                  |
| <b>Language Fluency, Frequency (%)</b>                |                          |                           |
| English Only                                          | 159 (74.0%)              | 114 (78.1%)               |
| Multilingual                                          | 56 (26.0%)               | 32 (21.9%)                |
| <b>Year in School, Frequency (%)</b>                  |                          |                           |
| 1 <sup>st</sup>                                       | 180 (83.7%)              | 124 (84.9%)               |
| 2 <sup>nd</sup>                                       | 22 (10.2%)               | 14 (9.6%)                 |
| 3 <sup>rd</sup>                                       | 10 (4.7%)                | 7 (4.8%)                  |
| 4 <sup>th</sup>                                       | 2 (0.9%)                 | 1 (0.7%)                  |
| Unreported                                            | 1 (0.5%)                 | 0 (0.0%)                  |
| <b>Academic Major, Frequency (%)</b>                  |                          |                           |
| Aeronautical Management Technology                    | 30 (14.0%)               | 19 (13.0%)                |
| Applied Biological Sciences                           | 8 (3.7%)                 | 5 (3.5%)                  |
| Automotive Engineering                                | 22 (10.2%)               | 13 (8.9%)                 |
| Chemical Engineering                                  | 1 (0.5%)                 | 1 (0.7%)                  |
| Electrical Engineering                                | 8 (3.7%)                 | 6 (4.1%)                  |
| Engineering                                           | 21 (9.8%)                | 14 (9.6%)                 |
| Environmental Resource Management                     | 2 (0.9%)                 | 1 (0.7%)                  |
| Graphic Information Technology                        | 18 (8.4%)                | 14 (9.6%)                 |
| Human Systems Engineering                             | 13 (6.0%)                | 8 (5.5%)                  |
| Information Technology                                | 13 (6.0%)                | 11 (7.5%)                 |
| Interdisciplinary                                     | 2 (0.9%)                 | 1 (0.7%)                  |
| Manufacturing Engineering                             | 5 (2.3%)                 | 5 (3.4%)                  |
| Mechanical Engineering                                | 33 (15.3%)               | 25 (17.1%)                |
| Robotics Engineering                                  | 22 (10.2%)               | 14 (9.6%)                 |
| Software Engineering                                  | 14 (6.5%)                | 6 (4.1%)                  |
| Sustainable Horticulture                              | 1 (0.5%)                 | 1 (0.7%)                  |
| Technical Communication                               | 2 (0.9%)                 | 2 (1.4%)                  |
| <b>Aspirations, Mean (SD), 10-point scale</b>         |                          |                           |
| I want to learn more about engineering and design.    | 8.4 (2.0)                | 8.5 (2.1)                 |
| I want to learn more about psychology and behavior.   | 6.3 (2.3)                | 6.3 (2.4)                 |
| I want my work to combine several areas of expertise. | 7.7 (1.9)                | 7.7 (1.9)                 |
| I want to solve important real-world problems.        | 8.3 (1.9)                | 8.4 (1.9)                 |
| I want to be creative and innovative.                 | 8.9 (1.6)                | 8.9 (1.6)                 |
| I want to be ethical and compassionate                | 8.5 (1.8)                | 8.7 (1.7)                 |
| I want to work with a variety of different people.    | 8.0 (2.0)                | 8.0 (2.0)                 |
| I want to improve my career opportunities.            | 9.4 (1.0)                | 9.5 (1.0)                 |

## **Human Systems Engineering Attitudes Survey (HSEAS)**

The HSEAS was inspired by engineering education instruments (Besterfield-Sacre et al., 1997; Hilpert et al., 2010; Olson et al., 2013) and developed over multiple iterations (Roscoe, Arnold, & Clark, 2020).

**Background.** Participants self-reported their year of birth, sex, race/ethnicity, languages, year in school, and academic major via open-ended items. Eight survey items elicited self-reported aspirations about engineering and psychology (e.g., “I want to learn more about psychology and behavior”) and personal goals (e.g., “I want to be creative and innovative”). Each item was a positively-worded statement and participants rated “how well the statement describes you” on a 10-point scale from “1” (Does Not Describe Me) to “10” (Describes Me Very Well) (Table 1).

**Topic Attitudes.** Ten items elicited self-reported attitudes about broad topics in STEM (i.e., science and math), psychology (i.e., human perception and memory, human reasoning, human motivation, and human interactions), and methodology (i.e., research methods, user-centered design, data analysis, and writing and communication). The survey noted that respondents might have “mixed feelings” and thus items were decomposed into three dimensions of perceived understanding, perceived usefulness, and perceived enjoyment. All ratings were given on a 10-point scale from “1” (Very Low) to “10” (Very High).

