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Promoting Empathy in Engineering Undergraduates: An Assessment of the Efficacy of an Interdisciplinary Service-Learning Design Course

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Abstract

Empathy is a phenomenon comprising affective processes and cognitive experiences. Empathy is a vital trait for engineers, facilitating a nuanced understanding of complex global challenges by integrating diverse stakeholder perspectives. How to best develop undergraduate engineering students' empathy over their coursework remains a focused area of study. This study examines the effects of an interdisciplinary service-learning engineering design course, "Entrepreneurial Engineering Design Studio," in fostering empathy among engineering sophomore-senior level undergraduates at a private technological university. The course integrates design thinking, service learning, and interdisciplinary collaboration, encouraging students to identify design opportunities and engage with customers to foster end-user empathy. A key feature of the course is a service-learning component executed in partnership with local non-profit organizations aiding individuals with disabilities. Before customer interactions, students participate in an accessibility simulation activity to better comprehend the daily experiences of individuals with disabilities, thereby fostering empathy in design.

Amidst the pandemic, the shift to remote interactions offered a distinctive lens to evaluate empathy development in three cohorts of students (N = 118) who completed the 40-item Empathy Quotient (EQ) self-report questionnaire pre- and post-course. Results compare EQ scores from students who received virtual service-learning experiences (cohorts 1 and 2) versus students who received in-person service-learning experiences (cohort 3).

Results at pre-course found female engineering students had higher EQ compared to males, seniors had higher EQ compared to juniors and sophomores, and biomedical engineering students had higher EQ compared to civil engineering, electrical engineering, industrial engineering, and mechanical engineering students. Results of repeated measures ANOVA found a general increase in EQ across time (pre- and post-) for sophomores and juniors in cohort 3.

To further cultivate empathy among engineering students, we recommended integrating similar interdisciplinary, service-learning experiences throughout their education. Such initiatives should not only occur at specific academic levels but be embedded across the curriculum to ensure a consistent development of empathetic skills, essential for addressing complex global challenges. We also suggest future research investigating empathy in engineering students utilize other measures of empathy to differentiate cognitive processes from affective experiences.

1. Introduction

Empathy is a fundamental aspect of human nature [1]. Empathy is essential for strengthening social connections and for building positive relationships. Empathy enables us to provide emotional support to others and motivates acts of kindness that, in turn, lead to a more compassionate and caring society [2]. Empathy also plays a vital role in conflict resolution [3]. It can help facilitate effective communication and promote cooperation and compromise. By understanding the impact our actions have on others and recognizing their emotions and needs, we become more conscientious and compassionate individuals. Empathy helps shape our moral compass and guides us to act in ways that are considerate and fair.

As empathy involves the ability to understand and share the feelings of others, it has been widely recognized as an invaluable skill in areas such as healthcare, counseling, social work, psychology, and even design [4]. It is only in the last decade or so that researchers in the field of engineering education have emphasized the critical role of empathy in addressing the complex, global challenges that today's engineers face [5, 6]. Empathy allows engineers to comprehend the needs, desires, and challenges of end-users or clients whose problems they are trying to solve [7]. The very nature of these problems requires a deep understanding of technical knowledge infused with the ability to integrate the perspectives of a variety of stakeholders to adeptly address these human problems.

Trait empathy is an individual's disposition that predisposes them to understand, perceive, and resonate with the emotions, perspectives and experiences of others [1]. Trait empathy is considered a fundamental aspect of personality and can vary in degree among individuals. According to scholarly literature in a variety of fields, including counseling, philosophy, and psychology, assessment of an individual's trait empathy should include measurement of both the cognitive component (perspective-taking) as well as the affective component (emotional responses), although in most instances of empathy, the cognitive and affective components of empathy co-occur [4, 8-10].

The cognitive component recognizes empathy as being dependent on the situation. Pedagogical strategies such as community-based service learning design experiences create situations in which perspective taking is inherent. In contrast, the affective component of empathy involves one's feelings and emotional responses and is not typical discourse in engineering course discussions. Much of the research in assessing empathy development in engineering education has focused on engineering design courses but has relied on students' perceptions of their empathy [7, 11].

While scholars agree that empathy is a learnable skill, questions still remain as to how to best develop engineering students' empathy over the course of their undergraduate education [7, 11-

14]. What pedagogies and classroom experiences can positively impact engineering students' empathetic development? And where and with what frequency should these educational contexts be woven throughout an already overloaded curriculum?

Community-engaged service learning has the dual goal of enriching student learning and generating value for communities [11] . Students that participate in community-engaged learning often benefit from a number of additional learning opportunities, including increased critical thinking and intercultural skills, increased communication skills, ability to engage with a variety of stakeholders during the design process, identifying unmet user needs, integrating information from many sources to gain insight and assessing and managing risk. Because of the complexities of students learning through projects engaged with real-world communities, faculty are sometimes hesitant to embed community-engaged learning into the engineering curriculum. A goal of this work is to demonstrate that the benefits to student outcomes far outweigh the added complexities. The impact of the context of the design project, specifically when those community interactions involve face-to-face engagement, can drive innovation, creativity as well as foster empathy development.

