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An Engineering and Nursing Collaborative: Incorporating the Concept of Empathy into First-Year Engineering Design to Increase Student Engagement

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Introduction

As defined by engineering accreditation agency ABET, engineering design is "a process of devising a system, component, or process to meet desired needs and specifications within constraints" [1]. One example constraint within this ABET definition is usability [1]. A related concept to usability is empathy. Empathy can strengthen the design process, inspiring engineers to create products that are easy to use.

In this study, we examine the use of human-centered design in an open-ended first-year design project to increase student engagement and empathy. In a first-year design course with three course sections, student groups in two sections were randomly assigned projects with sponsors who were nursing professors, and student groups in a third section were randomly assigned projects with sponsors who were librarians or a sustainable agriculture manager. Student groups working on nursing projects solved their assigned problems using human-centered design; student groups working on non-nursing projects solved their assigned problems using 2^k factorial design, a design of experiments statistical technique. The Student Response to Instructional Practices (StRIP) survey [2] was used to compare student engagement between nursing and non-nursing project groups, at two time periods. An Empathy survey [3] based on the Interpersonal Reactivity Index [4] and interpersonal self-efficacy survey work conducted by Hess et al. [5], was used to compare empathy between nursing and non-nursing project groups, at two time periods. Focus groups of students with nursing projects and students with non-nursing projects provided supplemental data for interpreting survey results.

Background

Empathy, as defined by the Oxford Dictionary, is "the ability to understand and appreciate another person's feelings, experience, etc." [6]. Empathy has been discussed as an important component of engineering professional formation [7, 8]. To increase the use of empathy in engineering design and engineering ethics, the incorporation of empathy case studies [9, 10], workshops [11], or modules [9, 12, 13] into the engineering curriculum has been investigated. Previous researchers have observed that inauthentic design experiences may prevent students from achieving desired learning outcomes [10, 14]. Loyola University Chicago (LUC) Engineering took a different direction in creating situative learning experiences [15, 16] that increase retention [17], specifically open-ended first-year design projects that solve problems for university sponsors such as nursing professors. For sponsors who are nursing professors only, the design process utilized is human-centered design, which focuses on meeting the needs of the intended users.

Human-Centered Design

Human-centered design engineering standard ISO 9241-210:2019 defines human-centered design as "an approach to systems design and development that aims to make interactive systems more usable by focusing on the user of the system and applying human factors/ergonomics and usability knowledge and techniques" [18]. Early proponents noted benefits of human-centered design, including increased productivity [19, 20], reduced errors, reduced training and support, improved acceptance, and enhanced reputation [20]. Empathy is an inherent consideration in this design technique. The first step of Stanford's human-centered design process is Empathize, during which a designer must observe, interview, and immerse with beneficiaries and stakeholders [21]. The Global design leader IDEO has practiced human-centered design for over forty years, and states that "All you have to do is empathize, understand them [users], and bring them along with you in the design process" [22].

IDEO's process involves three phases: Inspiration -> Ideation -> Implementation. In its *Field Guide to Human-Centered Design*, IDEO describes 57 methods that help designers execute its process [22]. Former IDEO engineer and current Olin College Academic Partner, Ela Ben-Ur, has a simpler human-centered design process, the Innovator's Compass® [23, 24], which is ideal for first-year design projects. As shown in Figure 1, the Innovator's Compass has an x-axis that spans (past and present) to future, and a y-axis that spans details to big picture.

Figure 1. Innovator's Compass®, by Ela Ben-Ur and innovatorscompass.org.

People are centered at the compass origin, and observations, principles, ideas, or experiments are centered in each compass quadrant. Ela has a design group ask the five basic questions noted in the compass to spur project design. Please note that, while the questions are numbered, the questions can be asked in any order.