**HSE Conceptions.** Open-ended items invited participants to express their “knowledge of Human Systems Engineering, which is strongly related to fields such as Human Factors, Ergonomics, Human-Computer Interaction, Human Systems Integration, and User-Centered Design.” Specifically, three questions were developed to elicit students’ ideas about the nature of HSE, methods used by HSE experts, and the value of HSE for improving engineering and

design. Importantly, students' potential descriptors were not known in advance, and thus these items were not created as closed questions. Open-ended qualitative items enabled the researchers to derive conceptions from students' own words with greater saturation and depth:

- “In your own words, define the field of Human Systems Engineering. What does ‘Human Systems Engineering’ mean to you?”
- “How would an engineer use Human Systems Engineering to improve their work? What are some of the methods they might use?”
- “Is learning about Human Systems Engineering useful to engineering students? What is the value of Human Systems Engineering?”

Following methodologies for coding qualitative verbal data (Chi, 1997), researchers developed a rubric for identifying descriptors expressed by participants. An initial set of descriptors was derived from program materials (Roscoe, Becker, et al., 2019), such as characterizing HSE as a “multidisciplinary field” that “uses design methods” to “improve user experience.” Participant responses were then inductively examined to elaborate, combine, add, or remove descriptors based on how students actually expressed themselves. This process also generated operational definitions and exemplar quotes (Table 2). Two coders were extensively trained on the rubric and completed three iterations of practice coding with discussion of discrepancies. The two coders then independently coded the binary presence of each descriptor in the entire dataset. Final coding reliability was high (all  $\kappa \geq .97$ ). Notably, despite the alignment between survey questions and coding dimensions, relevant descriptors could appear in response to *any* question. Participants received credit for a descriptor regardless of where it appeared in their responses.

Table 2. Descriptors, operational definitions, and excerpts for coding open-ended responses about HSE.

| Dimension                | Descriptor           | Brief Operational Definition                                                                                                                                                                                                                                          | Example Excerpt                                                                                                                                                                                                                                                       |
|--------------------------|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Definition of HSE</b> | Multidisciplinary    | HSE draws upon two or more fields of study, whether separate disciplines (e.g., psychology and engineering) or subfields within a discipline (e.g., cognitive and social psychology).                                                                                 | “Human systems engineering to me is the <u>integration of the broad fields of engineering and human psychology</u> to improve technology/products/services for mankind.”                                                                                              |
|                          | Human-Centered       | HSE draws upon and applies principles of psychology, sociology, anthropology, ergonomics, and social sciences related to human thought, feeling, and behavior. These fields are applied with regards to human needs, goals, abilities, and limitations.               | “Human systems engineering is the <u>application of the study of human behavior, limitations and abilities</u> to create safer, efficient, cost-effective products while also putting an emphasis on the <u>experience of all users</u> .”                            |
|                          | Engineering          | HSE is a field or subfield in the disciplines of engineering, technology, or design. Or, HSE directly participates in engineering, technology, and design processes or activities.                                                                                    | “Human Systems Engineering means <u>applying engineering concepts</u> to human interactions. This can involve using psychology to know how to better <u>implement an engineering concept</u> , or <u>using engineering</u> to help human systems progress.            |
|                          | Research-Based       | HSE is research-based and scientific in nature, and uses empirical scientific methods, data, and related scientific practices to generate and test hypotheses, solve problems, and make data-driven recommendations. HSE does not rely only intuition or opinion.     | “Where the human brain, and its resulting behavior is <u>studied as a "normal science," as opposed to a "soft science"</u> , and the <u>theories from these studies are applied</u> for useful applications the <u>same way that other scientific theories are</u> .” |
| <b>Methods of HSE</b>    | Survey and Interview | HSE uses methods that elicit or solicit responses (from participants, users, clients, or stakeholders) by asking questions in surveys, interviews, focus groups, or related formats. Questions may probe knowledge, attitudes, or behaviors, or similar self-reports. | “The designs would improve on fulfilling the customers’ request. <u>Surveys</u> of preliminary designs presented to customers.”                                                                                                                                       |
|                          | Observational        | HSE uses methods that collect data on peoples’ actions, interactions, and behaviors by observing them in lab or real-world settings. This category includes participatory methods and use of archival or trace data on prior behaviors.                               | “Understanding correlations between culture and preference from data. <u>Watch people use items</u> , see flaws, how they initially react to & with it.”                                                                                                              |

Table 2, continued.