This study examines the effects of an interdisciplinary service-learning engineering design course, "Entrepreneurial Engineering Design Studio," in fostering empathy among engineering undergraduates at a private technological university. This course was designed with the aim to enhance the students' situational curiosity, to build connections, and, through a human-centered design approach, to become stewards of value creation. The students work in an interdisciplinary team with a customer outside the University in a community-based service-learning design project. The customer engagement aspect of the course places students in a low familiarity design scenario. Empathy-building activities are built into the curriculum to prepare students to engage with their customers in a meaningful way.

This paper explores the following research question:

Can we affect engineering students' trait empathy development through classroom experiences designed specifically to impact empathy development?

2. Background

Lawrence Technological University has been an integral member of the Kern Entrepreneurial Engineering Network (KEEN) of institutions for over a decade-and-a-half. Through collaboration and a shared mission to infuse an entrepreneurial mindset (EM) into undergraduate engineering education, KEEN has cultivated this shared mission with more than 55 partner institutions across the United States [15]. Each of these schools are committed to supplementing the technical skills being taught in the classroom with a mindset that focuses on fostering curiosity, connections, and creating value – "the 3 C's". The KEEN framework, as shown in Table 1, seeks to describe the beneficial student outcomes that entrepreneurially-minded learning can bring to engineering undergraduates. Examples of these benefits include the ability to recognize opportunities to create personal, economic and societal value; to persist and learn from failure, and to integrate information from many sources to develop innovative solutions. Much of the student behaviors associated with EM development are founded on character. Individuals with a strong character are more likely to demonstrate empathy in their interactions and to enlist a compassionate approach to navigating the complexities of human experience.

Table 1. The KEEN Framework

KEEN STUDENT OUTCOMES	EXAMPLE BEHAVIORS
Entrepreneurial Mindset	**Curiosity** Demonstrate constant curiosity about our changing world Explore a contrarian view of accepted solutions **Connections** Integrate information from many sources to gain insight Assess and manage risk **Creating Value** Identify unexpected opportunities to create extraordinary value Persist through and learn from failure
Engineering Thought and Action	Apply creative thinking to ambiguous problems Apply systems thinking to complex problems Evaluate technical feasibility and economic drivers Examine societal and individual needs
Collaboration	Form and work in teams Understand the motivations and perspectives of others
Communication	Convey engineering solutions in economic terms Substantiate claims with data and facts
Character	Identify personal passions Fulfill commitments in a timely manner Discern and purse ethical practices Contribute to society as an active citizen

In order to provide undergraduates with ample opportunities to exercise their EM and to practice the 3 C's, a curricular thread was developed and is woven through our core engineering curriculum at Lawrence Tech. The sophomore piece of this curriculum thread is the course "Entrepreneurial Engineering Design Studio". This course emphasizes creating solutions through interdisciplinary team-based projects utilizing engineering tools and skills, along with opportunity identification, ideation, value analysis, and customer engagement. Many of the course learning outcomes were crafted to encompass exemplar KEEN behaviors.

After completing the course, students should be able to:

1. Integrate information from a variety of sources to generate, screen, and select promising design opportunities that will create value for potential customers.
2. Organize, plan, and manage a long-term engineering project within a team environment.
3. Explore prior and accepted solutions to identify and communicate the value of a unique design solution in terms of economic, personal, and societal value.
4. Describe the perspective of stakeholders in order to translate insight gained from customer feedback into design specifications at multiple stages in the design process.
5. Utilize and persist through a systematic design process in order to bring a unique design solution to fruition while assessing and managing risk.
6. Test concepts quickly via customer engagement to then identify and utilize technical tools and skills needed to develop a viable design solution.
7. Assess and manage risk associated with cost, value, and market implications at all stages of development.
8. Communicate design status and results to all stakeholders in verbal, written, and public presentation formats at appropriate points in the development timeline.

To support students in reaching these outcomes, a community-based service learning project was selected as the pedagogical approach. Specifically, students work with customers from non-profit organizations within the local disability community. This customer base was chosen to provide the students with an authentic, meaningful project that would promote curiosity as related to understanding the needs of the customer in their effort to develop a solution that would ultimately create value for their customer.

2.1. Defining Empathy

Integrating theories of empathy from counseling, engineering education, human-centered design, moral philosophy, neuropsychology and social psychology has led to an operational definition of empathy as phenomenon comprising a cyclical relationship among affective experiences, which elicit emotional responses in reactions to observations of others experiences; and cognitive processes, which relate to the attempt to “place ourselves in the shoes of others” [4, 8-10]. This definition takes into account empathy both as affective experiences – described by Empathetic Distress, i.e., experiencing self-oriented empathetic distress as a result of feeling for another, and Empathetic Concern, other-oriented feelings of concern or happiness for another – and as cognitive processes – described by Imagine-Self Perspective Taking, i.e., imagining how oneself would think and feel if they were another, and Imagine-Other Perspective Taking, imagining how another thinks or feels (see Figure 2)[13].