Human Factors and Medical Devices

The ISO standard definition of human-centered design includes application of human factors, which is an important consideration in the design of medical devices. In 1996, the Food and Drug Administration (FDA), which must approve or clear a medical device before it can be sold legally in the U.S., created new human factors design requirements for medical devices, to minimize use-related errors [25]. Shortly thereafter, in 1999, the Institute of Medicine (now National Academy of Medicine) published *To Err Is Human: Building a Safer Health System*, a report detailing that between 44,000 and 98,000 people die in hospitals annually as a result of preventable medical errors, which include the misuse of medical devices [26]. Although the Association for the Advancement of Medical Instrumentation (AAMI) had sponsored committees which produced human factors standards as far back as 1988, ANSI/AAMI HF75:2009 was the first comprehensive medical device standard detailing human factors design principles [27]. Included in this 441-page standard were sections on managing the risk of use error, anthropometry and biomechanics, environmental considerations, usability testing, alarm design, accessibility considerations, software-user interfaces, and hand tool design [28]. HF75 was revised in 2013 and then 2019.

The FDA now requires that premarket submissions for approval or clearance for legal sale of a medical device include a human-factors engineering or usability engineering (HFE/UE) report. "The level of detail of documentation submitted should be sufficient to describe... identification, evaluation, and final assessment of all serious use-related hazards for the device" [29]. Thus, empathy for two types of users is considered essential for patient safety. The FDA mandates deliberation and simplification of how *clinicians* use medical devices for *patient* diagnosis and/or treatment.

Empathy in Nursing

In nursing, empathy is often described as the ability "to walk in another person's shoes" or to view experiences through the "eyes of the patient." Empathy is an aspect of personality that plays an important role in developing interpersonal relationships and promoting effective communication. High levels of empathy benefit patient health and clinical outcomes, such as reduced psychological stress, improved self-concept, reduced anxiety and depression, and lower complication rates [30]. Essential to healing and wellness is the symbiosis of a person's physical, emotional, intellectual, spiritual and cultural aspects of personhood. The task of a nurse is to be curious and explore how each facet impacts patient choice and well-being. Nurses use empathy to gain understanding, make connections, and act or intervene in a manner consistent with the patient's values and beliefs.

Nursing faculty are challenged to explore instructional strategies that develop empathy in the novice practitioner. Undergraduate nursing students demonstrate a significantly higher level of empathy as compared to those in other undergraduate professions [30]. Individuals who choose the nursing profession may have an increased interest in human contact and willingness to care for people. However, undergraduate nursing students are often tested due to a lack of self-awareness, self-confidence, life-experiences, and a fear of saying or doing the wrong thing. It is easy to become paralyzed in new and uncomfortable situations, but empathy can be taught [31]. Creating an environment of psychological safety encourages students to summon the courage to take risks. Simulation is an effective and formative teaching-learning strategy for students to practice empathetic communication. A systematic review found that simulation-based interventions that are both immersive and experiential were the most effective method of empathic education [32]. In a scoping review of empathy in nursing students, simulation increased empathy levels and confidence, and is deemed beneficial for enhancing empathy awareness, sensitivity, and decreasing negative emotions [31].

Empathy is central to the nursing role, fostering and promoting the therapeutic nurse-patient relationship. Empathetic nursing care requires self-reflection, mindfulness, giving of oneself, and viewing the patient as a whole. Empathy allows patients to feel validated, understood, and respected. Collaboration and communication between nursing and engineering is essential to quality patient outcomes. Healthcare simulation relies on engineering technology such as models, to replicate real-life scenarios. Effective teamwork among professionals is critical to provide optimal learning experiences that translate into the patient-care environment.

B.S. Engineering Program and ENGR 101

"LUC's B.S. Engineering program is a general engineering program with specializations of biomedical, computer, and environmental engineering. Each specialization emphasizes a social justice application. For example, in biomedical engineering, students learn to design and test robust medical device software, in preparation for a medical device to be cleared or approved by the FDA. All patients should receive high-quality medical devices, regardless of their ability to pay. All Engineering courses are taught using mandatory active learning, which increases the retention of female students, students of color, and first-generation students [33-36]. Engineering course sections seat at most 24 students, to facilitate active learning" [37].

ENGR 101: Introduction to Engineering Design is a four-credit hour, semester course, taught three times per week, for 100 minutes each course meeting. Entering Engineering first-year students take ENGR 101 their first semester, enrolling in one of three course sections. Other than the course title and brief course description paragraph in the course catalog which mentions "requirement specifications" and "design iteration," students are unaware of what a design project entails.