| Dimension      | Descriptor      | Brief Operational Definition                                                                                                                                                                                               | Example Excerpt                                                                                                                                                                                                                               |
|----------------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Methods of HSE | Data Analytic   | HSE uses valid and reliable methods for coding, analyzing, interpreting, and visualizing data. These methods include quantitative tools (e.g., statistics) and qualitative tools (e.g., grounded theory).                  | “Using qualitative and quantitative information about humans physical structure and psychological responses/thought process, an engineer can tailor their design to physically accommodate humans or have a positive psychological response.” |
|                | Design          | HSE uses design methods (e.g., heuristic evaluations, prototyping, wireframes, simulations, and models) to evaluate designs, either among developers or with potential end-users.                                          | “Gathering a diverse group of individuals to test a product or <u>sending out a prototype</u> to be used to gauge real time reactions.”                                                                                                       |
| Value of HSE   | User Experience | HSE improves users’ subjective feelings, attitudes, and satisfaction toward designs, tasks, and systems. Refers specifically to perceptions rather than functioning.                                                       | “Yes, because it is good to understand how others think and <u>what they enjoy doing</u> to be able to <u>create something enjoyable</u> for everyone.”                                                                                       |
|                | Usability       | HSE improves designs or solves problems to make tasks and products function accurately and efficiently, resulting in better user performance and productivity. Refers specifically to functioning rather than perceptions. | “Creating a product that is not only advanced and <u>efficient</u> for its use but also has a <u>high success rate</u> because of the <u>ease of operation</u> ”                                                                              |
|                | Understanding   | HSE improves insight or understanding related to the tasks, products, or systems being designed. Can also refer to understanding other people or oneself.                                                                  | “Yes, because as stated above it allows the engineer to <u>understand clients at a deeper level</u> . Which can allow them to create a product much closer to their needs.”                                                                   |
|                | Society         | HSE improves society or quality of life for many people. HSE can address broad issues that impact many people, such as accessibility, inclusion, and equity.                                                               | “An opportunity to understand myself and the world <u>in order to better the world</u> through colaboratin, design, and innovation to help create things to be more efficient and <u>change the world</u> ”                                   |

**Attitudes toward psychology and engineering.** Eleven items elicited self-reported attitudes about engineers and psychologists. Participants rated their understanding of “what engineers do” and “what psychologists do,” and the extent to which engineers or psychologists “solve real-world problems,” “should be creative,” and “should be ethical.” Finally, participants indicated whether engineers and psychologists should learn about each other’s disciplines and “work together.” All items were presented as positively-worded statements. Participants rated their agreement on a 10-point scale, ranging from “1” (Strongly Disagree) to “10” (Strongly Agree).

### **Procedure**

Data collection took place in-person at two time points. Round 1 occurred within the first two weeks and Round 2 occurred within the final two weeks of the class. Paper-and-pencil surveys were distributed to students and the first page served as the consent form. Students could review the consent information, ask questions, and then decide whether to participate. Students who chose not to participate could use the time (about 15-20 minutes) on other activities. There was no penalty for not participating, although participants were entered into a raffle for a gift card. Data from the surveys were subsequently de-identified and transcribed by members of the research team.

### **Results**

Examination of HSEAS responses from Round 1 reveals participants’ attitudes and conceptions prior to instruction (RQ1). Comparison of responses from Round 1 to Round 2 reveals how attitudes and conceptions changed over time (RQ2). If HSE 101 adequately fulfills its instructional purpose, we expect attitudes to become more positive over time (e.g., more favorable toward bridging the disciplines) and for conceptions of HSE to become broader or more complete.



Table 3. Perceived understanding, usefulness, and enjoyment of disciplinary topics.