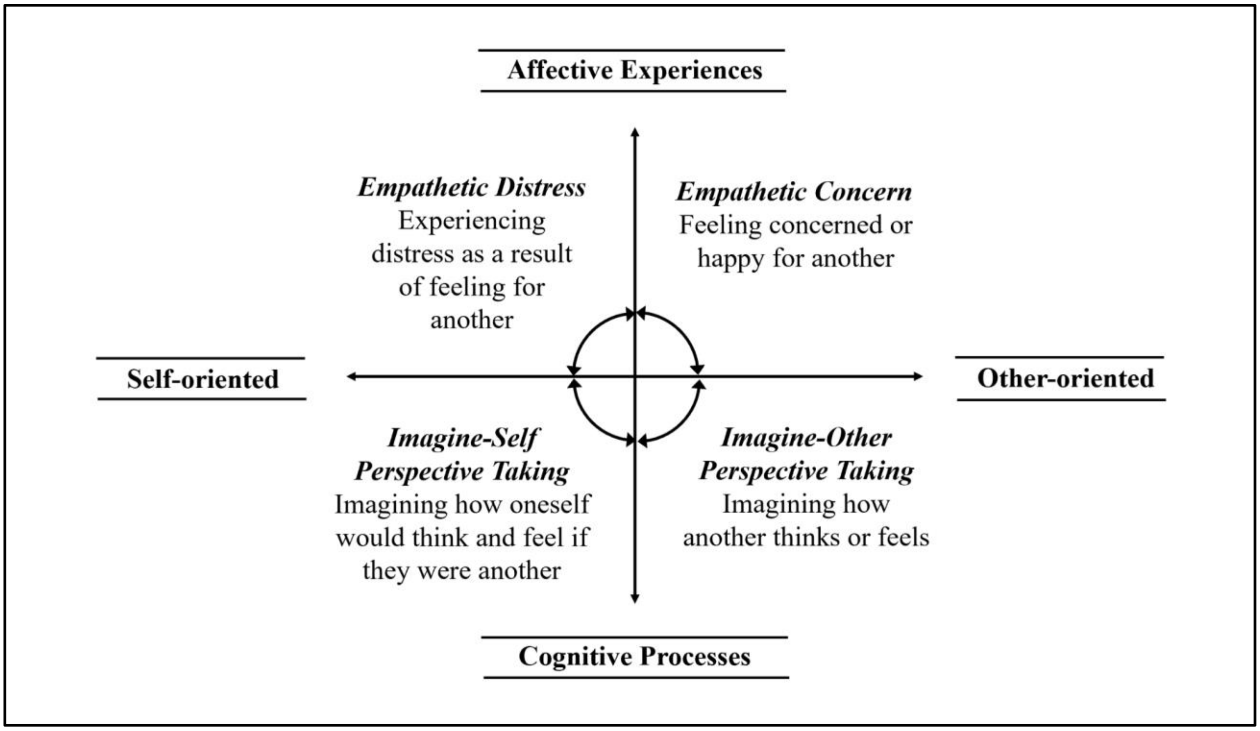

Figure 2. Empathy as Cyclical Relationship Among Affective Experiences and Cognitive Processes

2.2 Measuring Empathy

Assessing an individual’s trait empathy requires assessing both the cognitive and affective components of empathy [16]. Two of the most commonly used empathy assessment instruments are the Empathy Quotient (EQ) [8] and the Interpersonal Reactivity Index (IRI) [17]. The EQ, developed by Baron-Cohen and colleagues in 2004, provides a broad, assessment of the co-occurring cognitive and affective components of empathy levels in individuals. It consists of items related to social skills, understanding others' emotions, and responding to others' feelings. While the EQ is a unidimensional measure of empathy, it offers valuable insights into an individual's overall level of empathy and can be used to assess changes in empathy over time. The Interpersonal Reactivity Index (IRI) is a multidimensional measure of empathy developed by Davis in 1980. It assesses four components of empathy: Perspective Taking, Fantasy, Empathic Concern, and Personal Distress. It provides insight into both cognitive and affective aspects of empathy. For the purposes of this study, participants’ trait empathy was measured using the EQ, due to its contemporary development and because the additional components in the IRI, specifically Fantasy and Personal Distress, did not appear to be aligned with the dimensions of empathy that the pedagogical strategies addressed.