A main instructor in each course section teaches three-credit hours, with the majority of course meeting time devoted to SolidWorks instruction. The first author teaches the fourth credit hour of each section, specifically thirteen out of 41 course meetings. Of thirteen course meetings, five are exclusively devoted to design topics.

At the third course meeting of ENGR 101, the first author has students sit in their newly assigned design groups of three or four students. One student from each group draws a slip of paper with a project name, sponsor name, and sponsor contact information. Sponsors are all university employees. Two or three nursing professors from the Center for Simulation Education in the

School of Nursing sponsor projects in sections 1 and 2. These projects provide pre-licensure, sophomore nursing students with tangible models to enhance their learning. Design projects include: 1) anatomical models of the human body, 2) developmentally appropriate toys for pediatric patients, and 3) safety equipment necessary for certain pediatric health conditions. Some examples include a stomach model with a gastrostomy feeding tube inserted; a lung containing a pleural chest tube to promote fluid drainage; age-appropriate toys which are suitable for children who have neurodiverse conditions; and child-friendly, protective gear for pediatric patients suffering from epilepsy. These projects require the engineering students to research and understand human anatomy, the pathophysiology of selected diseases/conditions, pediatric human development, and specific safety considerations unique to individuals. The Sustainable Agriculture Manager in the School of Environmental Sustainability and University Librarians sponsor projects in section 3. Infrequently, an Engineering professor sponsors a project.

During this third course meeting, the design process that is utilized is discussed:

- Identify user need and define the problem
- Identify constraints and measurable requirements
- Define the system that contains the problem by making measurements
- Analyze measurements to determine most significant factors
- Iterate through potential solutions
- Select best solution through testing

Students are reminded (after having reviewed the syllabus during the first course meeting) that 45% of their total ENGR 101 grade is related to design project assessments:

• First required meeting with first author & MS Teams use	3%
• Project Requirement Specification	5%
• Second required meeting with first author & MS Teams use	3%
• Progress Report	8%
• Third required meeting with first author & MS Teams use	3%
• Final Presentation	5%
• Final Report	10%
• Budget exceeding $100	(-10%)
• Sponsor satisfaction grade	8%

Before each milestone document is due, each student group meets with the first author, after meeting with its sponsor. The first author checks that each group is making sufficient progress towards meeting sponsor/user needs before their assignment is due.

During the eighth course meeting, students in sections 1 and 2 learn how to use the Innovators Compass® to move their project forward. Students in section 3 learn how to conduct 2^k factorial design experiments, so that they can define their sponsor's problem as a model of k factors that affect a response [38]. Section 3 student groups each meet one extra time with the first author to determine four factors which could significantly affect their project. The first author then uses software package Design-Expert to generate a run table of 19 (2^4 + 3 center points) experiments for the students to conduct. During the last three course meetings during week 14, each student group gives its Final Presentation to instructors, sponsors, other Engineering faculty members, and other students. As described, sponsor/user needs are emphasized throughout course meetings discussing the project. However, empathy is not explicitly discussed.

Methodology

Per the IRB-approved protocol, after an ENGR course's final grades were posted, de-identified survey data were used for secondary analysis. Separately, after informed consent was obtained, students participated in an empathy survey or a focus group. The quantitative data were analyzed using IBM SPSS Statistics v29. Descriptive statistics were conducted to obtain counts and proportions. An independent means t-test was used to analyze differences in average scores for Likert scale items. The qualitative data was coded using Microsoft Excel. Codes were then grouped by emerging themes.

Participants

During Fall 2023, 51 first-year students enrolled in three sections of ENGR 101. Four of the first-year students in section 2 were assigned a SolidWorks guitar amplifier case project sponsored by an Engineering professor; these four students were excluded from the study. Of the remaining 47 first-year students, 21/47 = 45% were male. Student groups with nursing projects were 54% male; student groups with non-nursing projects were 17% male.

During the course, students were given the option of completing a student engagement survey, during week 2, and a combination student engagement/empathy survey, during week 14. For completion of either the student engagement survey or combination student engagement/empathy survey, a student received +1 extra-credit point (worth 1% of total final grade).