| Dimension                      | Round 1   | Round 2   | Wilks' $\lambda$ | $F$    | $p$    | $\eta^2$ |
|--------------------------------|-----------|-----------|------------------|--------|--------|----------|
| <b>Perceived Understanding</b> |           |           |                  |        |        |          |
| <b>STEM Topics</b>             |           |           | .99              | < 1.00 | .400   | .01      |
| Science                        | 7.0 (1.6) | 7.0 (1.6) |                  |        |        |          |
| Math                           | 7.7 (1.7) | 7.6 (1.8) |                  |        |        |          |
| <b>Psychology Topics</b>       |           |           | .82              | 7.65   | < .001 | .18      |
| Perception and Memory          | 6.0 (2.0) | 7.0 (1.8) |                  |        |        |          |
| Reasoning                      | 6.6 (2.0) | 7.1 (1.7) |                  |        |        |          |
| Motivation                     | 6.5 (2.2) | 7.3 (1.8) |                  |        |        |          |
| Interactions                   | 6.7 (2.1) | 7.2 (1.8) |                  |        |        |          |
| <b>Methodology Topics</b>      |           |           | .88              | 4.81   | < .001 | .12      |
| Research Methods               | 7.3 (1.7) | 7.6 (1.8) |                  |        |        |          |
| User-Centered Design           | 6.5 (2.1) | 7.2 (1.9) |                  |        |        |          |
| Data Analysis                  | 6.8 (2.0) | 7.1 (1.9) |                  |        |        |          |
| Writing and Communication      | 7.7 (1.7) | 8.0 (1.6) |                  |        |        |          |
| <b>Perceived Usefulness</b>    |           |           |                  |        |        |          |
| <b>STEM Topics</b>             |           |           | .97              | 2.18   | .116   | .03      |
| Science                        | 8.0 (2.0) | 8.3 (1.6) |                  |        |        |          |
| Math                           | 8.6 (2.0) | 8.5 (2.0) |                  |        |        |          |
| <b>Psychology Topics</b>       |           |           | .95              | 2.04   | .092   | .05      |
| Perception and Memory          | 8.2 (1.8) | 8.0 (2.0) |                  |        |        |          |
| Reasoning                      | 8.4 (1.7) | 8.4 (1.7) |                  |        |        |          |
| Motivation                     | 8.2 (1.9) | 8.4 (1.8) |                  |        |        |          |
| Interactions                   | 8.3 (1.9) | 8.4 (2.0) |                  |        |        |          |
| <b>Methodology Topics</b>      |           |           | .95              | 1.92   | .109   | .05      |
| Research Methods               | 8.5 (1.6) | 8.2 (2.0) |                  |        |        |          |
| User-Centered Design           | 8.3 (1.8) | 8.2 (1.8) |                  |        |        |          |
| Data Analysis                  | 8.5 (1.9) | 8.5 (1.9) |                  |        |        |          |
| Writing and Communication      | 8.9 (1.4) | 8.9 (1.4) |                  |        |        |          |
| <b>Perceived Enjoyment</b>     |           |           |                  |        |        |          |
| <b>STEM Topics</b>             |           |           | .99              | < 1.00 | .717   | .00      |
| Science                        | 6.7 (2.2) | 6.6 (2.3) |                  |        |        |          |
| Math                           | 6.7 (2.6) | 6.6 (2.6) |                  |        |        |          |
| <b>Psychology Topics</b>       |           |           | .98              | < 1.00 | .696   | .02      |
| Perception and Memory          | 6.6 (2.2) | 6.9 (2.2) |                  |        |        |          |
| Reasoning                      | 6.7 (2.1) | 7.1 (2.1) |                  |        |        |          |
| Motivation                     | 7.1 (2.2) | 7.3 (2.1) |                  |        |        |          |
| Interactions                   | 7.2 (2.4) | 7.4 (2.2) |                  |        |        |          |
| <b>Methodology Topics</b>      |           |           | .99              | < 1.00 | .868   | .01      |
| Research Methods               | 6.3 (2.2) | 6.2 (2.3) |                  |        |        |          |
| User-Centered Design           | 7.0 (2.1) | 7.1 (2.1) |                  |        |        |          |
| Data Analysis                  | 6.0 (2.3) | 6.0 (2.3) |                  |        |        |          |
| Writing and Communication      | 6.0 (2.6) | 6.1 (2.3) |                  |        |        |          |

Note. For multivariate tests of STEM Topics (Science and Math), the  $F$  parameter is  $F(2,144)$ . For multivariate tests of Psychology Topics (Perception, Reasoning, Motivation, and Interactions) and Methodology Topics (Methods, Design, Analysis, and Communication, the  $F$  parameter is  $F(4,142)$ .

## Self-Reported Topic Attitudes

In Round 1, participants rated their perceived topic *understanding* positively (Table 3). Perceived understanding of STEM topics, psychology topics, and methodology topics were all favorable. Perceived understanding of science, math, research methods, and writing somewhat were higher than perceived understanding of most psychology topics, user-centered design, or data analysis. Participants may have felt that they had familiarity with science and research, but were less sure of their knowledge of human-centered concepts. This pattern makes sense for engineering majors who had sufficient awareness of human-centered engineering to choose HSE 101.

Participants reported no increase in their perceived understanding of STEM topics. However, there were modest but statistically significant shifts in overall perceived understanding of psychology and methodology topics over the semester (Table 3). Further inspection of specific psychology topic items revealed significant self-reported growth in perceived understanding of human perception,  $F(4,142) = 28.30, p < .001, \eta^2 = .16$ ; reasoning,  $F(4,142) = 10.02, p = .002, \eta^2 = .06$ ; motivation,  $F(4,142) = 19.36, p < .001, \eta^2 = .26$ ; and social interactions,  $F(4,142) = 8.17, p = .005, \eta^2 = .05$ . Similarly, closer inspection of ratings for individual methodology items revealed significant self-reported growth in perceived understanding of user-centered design,  $F(4,142) = 17.04, p < .001, \eta^2 = .10$ ; and similar but nonsignificant trends for research methods and communication. Overall, these trends are in alignment with the curriculum and focus of HSE 101, which sought to teach psychological concepts to engineering students.

Perceptions of the *usefulness* of STEM, psychology, and methodology topics were strong and positive from the outset (all Round 1 average ratings  $\geq 8.0$ ) (Table 3). These attitudes remained stable; no statistically significant growth or decline was reported from Round 1 to Round 2. One interpretation is that learners were already “sold” on HSE and interested in

learning about psychology in engineering—perhaps why they enrolled in HSE 101 in first place. It is also encouraging that perceived usefulness did not decline after learners were formally exposed to HSE.