2.3 Service Learning as a Pedagogical Strategy for Empathetic Growth

Service learning is a high-impact community-engaged pedagogy that integrates meaningful community service with academic learning outcomes [18]. Students apply their knowledge and skills in hands-on, authentic experiences that address real community needs. Successful service learning experiences center on building a collaborative relationship with the community partner to develop solutions that focus on the needs of the customer. Building this collaborative relationship to the mutual benefit of the students and the community partner requires immersion in the community which, in turn, leads to development of empathy not only for the individuals in the community but for the community as a whole.

In the course “Entrepreneurial Engineering Design Studio”, students worked with an organization that provides meaningful programming for individuals with severe multiple disabilities (SXI). The organization has created assembly lines of assistive devices that people with a wide range of disabilities - both physical and cognitive - can take part in with the help of a volunteer. At the completion of the assembly line, the participant has created a “kit” that is then donated to a charitable organization. The benefits of these activities are realized by all involved - the participants engage in meaningful activities that provide social interactions as well as physical activity while affording them the opportunity to give back to their community; the volunteers assisting the participants are often students in need of experience engaging with the disability community (such as student nurses and occupational therapists as examples); the donated kits benefit the charitable organization.

Through engagement with the disability community, students are able to recognize their common humanity with their customers after collaborating with them throughout the design process. In these encounters, students learn to adjust goals and compromise - their initial concept ideas are not always focused on their customer needs. Learning from stakeholders and keeping an open mind are common themes in most successful project outcomes.

For many students, the studio course is their first opportunity to work with people with disabilities. In preparing students to interact with their customers, a foundation of general knowledge in disability awareness and some guidelines on effective, respectful communication using ‘person-first’ language are provided [19]. This general knowledge and awareness challenges some common myths about people with disabilities. Students are made aware that the disability community does not discriminate - people of every color, gender, religion, ethnicity or age are, or may become, a member of this community. Having this awareness and understanding of the disability community helps to put the impact of the students’ projects in perspective [20].

By infusing empathy for others into the students' experiential learning at the early stages of the course, all phases of the design process–from opportunity identification to ideation to prototype testing–will reflect insights that are both innovative and responsive to actual user needs and desires. To initiate this user-centered, empathetic design approach, students engage in an accessibility simulation exercise on the first day of class designed to foster greater understanding of the everyday experiences of people with disabilities [21]. In this exercise, students break into groups and engage in multiple simulation activities including:

1. Mobility impairment in which students ambulate using either a wheelchair or a walker,
2. Dexterity impairment in which students place braces on both hands that limit range of motion,
3. Vision impairment in which students wear specially-designed goggles with lenses designed to simulate a variety of conditions [22]

Before beginning each simulation activity, the students must predict what they anticipate as the most difficult aspect of dealing with that particular disability. The students then perform a prescribed list of common, everyday tasks and conclude the activity by reflecting on the difficulties they experienced, both predicted and unanticipated. As engaged participants, the students experience some of the realities that their customers experience in their everyday lives [20].

The opportunity to engage with a customer from the disability community provides the students with a range of stakeholders to better understand the users' needs and expectations. Most times, when observing SXI individuals for the first time and watching them engage in activities to identify an opportunity for design, engineering students focus on how to make the task more efficient. With this community, efficiency is not the end goal—the focus is making the activities more engaging. The students are then tasked with understanding what makes an activity "engaging". As a designer, this skill is invaluable because designers often design for people who are unlike themselves [12].

2.4 Design Thinking as an Educational Context for Empathetic Design

Design thinking is an iteration on the engineering design process that front-loads the process with activities that help designers develop empathy for the end-user [23, 24]. The design thinking methodology is summarized in Figure 3.