Tools

Two surveys were administered. The Student Response to Instructional Practices (StRIP) survey [2] was used to assess student engagement. This validated instrument is based on a framework of student response factors: Value, Positivity, Participation, Distraction, and Evaluation. It uses a 5-point Likert scale. As part of the StRIP survey, students were also asked about project excitement and concerns. An Empathy survey [3], based on the Interpersonal Reactivity Index (IRI) [4] and interpersonal self-efficacy survey work conducted by Hess et al. [5], was also administered. This validated instrument contains four constructs: Interpersonal Self-Efficacy, Emotional Regulation, Perspective Taking, and Empathic Concern. It uses a 9-point Likert scale. As part of the Empathy survey, students were asked about memorable aspects of the project.

Methods

The StRIP survey was used to compare student engagement between nursing and non-nursing project groups, at week 2 and week 14 of the course. The StRIP questions chosen for the survey investigated the factors of Value, Positivity, Participation, and Distraction. The Empathy survey was also administered at week 14. The Empathy questions chosen for the survey investigated the constructs of Interpersonal Self-Efficacy, Perspective Taking, and Empathic Concern. As had been conducted previously, students from three nursing projects were invited to share their projects with sophomore nursing students seven weeks after the course ended, which is equivalent to week 22. During week 23, students from non-nursing projects and the students from nursing projects who met with sophomore nursing students were recruited to complete a second Empathy survey and to participate in a focus group, for a \$5 and \$25 Starbucks gift card, respectively.

Results

In this section, StRIP survey, Empathy survey, and qualitative survey results are reported.

StRIP Surveys

Forty-eight students completed the pre-StRIP surveys. Four guitar amplifier case pre-StRIP surveys were excluded. This non-Nursing SolidWorks project in Section 2 was sponsored by an Engineering professor, and conducted using human-centered design. With these four exclusions, the pre-StRIP survey sample was 44. Twenty-two students completed the post-StRIP survey. Only 20 students completed both the pre and post surveys.

A paired t-test was first conducted to test the difference between pre- and post-survey responses among the 20 students who completed both surveys, and no statistical significance was found (Table 1). A paired t-test was also conducted for the 15 students who completed the nursing project only, but no statistical significance was found.

Next, an independent samples t-test was used to examine differences between the nursing and non-nursing projects on the pre-StRIP and post-StRIP surveys (Table 2). Specifically, average pre-StRIP score differences were examined between the nursing and non-nursing projects; a separate independent means t-test was conducted for average post-StRIP differences between the nursing and non-nursing projects. Each participant belonged to one group for pre-StRIP analysis (nursing or non-nursing); the same was true for the post-StRIP analysis. No statistical significance was found between nursing (n=33) and non-nursing (n=11) projects on the pre-StRIP survey. However, the Value subscale of the post-StRIP survey showed a statistically significant difference ($p = 0.24$) between nursing (n=15) and non-nursing (n=6) projects. For the Value post-StRIP subscale, students who worked on a non-nursing project averaged higher scores (4.78 ± 0.27) than students who worked on a nursing project (4.29 ± 0.45).

Empathy Surveys

Only 20 students completed the pre-empathy survey. Although 8 students who worked on nursing projects met with sophomore nursing students, none of these students completed a post-empathy survey or participated in a focus group. Therefore, the analysis described in this section includes results from the pre-empathy survey only and provides insight into student empathy during one time period (week 14). One student who worked on a non-nursing project agreed to participate in a focus group, but declined to complete a post-empathy survey. The “focus group” interview results were not included, as they were from a single student.

An independent samples t-test was conducted to test differences in empathy between students working on the nursing (n=15) and non-nursing (n=6) projects (Table 3). A statistically significant difference in the mean Interpersonal Self-Efficacy subscale was found between non-nursing and nursing projects (p = .007). For the Interpersonal Self-Efficacy subscale, students who worked on a non-nursing project averaged higher scores (8.75 ± 0.27) than students who worked on a nursing project (8.03 ± 0.54).

Table 1. Paired StRIP pre- and post-survey data for 20 students.