Perceived *enjoyment* of STEM, psychology, and methods topics was also generally favorable at Round 1 and did not change in Round 2. These findings suggest that there are opportunities for HSE 101 instructors to identify alternative factors (e.g., curriculum or pedagogy) that promote excitement or personal connection, but students are at least receptive to the topics.

### **Student Conceptions of Human Systems Engineering**

Preceding analyses revealed that participants perceived positive growth in their understanding of psychological concepts and user-centered design that are central to HSE. To further explore participants' conceptions of HSE, a second analysis coded open-ended responses to questions about the nature of HSE, HSE methods, and the value of HSE (Table 4).

In Round 1, nearly all participants (98.6%) described HSE as a human-centered discipline, and most participants recognized HSE as an engineering discipline (74.0%)—of course, these concepts are embedded in the course name. About half of participants understood that HSE can improve usability (49.3%) or improve understanding of people, systems, or oneself (48.6%). These are fundamental aspects of HSE that are likely articulated early in the course. In addition, familiarity with HSE may be what drew students to the course along with perceived usefulness. Fewer participants articulated that HSE is inherently multidisciplinary (18.5%) or empirical (28.8%), or recognized the value of HSE for improving user experience (19.2%). The largest omissions pertained to methods. Except for surveys (13.0%), participants rarely mentioned methods that HSE practitioners use to improve engineering. These patterns suggest

that students enrolled in HSE with a vague sense of what the field “is” but not necessarily all that HSE “does.”

In Round 2, most descriptors were expressed slightly more often and with similar distributions as in Round 1. However, several descriptors exhibited a larger increase. Specifically, 85.6% of participants now acknowledged HSE as an engineering-based field, 61.0% expressed that HSE improves usability, and 61.6% expressed that HSE improves understanding.

To further characterize changes, we computed aggregate “scores” for each dimension by summing the occurrence of descriptors in each category (Table 4). There was a significant multivariate effect spanning all three dimensions, Wilks’  $\lambda = 0.90$ ,  $F(3,143) = 5.18$ ,  $p = .002$ ,  $\eta^2 = .10$ , further supporting the interpretation that students expanded their conceptions of HSE over time. This modest growth seemed driven by students’ ability to define HSE and recognize the value of the discipline. We also examined participants’ expression of “new” descriptors in Round 2—descriptors they had *not* stated in Round 1. On average, participants included 1.6 new concepts in Round 2, which was significantly greater than zero,  $t(145) = 15.06$ ,  $p < .001$ ,  $d = 1.25$ .

Table 4. Expression of HSE descriptors across Round 1 and Round 2 survey administrations.

| Descriptor        | Round 1   | Round 2   | $F(1,145)$ | $p$  | $\eta^2$ |
|-------------------|-----------|-----------|------------|------|----------|
| <b>Definition</b> | 2.2 (0.8) | 2.4 (0.7) | 6.45       | .012 | .04      |
| Multidisciplinary | 18.5%     | 20.5%     |            |      |          |
| Human-Centered    | 98.6%     | 99.3%     |            |      |          |
| Engineering       | 74.0%     | 85.6%     |            |      |          |
| Research-Based    | 28.8%     | 33.6%     |            |      |          |
| <b>Methods</b>    | 0.3 (0.5) | 0.4 (0.7) | 3.51       | .063 | .02      |
| Survey            | 13.0%     | 17.1%     |            |      |          |
| Observational     | 5.5%      | 9.6%      |            |      |          |
| Analytical        | 4.8%      | 7.5%      |            |      |          |
| Design            | 3.4%      | 4.8%      |            |      |          |

|                 |           |           |      |      |     |
|-----------------|-----------|-----------|------|------|-----|
| <b>Values</b>   | 1.2 (0.8) | 1.5 (0.8) | 7.89 | .006 | .05 |
| User Experience | 19.2%     | 21.2%     |      |      |     |
| Usability       | 49.3%     | 61.0%     |      |      |     |
| Understanding   | 48.6%     | 61.6%     |      |      |     |
| Society         | 7.5%      | 5.5%      |      |      |     |

Overall, participants were able to provide more complete and nuanced explanations of HSE, methods, and values over time. Participants' self-reported perceived growth in understanding was not unfounded. These patterns are generally aligned to the goals of introductory courses to showcase a field and promote its value. Methodological topics are more specifically covered in 200- and 300-level courses on research methods and statistics. However, based on these findings, perhaps these topics should be integrated further in the introductory course.