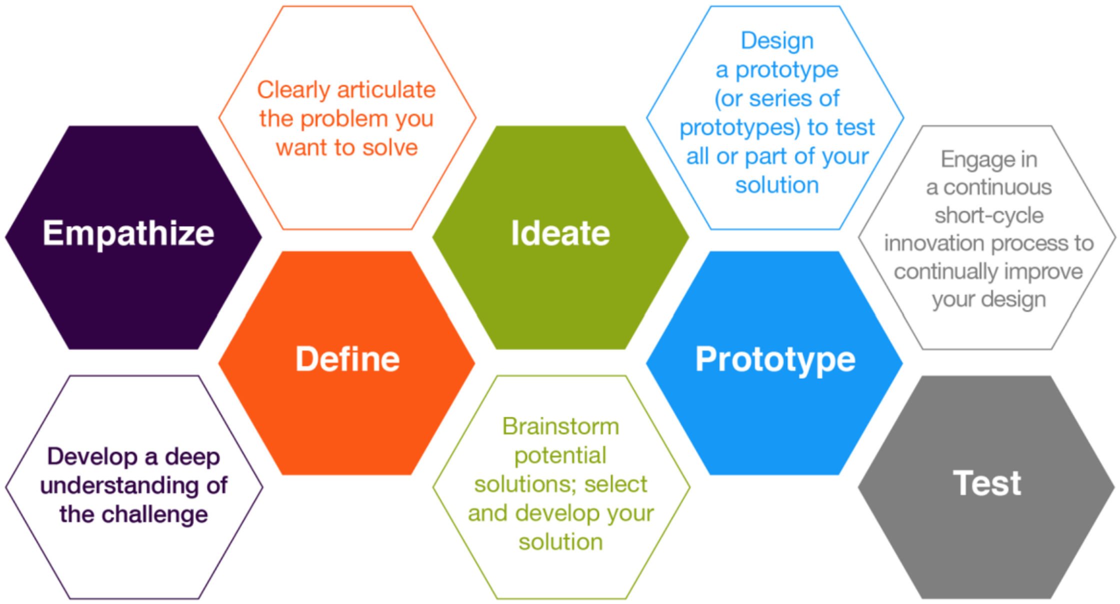

Figure 3. Design Thinking Process

The first two steps in this highly nonlinear, iterative process typically involve ethnographic activities in order to develop a greater understanding of the customer and their unmet needs. These ethnographic activities are most effective when they occur in a natural setting, namely observing the customers engaging in the activities and tasks that you expect to innovate, i.e., behaviors can only be understood in the everyday context in which they occur. Hess and Fila propose that designers who participated within a service learning course and were provide the opportunity to interact with end users utilized a wider variety of other-oriented empathetic techniques (both affective and cognitive) within their design approaches when compared to designers with no engagement with the end user (see Figure 2)[13].

No matter the design pedagogy adopted, the critical factor in empathetic design is the shift from an "expert" mindset to a user-centric mindset. Student teams that are not able to make this mindset shift tend to exclude their customers from the design process. Empathetic design requires students to shift their perspective from designing *for* an end user to designing *with* an end user [13].

In the sophomore design studio, students engage with their customers four times over the course of the semester. These visits occur at specific points in the design process that require customer feedback. Before each visit, students prepare for the customer interaction based on the information that they need to obtain. Getting the right customer input is essential to the creation of value for their customers and to a final design that considers the needs of the customers.

At their initial site visit, the students are focused on identifying potential opportunities for design. The topics of ethnography and painstorming are delivered to the students before the visit to emphasize the need for a naïve state of mind when observing the customers in their natural setting. With this focused observation, the pain points for the customers become more easily recognized as opportunities for innovation.

After the students have formed their teams around the opportunity that they are most passionate about pursuing and completed some preliminary research, the teams return to collect feedback from the customer and other stakeholders to better define the problem and develop a list of design requirements based on their customers' needs. The purpose of this second visit is to gain insight into the potential for innovation based on what their customer views as successful execution of each step in the task they are performing.

The teams do not return to the site for their third visit until they have selected a final concept for design. To prepare for the third site visit, teams build full-scale mock-up prototypes of their final design concept constructed of cardboard, tape, and repurposed materials. The purpose of this prototype is to communicate to their customer both the form and function of their design concept in a preliminary way. The focus of this customer interaction is to validate the viability of the design. Once the viability of their design is validated with the customer, teams finalize product architecture and component drawings. They then select and order materials to begin building their final working prototypes.

For the fourth site visit, teams bring their working prototypes to their customers to test these prototypes with respect to the target specifications they prescribed for their designs. In addition, teams consider robust design methodology principles to predict and test the capabilities of their designs under nonideal conditions. This fourth visit focuses on the value created for the customer, both quantitatively, in meeting the target specifications, and qualitatively, in the subjective evaluation of the prototype by the customer.

This interaction with real customers is a unique aspect of this course and has made a significant impact on the students' experience. The students' ability to use their developing engineering tools in this way provides for a more meaningful experience as they are able to see directly the impact their designs have in creating real value as defined by their customer. The ultimate course outcome is that this awareness and understanding of the perspectives and motivations of others will propagate into their professional lives as practicing engineers [20].

3. Research Method

3.1 Participants

This study involved three cohorts of students (N = 118) enrolled in the course "Entrepreneurial Engineering Design Studio" designed to integrate empathetic design principles into their learning experience. As shown in Table 2, the participants were divided into two groups based on the type of service-learning experiences they received: virtual service-learning (cohort 1, n = 47; and cohort 2, n = 28) and in-person service-learning (cohort 3, n = 43). We categorized cohorts 1 and 2 students as "non-engaged", and cohort 3 students as "engaged".