	Pre-Survey (N = 20) Mean (SD)	**Post-Survey (N = 20)** Mean (SD)
Distraction Subscale		
I gave the activity minimal effort.	1.15 (.37)	1.10 (.31)
I distracted my peers during the activity.	1.35 (.49)	1.30 (.57)
I pretended to participate in the activity.	1.15 (.37)	1.00 (.00)
I talked with classmates about other topics besides the activity.	2.30 (.87)	2.35 (.81)
I surfed the internet, checked social media, or did something else instead of doing the activity.	1.25 (.55)	1.40 (.60)
Average item response on Distraction Subscale.	1.44 (.40)	1.43 (.28)
Participation Subscale		
I tried my hardest to do a good job.	4.55 (.95)	4.80 (.41)
I participated actively (or attempted to).	4.75 (.55)	4.85 (.37)
Average item response on Participation Subscale.	4.65 (.52)	4.83 (.29)
Positivity Subscale		
I felt positively towards the instructor.[a]	4.58 (.61)	4.47 (.61)
I felt the instructor had my best interests in mind.	4.55 (.61)	4.60 (.50)
I enjoyed the activity.	4.20 (.70)	4.15 (.75)
Average item response on Positivity Subscale.	4.43 (.48)	4.40 (.49)
Value Subscale		
I felt the effort it took to do the activity was worthwhile.[a]	4.00 (.75)	4.32 (.48)
I saw the value in the activity.	4.35 (.67)	4.50 (.51)
I felt the time used for the activity was beneficial.	4.55 (.61)	4.45 (.61)
Average item response on Value Subscale.	4.32 (.49)	4.43 (.47)

Notes:

- [a]n = 19
- 1 = almost never (<10% of the time); 2 = seldom (~30% of the time); 3 = sometimes (~50% of the time); 4 = often (~70% of the time); 5 = very often (>90% of the time).

Table 2. StRIP pre- and post-survey data for students assigned to non-Nursing and Nursing projects.

	Pre-Survey		**Post-Survey**	
	Non-Nursing (N = 11)	**Nursing (N = 33)**	**Non-Nursing (N = 6)**	**Nursing (N = 15)**
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Distraction Subscale				
I gave the activity minimal effort.	1.18 (.60)	1.36 (.70)	1.00 (.00)	1.13 (.35)
I distracted my peers during the activity.	1.27 (.47)	1.45 (.71)	1.33 (.52)	1.27 (.59)
I pretended to participate in the activity.	1.18 (.41)	1.21 (.49)	1.00 (.00)	1.00 (.00)
I talked with classmates about other topics besides the activity.	2.09 (.70)	2.48 (1.09)	2.67 (1.03)	2.20 (.68)
I surfed the internet, checked social media, or did something else instead of doing the activity.	1.27 (.65)	1.67 (1.02)	1.50 (.55)	1.40 (.63)
Average item response on Distraction Subscale.	1.40 (.36)	1.64 (.50)	1.50 (.21)	1.40 (.30)
Participation Subscale				
I tried my hardest to do a good job.	4.09 (1.58)	4.41 (.91)	5.00 (.00)	4.73 (.46)
I participated actively (or attempted to).	4.73 (.47)	4.58 (.71)	4.83 (.41)	4.87 (.35)
Average item response on Participation Subscale.	4.41 (.92)	4.50 (.66)	4.92 (.20)	4.80 (.32)
Positivity Subscale				
I felt positively towards the instructor.	4.45 (.93)	4.56 (.67)	4.50 (.55)	4.40 (.63)
I felt the instructor had my best interests in mind.	4.45 (.93)	4.42 (.71)	4.83 (.41)	4.53 (.52)
I enjoyed the activity.	4.09 (.70)	4.24 (.66)	4.67 (.52)	4.00 (.76)
Average item response on Positivity Subscale.	4.33 (.71)	4.40 (.54)	4.67 (.37)	4.31 (.50)
Value Subscale				
I felt the effort it took to do the activity was worthwhile.[b]	4.00 (.94)	4.18 (.68)	4.67 (.52)	4.27 (.46)
I saw the value in the activity.	4.18 (.75)	4.42 (.66)	4.83 (.41)	4.33 (.49)
I felt the time used for the activity was beneficial.	4.45 (.69)	4.48 (.71)	4.83 (.41)	4.28 (.59)
*Average item response on Value Subscale.**	4.24 (.60)	4.37 (.58)	4.78 (.27)	4.29 (.45)

Notes:

- [b] n = 10 for Non-Nursing & n = 32 for Nursing
- * = statistically significant difference $p < 0.05$ between Non-Nursing & Nursing post-test means only.