Table 5. Example Round 1 and Round 2 participant responses about HSE, methods, and values.

|          | <b>Round 1</b>                                                                                                                                                                                                                                                                                                                                          | <b>Round 2</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>A</b> | <p>I think Human Systems Engineering is basically <u>the way the body works, or physiology</u>.</p> <p>They could use what they learned about human systems engineering and apply it to their body when they are in need.</p> <p>Yes it is valuable for engineering students because they will be <u>able to understand how the body works</u>.</p>     | <p>Human System Engineering to me, means the field of study where <u>you study the psychology of humans</u> so that <u>engineers can design products for user favorability</u>.</p> <p>I might use the various stuff we learned such as memory, perception, mirror neurons, etc. to design products.</p> <p>Yes it is very useful and it is a <u>foundation for product improvement</u> and design.</p>                                                                                                                                                                 |
| <b>B</b> | <p>The intricate workings of <u>interpersonal as well as person/technology interactions and innovations of these processes</u>.</p> <p>An engineer could improve the way they interact with other people in their career as well as how they go about completing job tasks.</p> <p>Yes, it can teach students valuable skills for job interactions.</p> | <p>Human Systems Engineering <u>is a type of engineering that takes human nature and behavior into account while designing products</u>.</p> <p>An engineer could use Human Systems Engineering <u>forms of behavioral study and analysis while designing and testing their product to monitor how well the user can learn how to use it as well as how the user feels while operating it</u>.</p> <p>Yes, Human Systems Engineering offers a perspective to <u>improve products towards the user, which can make these products much safer and more effective</u>.</p> |

Several excerpts help to exemplify student growth (see Table 5). In Round 1, *Participant A* expressed a view of HSE that was rooted in physiology. In Round 2, *Participant A* expressed a more nuanced perspective beyond anatomy, along with empirical applications of psychology to improve user experience and usability. *Participant B* began with a fairly vague description of HSE that focused on career issues. In Round 2, *Participant B* was able to express a well-rounded perspective on HSE that further incorporated both methodology and values.

### **Attitudes toward bridging engineering and psychology**

One remaining question is whether participants' attitudes toward engineering, psychology, and bridging the disciplines shifted along with their understanding. Several HSEAS items elicited participants' beliefs about "engineers" and "psychologists" and linking the two fields (Table 6).

From the outset, participants self-reported that they understood "what engineers do" and endorsed beliefs that engineers solve important problems and should be creative and ethical. Problem-solving and creativity were the most strongly endorsed. A significant shift in attitudes was observed, driven by growth in perceived understanding of what engineers do,  $F(4,142) = 33.39$ ,  $p < .001$ ,  $\eta^2 = .19$  ; and stronger beliefs that engineers should be ethical and compassionate,  $F(4,142) = 17.64$ ,  $p < .001$ ,  $\eta^2 = .11$ . Perceptions of psychologists were similar. Participants self-reported understanding "what psychologists do" and endorsed beliefs that psychologists solve important problems and should be creative and ethical. Ethics and compassion was the most strongly endorsed category. A significant shift in attitudes toward psychologists stemmed primarily from growth in perceived understanding of what psychologists do,  $F(4,142) = 34.19$ ,  $p < .001$ ,  $\eta^2 = .19$  ; and stronger beliefs that engineers should be creative and innovative,  $F(4,142) = 5.91$ ,  $p = .016$ ,  $\eta^2 = .04$ .

Participants were initially positive toward engineers learning about psychology and about the two disciplines working together; they seemed lukewarm toward psychologists learning about engineering. Over time, all of these attitudes increased significantly. A significant multivariate effect was driven by stronger endorsements of engineers learning about psychology,  $F(3,143) = 19.71$ ,  $p < .001$ ,  $\eta^2 = .12$ ; psychologists learning about engineering,  $F(3,143) = 8.01$ ,  $p = .005$ ,  $\eta^2 = .05$ ; and engineers and psychologists working together;  $F(3,143) = 8.69$ ,  $p = .004$ ,  $\eta^2 = .06$ . Taken together, these findings offer evidence that engineering students increasingly appreciated the value of multidisciplinary and bridging the disciplines.

Table 6. Perceptions of engineers, psychologists, and bridging the disciplines.

| Attitudes                                          | Round 1<br>( <i>n</i> = 146) | Round 2<br>( <i>n</i> = 146) | Wilks'<br>$\lambda$ | <i>F</i> | <i>p</i> | $\eta^2$ |
|----------------------------------------------------|------------------------------|------------------------------|---------------------|----------|----------|----------|
| <b>Engineers</b>                                   |                              |                              | .74                 | 12.67    | < .001   | .26      |
| I understand what engineers do.                    | 7.9 (1.6)                    | 8.6 (1.3)                    |                     |          |          |          |
| Engineers solve important real-world problems.     | 9.1 (1.1)                    | 9.2 (1.0)                    |                     |          |          |          |
| Engineers should be creative and innovative.       | 9.3 (1.2)                    | 9.5 (1.0)                    |                     |          |          |          |
| Engineers should be ethical and compassionate.     | 8.2 (2.1)                    | 8.9 (1.5)                    |                     |          |          |          |
| <b>Psychologists</b>                               |                              |                              | .80                 | 8.87     | < .001   | .20      |
| I understand what psychologists do.                | 7.2 (1.9)                    | 8.1 (1.6)                    |                     |          |          |          |
| Psychologists solve important real-world problems. | 8.1 (1.9)                    | 8.4 (1.7)                    |                     |          |          |          |
| Psychologists should be creative and innovative.   | 8.1 (2.1)                    | 8.5 (1.7)                    |                     |          |          |          |
| Psychologists should be ethical and compassionate. | 9.3 (1.1)                    | 9.5 (1.0)                    |                     |          |          |          |
| <b>Bridging Psychology and Engineering</b>         |                              |                              | .87                 | 7.07     | < .001   | .13      |
| Engineers should learn about psychology.           | 7.7 (2.0)                    | 8.5 (1.8)                    |                     |          |          |          |
| Psychologists should learn about engineering.      | 6.5 (2.5)                    | 7.1 (2.4)                    |                     |          |          |          |
| Engineers and psychologists should work together.  | 8.0 (2.1)                    | 8.6 (1.9)                    |                     |          |          |          |