Table 2. Demographic Characteristics of Students

Characteristic	n (%)	Characteristic	n (%)
Engaged		Major	
No (Cohorts 1 and 2)	75 (63.6)	Biomed Engineering	17 (14.5)
Yes (Cohort 3)	43 (36.4)	Civil Engineering	19 (16.2)
Gender		Elec Comp Engineering	3 (2.6)
Female	31 (26.3)	Industrial Engineering	5 (4.3)
Male	87 (73.7)	Mechanical Engineering	73 (62.4)
Level			
Sophomore	66 (55.9)		
Junior	47 (39.8)		
Senior	5 (4.2)		

3.2 Procedure

At the beginning of the course, and again upon its completion, all students were asked to complete the Empathy Quotient (EQ) self-report questionnaire, designed to measure empathy in adults [8]. The EQ consists of 40 items related to empathy, with each item scored as 2, 1, or 0, leading to a potential maximum score of 80 and a minimum score of zero. The EQ was administered in a digital format during class time, ensuring that all students had the opportunity to participate without external pressures. The EQ demonstrated high internal consistency reliability at both pre-course (Cronbach's $\alpha = 0.838$) and post-course (Cronbach's $\alpha = 0.874$).

The service-learning component of the course was tailored according to the cohort. Cohorts 1 and 2 engaged in virtual service-learning projects, which allowed them to collaborate with community partners through online platforms and customer advocates. Cohort 3, on the other hand, participated in traditional in-person customer engagement activities throughout the design thinking process, directly interacting with the community and its members.

3.3 Statistical Analysis

Statistical analyses were conducted using JASP [25], an open-source statistical software that is built on top of the R statistical language. Pre- and post-course EQ scores were analyzed to assess both within-subject changes over time (from pre- to post-course) and between-subject differences across student characteristics such as gender, academic standing, major, and level of customer engagement. Repeated measures ANOVA was utilized to detect changes in mean empathy levels within subjects from pre- to post-course, and to identify differences in empathy levels between subjects based on characteristics and levels of engagement. Engagement was categorized as either no engagement, corresponding to virtual service-learning, or engagement, corresponding to in-person service learning. These analyses were performed regardless of the level of significance.

4. Results

Overall, with the exception of between-subjects gender differences, no significant effects were observed either within subjects or between subjects at the 95% confidence level (i.e., $p < 0.05$). However, small descriptive changes in empathy were noted both within and between subjects at very low effect sizes (i.e. $\eta^2 < 0.03$). Consequently, in the subsequent sections of the Results, we present various visualizations to illustrate the study's effects.

4.1 Baseline Level of Empathy in Engineering Students

To establish a baseline for comparing empathy levels, we utilized the Empathy Quotient (EQ) ranges reported by Baron-Cohen and Wheelwright [8], to generate a normal distribution of empathy scores among adult controls. Similarly, we generated a normal distribution for the empathy scores collected from our engineering student participants. This approach allowed for a direct comparison between the two groups. Our analysis revealed that the empathy levels of engineering students were generally lower than those observed within the control group of adults, as evidenced by the distributions represented in Figure 4.

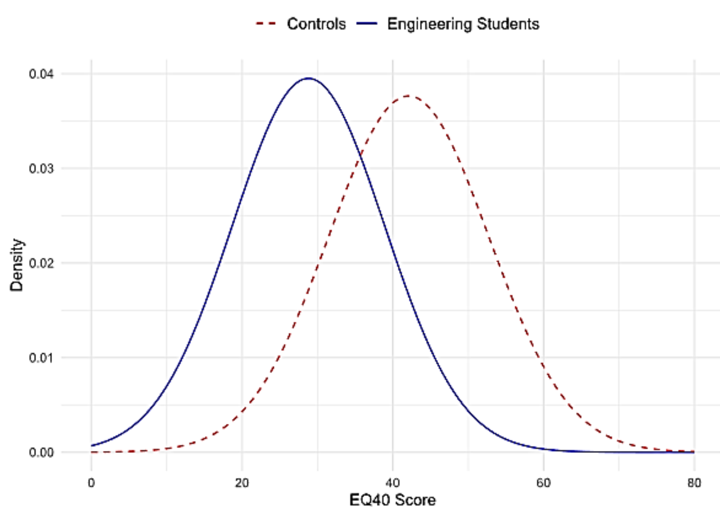

Figure 4. Empathy in Engineering Students vs. Controls

4.2 Pre-Post Empathy across Student Characteristics

Post-course empathy scores for all students were slightly higher than pre-course scores, with a mean (SD) of 29.1 (10.3) compared to 28.6 (9.75). As shown in Figure 5, Panel A, this pattern persisted across gender, although males exhibited significantly lower overall empathy levels than females as observed in other studies, $p < 0.001$, $\eta^2 = 0.092$ [26]. Sophomore students showed a similar increase in empathy over time as both females and males; however, juniors and seniors both experienced declines in empathy over time (see Figure 5, Panel B). When examining changes in empathy over time by major, biomedical engineering and industrial engineering students showed increased empathy over time (see Figure 5, Panel C). Additionally, while students who were either engaged or not engaged with the in-person service-learning component of the course showed increases in empathy over time, those who were engaged experienced ~~a~~ slightly more growth in empathy than those who were not engaged (see Figure 5, Panel D).