Qualitative Survey Analysis

Answers to three questions included in pre- and post-surveys were qualitatively analyzed.

Project Aspects Students Were Excited About (Pre-Survey)

After two weeks of working on their design projects, students were asked what they are most looking forward to on the pre-StRIP survey. Eleven students who completed non-nursing projects and 33 who completed nursing projects submitted responses. Common themes from both groups were the desire to build the model, create a final product, and work in a team. Only the non-nursing project group explicitly mentioned problem-solving and creating solutions. Themes that were unique to the nursing project group included the desire to engage in the design process and use tools such as CAD (computer-aided design) and 3D printing. The nursing project group also specifically highlighted the audience who would benefit from their project.

- Non-nursing projects: Four of the 11 respondents (36%) who completed non-nursing projects noted that they were looking forward to problem solving and developing creative solutions for the design project. Two of these four students also highlighted the opportunity to work with their teammates. Another four respondents (36%) explained that they were looking forward to reaching the end result and creating the final product. Two respondents (18%) were eager to engage in the building process.
- Nursing projects: Many students who worked on nursing projects (n = 14; 42%) also stated that they were looking forward to engaging in the design process. Three of these 14 students commented on who would benefit from their project (e.g., children with autism, other nursing students in their cohort). Similar to the non-nursing project students, four of the 33 nursing project respondents (12%) shared the desire to see the final product.

Project Concerns (Pre-Survey)

On the pre-StRIP survey, students were also asked to share their concerns after working on the design project for two weeks. Eleven respondents from the non-nursing project group and 33 from the nursing project group again submitted responses. Common themes from both groups included concerns about working in a team, the budget, and materials. Non-nursing project students noted that they were anxious about resolving their design issue. Only nursing project students mentioned their concern for the usability of their project.

- Non-nursing projects: Three of the 11 respondents (27%) who completed non-nursing group projects were concerned about finding cost effective and sustainable solutions. Another three (27%) were generally worried about finding a solution to resolve the issue. Two students (18%) were anxious about working in a team.
- Nursing projects: Most respondents (n = 11; 33%) from the nursing project group were concerned about group dynamics (e.g., scheduling conflicts, ensuring that group members remain accountable, and making worthwhile contributions to the project). Five respondents (15%) were concerned about the budget and material constraints. Three respondents (9%) were worried about ensuring that their project was useful for the intended user.

Memorable Aspects of the Design Project (Post-Survey)

Once the design project was completed, students were asked to describe the aspects of the

Table 3. Empathy survey data for students assigned to non-Nursing and Nursing projects.

	Non-Nursing (N = 6) Mean (SD)	**Nursing (N = 15)** Mean (SD)
Interpersonal Self-Efficacy Subscale		
I feel prepared to work with people who define a problem differently than I do.	8.33 (.52)	7.47 (.92)
I am prepared to meet and work with individuals from different backgrounds.	9.00 (.00)	8.73 (.46)
I value opinions that are different from my own.	9.00 (.00)	8.20 (.86)
I am generally able to understand the viewpoints of others.	8.67 (.82)	7.73 (.96)
*Average item response on Interpersonal Self-Efficacy Subscale.**	8.75 (.27)	8.03 (.54)
Empathetic Concern Subscale		
I often have tender, concerned feelings for people less fortunate than me.	8.00 (.89)	7.93 (1.28)
Sometimes I don't feel very sorry for other people when they are having problems. (R)	8.00 (1.26)	7.47 (1.46)
When I see someone being taken advantage of, I feel kind of protective towards them.	8.33 (.82)	7.13 (1.73)
Other people's misfortunes do not usually disturb me a great deal. (R)	6.83 (1.72)	6.80 (2.04)
When I see someone being treated unfairly, I sometimes don't feel very much pity for them. (R)	8.33 (1.21)	8.27 (.70)
Average item response on Interpersonal Empathetic Concern Subscale.	7.90 (.64)	7.52 (.88)
Perspective-Taking Subscale		
I sometimes find it difficult to see things from another's point of view. (R)	7.00 (1.55)	6.47 (1.68)
I try to look at everybody's side of a disagreement before I make a decision.	7.67 (1.03)	7.93 (.70)
If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. (R)	6.33 (2.42)	6.33 (1.72)
I believe that there are two sides to every question and try to look at them both.	8.50 (.84)	7.67 (.90)
Before criticizing somebody, I try to imagine how I would feel if I were in their place.	7.67 (1.63)	7.40 (.91)
Average item response on Interpersonal Perspective-Taking Subscale.	7.43 (1.10)	7.16 (.82)