Note. For MANOVA tests of attitudes about engineers and psychologists, the *F* parameter is  $F(4,142)$ . For the MANOVA test of attitudes about bridging the disciplines, the *F* parameter is  $F(3,143)$ .

## Discussion

Introductory courses serve an important role in communicating foundational disciplinary (and potentially interdisciplinary) concepts, generating engagement, and influencing career goals (Gasiewski et al, 2012; Gurung & Neufeld, 2021; Pfund et al., 2018). For future engineers, introductory courses that teach psychology interwoven with engineering (e.g., HSE 101) may

facilitate human-centered engineering—helping engineers understand whom they are engineering *for* and *with*, as well as understanding their *own* engineering work and biases (Roscoe, Becker, et al., 2019; Hynes & Swenson, 2013; Oehlberg et al., 2012, Pannasch et al., 2021; Wickens et al., 2021). Learning about relevant concepts (e.g., human perception, reasoning, motivation, and social interactions) is a prerequisite for taking these factors into account. Similarly, future engineers should benefit from learning how to enact human-centered design methods. Although introductory psychology courses are informative and readily available (Gurung & Neufeld, 2021), it is worthwhile to explore tailoring psychology curricula to engineering audiences, which aligns with calls for innovation and research on teaching psychology (Gurung & Hackathorn, 2018).

The current study investigated the attitudes and conceptions of students in Introduction to Human Systems Engineering (“HSE 101”), an entry-level course for a degree program focused on applied psychology, human factors, human-computer interaction, and related aspects of human-centered engineering. Analyses considered how students perceived HSE and the bridging of psychology and engineering, both at the start and end of the course. An important caveat is that HSE 101 is only one course—students were likely enrolled in other engineering courses, general education courses, and perhaps concurrent HSE courses. Thus, the current study cannot and was not intended to credit HSE 101 as the sole source of conceptual or attitude shifts. However, meaningful trends provide evidence of the value of HSE 101.

Responses to the Human Systems Engineering Attitude Survey (HSEAS) at the beginning of the semester (i.e., Round 1) helped to characterize the students who chose to enroll in HSE 101. This population—primarily engineers and students invested in technology-centered careers—was already positive toward HSE, psychology, and linking the disciplines. These

students also perceived substantial usefulness of such concepts and methods. These findings suggest that there is an enthusiastic audience of engineering students who want to learn about human-centered design. These students were also committed to solving meaningful problems through creativity, innovation, ethics, and compassion. Thus, tailoring traditional “PSY 101” instruction to this audience might drive fruitful collaborations between psychology and engineering programs.

Triangulation across survey components also revealed that students expanded their conceptions of HSE and perceived growth in their understanding of psychology concepts over time. In parallel, students’ attitudes toward psychology, user-centered design, and bridging psychology and engineering also became more positive. Students believed that engineers and psychologists should learn about each other’s fields and should work together. Thus, HSE 101 appeared to serve its intended purpose: students were exposed to and learned about psychology and human systems engineering, and the course appeared to inspire and reinforce awareness and support for human-centered engineering principles and interdisciplinary methods.

### **Future Work**

Participants’ attitudes and conceptions also revealed targets for curricular improvement. First, students’ ability or willingness to discuss HSE methods and techniques seemed to lag behind their knowledge of the discipline and its value. Methods are explicitly taught in subsequent courses for which HSE 101 is a prerequisite, such as “Experimental Methods for Human Systems Research” (HSE 290), “Statistics for Human Systems Research” (HSE 230), and “Qualitative Research Methods” (HSE 390). Students who pursue HSE via dual major, minor, or certificate degrees receive some of this information. However, it may be powerful to highlight core methods and applications earlier via HSE 101. The curriculum could more clearly articulate

how research and data-driven methods contribute to HSE principles and attaining the value of HSE work.