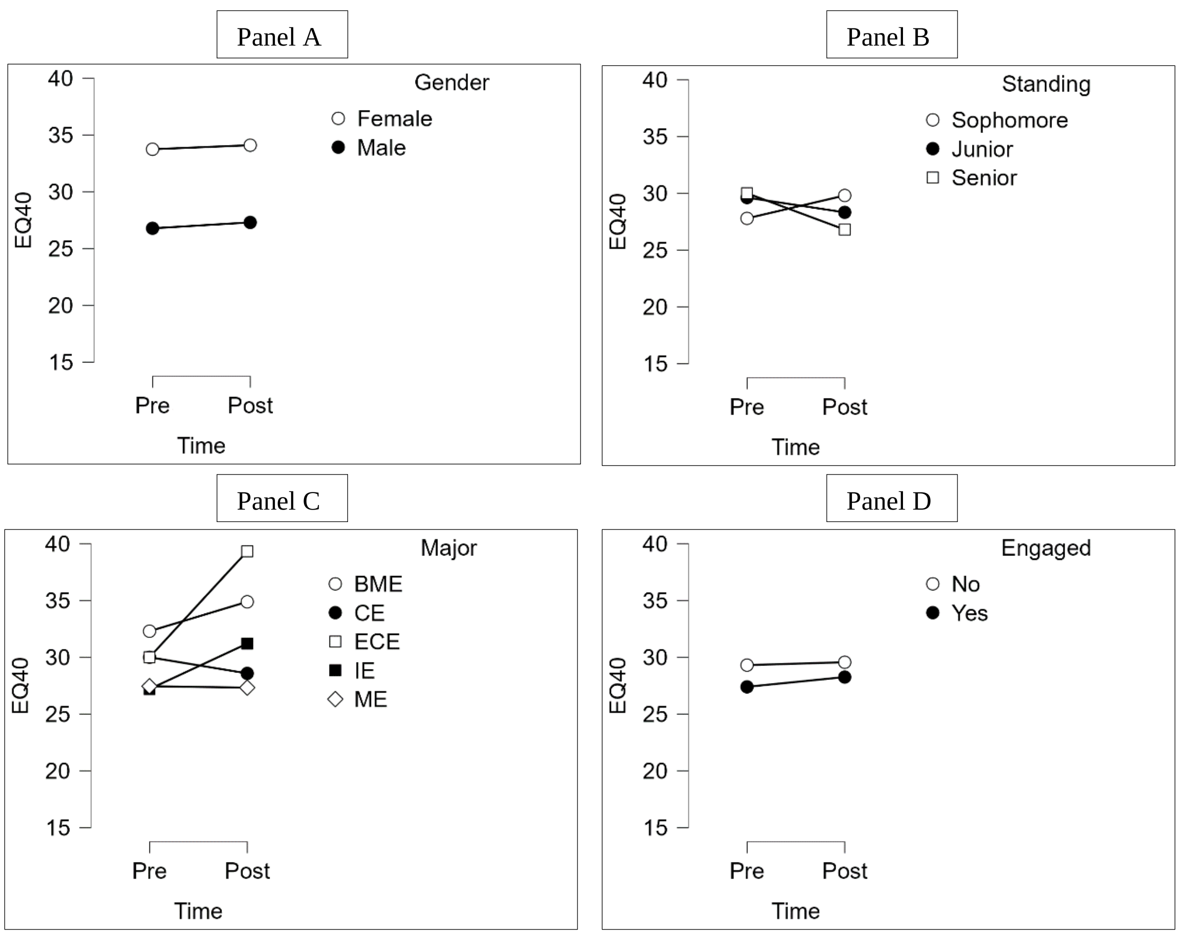

Figure 5. Empathy as a Function of Time * Student Characteristics

4.3 Pre-Post Empathy across Student Characteristics and In-Person Engagement

When analyzing changes in empathy over time, differentiated by gender and engagement, females engaged in in-person service-learning showed greater increases in empathy levels over time compared to those who were not engaged (see Figure 6).