Notes:

- Response options for each item were: 1 = Strongly Disagree; 2 = Moderately Disagree; 3 = Somewhat Moderately Disagree; 4 = Slightly Disagree; 5 = Neutral; 6 = Slightly Agree; 7 = Somewhat Moderately Agree; 8 = Moderately Agree; 9 = Strongly Agree.
- (R) = reverse item.
- * = statistically significant difference $p < 0.05$

project that they wanted to remember the most. A total of 21 students submitted responses, 15 of whom were in the nursing project group, and 6 who were in the non-nursing project group. Across both groups, the most commonly highlighted aspect of the projects was teamwork and relationship building. Although both groups also noted the skills developed, they focused on different methodologies. For example, a respondent from the non-nursing group specifically highlighted 2^k factorial design while a student from the nursing group wanted to remember how to use SolidWorks.

- Non-nursing projects: Four respondents (67%) highlighted the "fun" they had working on the project with their classmates and relationships built. The other two respondents wanted to remember their group presentation (17%) and how to use a 2^k factorial design (17%).
- Nursing projects: Most students in the nursing group (n = 12; 80%) shared that they wanted to remember the collaboration that occurred in their teams. One such respondent shared, "I want to most remember how me and a group of people, that I didn't know at the start of the semester, came together to make an anatomical model of a stage 3 pressure ulcer out of nothing." Two respondents (13%) noted the use of SolidWorks.

Discussion

Although 51 students enrolled in three sections of ENGR 101, only 44 students completed the pre-StRIP survey, 21 students completed the post-StRIP survey, and 20 students completed both pre- and post- StRIP surveys. Subdividing the 21 students who completed post-StRIP surveys into those who worked on nursing and non-nursing projects resulted in sample sizes of 15 and 6 students, respectively. With such small sample sizes, statistically significant differences in student engagement must be interpreted with caution, as the t-test is likely to be underpowered. Additionally, small sample sizes in t-tests can lead to increased Type II error (i.e., failing to reject a false null hypothesis), limited generalizability, and a violation of the t-test's assumption of normality, all of which creates unreliable results.

However, the StRIP survey results in Table 2 do demonstrate that Engineering first-year students, regardless of the assigned project, are engaged. As Nguyen, et al. previously demonstrated, student responses to in-class activities move towards the extremes of the StRIP range for active-learning versus traditional courses. Specifically, for the following activity items, active-learning courses elicit higher mean ratings (closer to 5) for positive-type responses and lower mean ratings (closer to 1) for negative-type responses:

- I participated actively (or attempted to) [Positive-type response]
- I felt the instructor had my best interests in mind [Positive-type response]
- I pretended to participate in the activity [Negative-type response]
- I talked with classmates about other topics besides the activity [Negative-type response] [39]

As demonstrated by student responses to a question about memorable aspects of the project, students enjoyed the active learning they experienced by working on an open-ended design project their first semester of Engineering. Students wanted to remember "How we were given little information and we were still able to come up with a pretty cohesive design." What some wanted "to remember most about this project is the process of designing the assigned model with my group. It was an interesting and fun experience." They also wanted to remember "collaborating with my 'Group', working together to come up with a solution to our problem, and the ways we were able to overcome obstacles in our way. Overall, I would like to remember the progress we made in working together."