In addition, perceptions that HSE can “improve society” were infrequently expressed and was the only descriptor that *decreased* in frequency from Round 1 (7.5%) to Round 2 (5.5%). The rarity and decrease of this perception was somewhat disheartening. Given ideological challenges that discourage societal engagement for engineers (Cech, 2014; Slaton, 2015), HSE 101 and similar coursework might serve a valuable role in promoting or nurturing pro-social attitudes. Indeed, there are numerous teachable examples of the positive societal impact of HSE-related work (Roscoe, Chiou, & Wooldridge, 2019). One tentative hypothesis is that integrating more societally-relevant and culturally-relevant content might also increase engagement and learning.

The iteratively-designed and tested HSEAS provides educators and researchers with a tool for assessing attitudes or investigating pedagogical hypotheses. For example, the survey might be used to test whether methods courses successfully raise awareness, understanding, and appreciation of core techniques and practices. Likewise, the HSEAS might be deployed in topical, upper-division courses (e.g., instructional design or human factors in transportation) to examine how exposure to advanced topics and applications contribute to shifts in conceptions and attitudes. Aside from course-specific assessments, the HSEAS might also be used longitudinally to “track” students’ evolving experiences from their first year through graduation or even as alumni. In concert with data on course performance and related metrics (e.g., course completion; Hudson et al., 2015), the HSEAS might help to diagnose why some students disengage from HSE courses whereas others become enthusiastic advocates for the field.

Several limitations also suggest fruitful next steps. First, the current sample only included students enrolled in HSE 101, but the HSEAS could also be deployed in alternative courses (e.g., PSY 101) to enable quasi-experimental comparisons of learning and attitude change. The current study provided sufficient suggestive evidence to warrant more formal evaluations of HSE 101. Importantly, we were unable to analyze students who did not (or chose not to) enroll in HSE 101. Students' who "opted in" were probably more open-minded about human-centered engineering already, which likely contributed to their consistently favorable attitudes. Alternative sampling strategies will be needed to reach students in non-enrolled populations to learn more about their decision-making process (e.g., lack of awareness, lack of interest, or lack of time).

Our sample was also demographically constrained based on available enrolled students. Participants reflected a skewed population typical of engineering disciplines in the United States (i.e., predominantly White men). Exploratory analyses suggested that male and female students did not differ in their responses across the semester, but that analysis was imbalanced and under-powered (i.e.,  $n = 24$  female students versus  $n = 122$  male students). Similarly, exploratory analyses found no differences among students who self-identified as "White" versus "Black, Indigenous, or People of Color" (i.e., inclusive of Asian, Black, Hispanic, Middle Eastern, Native American, and/or Multiracial). However, this binary comparison lacked validity by collapsing diverse demographic groups into a single "BIPOC" category, which ignored multiple aspects of intercategory and intracategory variance. Nuanced comparisons of individual categories lacked sufficient power to draw conclusions. Thus, although we did not observe strong evidence of demographic differences, we could not conclude that such effects were not present. In future work, studies of the experiences, expectations, and attitudes of students might

be more effectively conducted using qualitative methods (e.g., interviews and focus groups) that allow for richer and more meaningful input from underrepresented individuals and communities.

We did observe a thought-provoking pattern regarding attrition and language. Students who completed *only* the first survey were slightly more likely to report being multilingual, including students for whom English may be a non-fluent language. We did not have specific data on why students were absent, had withdrawn, or chose not to complete the Round 2 survey. Thus, no conclusions could be drawn about these cases. However, the complex ways in which students navigate their language(s), language identity, and language of instruction may have a significant influence on their success and decision-making in higher education (Jang & Brutt-Griffler, 2019; Neumann et al., 2019). Future work should consider how language impacts HSE 101 engagement.

Finally, HSE 101 sections were taught by three different instructors. Each instructor used different textbooks, syllabi, teaching styles, and assessments, and taught on different days and times throughout the week. Post-hoc analyses (not reported for brevity) suggested that there may indeed be potential differences between instructors, but the study was not designed to validly tease apart this highly complex variance. In future studies, it may be productive to systematically compare the *same* instructors teaching multiple sections in *different* ways, or to standardize the curriculum to reduce variance. The HSEAS instrument (or components) could be used as a diagnostic tool for assessing the effects of these comparisons and their impact on learners.

## **Conclusion**

Human thoughts, feelings, and behaviors—fundamental foci of psychology—are integral to all aspects of effective engineering. The current research suggests that the teaching of psychology can be meaningfully integrated with engineering and design, and introductory coursework in

human systems engineering can help prepare engineers to embrace human-centered principles and approaches in their careers.

### **Acknowledgements**

The authors are grateful to Jenna Forrey, Kiara Crawford, Xavier Wallace, and Dr. Heather Lum for their contributions to the project, and to Dr. Jeffrey Thomas, Dr. Jaimie McNabb, and Dr. Vipin Verma for generously granting access to their classrooms. This project was supported by the National Science Foundation (NSF 1712328). Opinions, findings, conclusions, or recommendations expressed in this work are those of the authors and do not necessarily reflect the views of the NSF.

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