The majority of U.S. Engineering programs have implemented first-year design projects [40], but project implementation differs between institutions. At LUC, each student group solves a problem their first semester for a campus sponsor. The first-year design project is administered as a first step towards LUC's industry-sponsored, two-semester capstone project that students complete during senior year. This first-year situative learning experience provides meaningful practice in solving a design problem, which is a fundamental engineering professional practice [15].

As with StRIP survey results, Empathy survey results should be interpreted with caution. Only 21/51 students completed the pre-Empathy survey at week 14, and no student completed the post-Empathy survey at week 23. Pre-Empathy survey responses were submitted by six students with non-Nursing projects and 15 students with Nursing projects.

However, the pre-Empathy survey results in Table 3 do demonstrate that Engineering first-year students, regardless of the assigned project, are empathic. Hess, et al. constructed their Empathy survey with a 9-point Likert scale. At week 14 of the design project, the average item response for the Interpersonal Self-Efficacy, Empathetic, and Perspective-Taking subscales ranged from 7 to 9. In contrast, when the Empathy Survey was deployed in an introductory biomechanics course at another institution, the average item response for these subscales ranged from 6 to 7 [41]. Future research could conduct measurement invariance tests to examine directly whether the magnitude of item-level means are statistically different across LUC Engineering students and non-LUC engineering students.

At first glance, it is surprising that first-year students exhibited empathy for their first-year design projects, even though empathy was never mentioned in the course. However, the first author consistently emphasized during the design process that the students needed to solve their sponsor's problem, which required the students to listen to the sponsor and consider user needs.

Students who choose to attend LUC may also value or have a disposition toward empathetic feelings and behaviors. The LUC mission focuses on the centrality of academic excellence, grounded in the Catholic faith tradition. Our students, faculty, and staff come from all faiths and backgrounds, but all strive toward the same goal of "being men and women for and with others." Ignatian pedagogy stresses the importance of knowledge, curiosity, and global perspectives to promote social justice for all [42]. Mission integration in teaching, scholarship, and community supports core beliefs.

It has been suggested that empathy varies by gender, which could influence the Empathy survey analysis. Empathy measurement by the IRI, incorporating the four subscales of Perspective Taking, Empathic Concern, Personal Distress, and Fantasy, has been shown to differ by gender [43]. However, Hess et al. developed and validated an Empathy survey that does not include the

IRI Personal Distress and Fantasy subscales [5], which are the subscales that vary by gender [44].

If this study were to be continued, survey fatigue would need to be addressed. Instead of combining the StRIP and Empathy surveys into one instrument, a future study might use only one survey to reduce the instrument length for respondents. Additionally, we do not know how many other studies students participated in during the 2023-2024 academic year before this project. To reduce survey fatigue, institution researchers might collaborate to ensure that they are not recruiting from the same cohort of students. Future researchers should pay special attention to factors known to negatively impact responses rates, such as poor presentation and length [45]. Commonly recommended techniques for increasing response rates include the use of reminders, incentives, and personal invites [46]. Researchers for this project employed several of these techniques, but still experienced difficulty recruiting students to participate in the study.

Conclusion

In summary, we examined the use of human-centered design in an open-ended first-year design project to increase student engagement and empathy. In a first-year design course with three course sections, student groups in two sections were randomly assigned projects with sponsors who were nursing professors, and student groups in a third section were randomly assigned projects with sponsors who were librarians or a sustainable agriculture manager. The StRIP survey was used to compare student engagement between nursing and non-nursing project groups, at two time periods. An Empathy survey developed by Hess et al. was used to compare empathy between nursing and non-nursing project groups, at two time periods.

Using the StRIP survey and qualitative analysis, we determined that LUC Engineering first-year students are engaged in their first Engineering design course. This course and all the courses in the B.S. Engineering curriculum are taught using active learning. Using the Empathy survey and qualitative analysis, we determined that Engineering first-year students are also empathic, regardless of whether the design process is taught as a human-centered design process or 2^k factorial design process. The first-year design instructor emphasized solving a sponsor's design problem by listening to the sponsor and considering user needs. This emphasis was followed by both students working on nursing projects or non-nursing projects. Engineering and nursing students have inherent empathetic qualities unique to their disciplines.

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