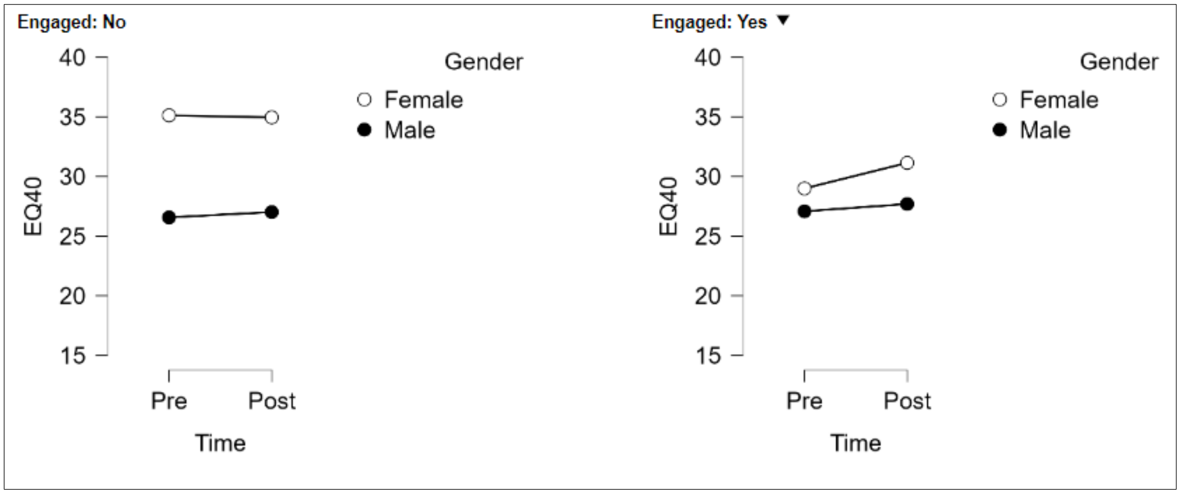

Figure 6. Empathy as a Function of Time * Gender * Engaged

When analyzing changes in empathy over time by student year and engagement, there was no effect of engagement on empathy (see Figure 7).

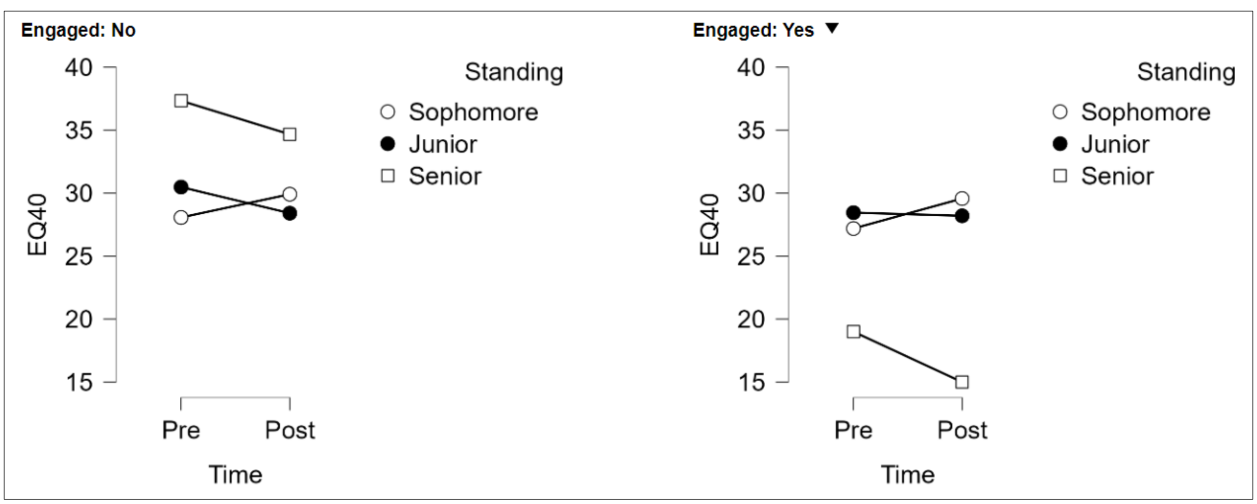

Figure 7. Empathy as a Function of Time * Standing * Engaged

5. Discussion

5.1 Study Summary

This study sought to evaluate the impact of the "Entrepreneurial Engineering Design Studio," an interdisciplinary service-learning engineering design course, on fostering empathy among engineering undergraduates. Through an analysis of Empathy Quotient (EQ) scores collected before and after course completion from three cohorts of students, our findings help to characterize empathy development within an engineering educational context. Notably, we found slight increases in post-course empathy scores across all students, with variations observed when dissecting the data by gender, class standing, major, and type of service-learning engagement.

The study's findings, that engineering students initially exhibited lower empathy levels compared to a control group, yet demonstrated increases in empathy following the course, particularly among those engaged in in-person service-learning, underscore the value of experiential learning in engineering education [18]. This is consistent with qualitative insights that the researchers observed by means of student reflections in a final deliverable for the course. A technical paper documenting the students' design project culminates with a section asking the student to describe the "Community Impact" of their project and a "Conclusion" section in which students describe the impact that the course has had on their development as an engineer.

One such student that experienced face-to-face interactions with their customer over the course of their project commented:

> "The community at large would be impacted by the Brilliant Bottle Pod because it creates a larger conversation about how individuals with disabilities are productive members of a community and are just as valuable as non-disabled people in the workplace. Simple and inexpensive inventions like ours help disabled individuals reach their maximum potential. If companies were to invest more in creating inventions like the Brilliant Bottle Pod then they would realize how large of an impact it would make on the community by making the workforce stronger and larger."

And reflecting on how the course and project had impacted their professional development, the student had this to say:

> "Before taking this class I never really thought about using my skill as an engineering student to help people with disabilities. However, the entire experience of going to the STEP facility seeing the employees and how happy they are to see you and talk to you has really changed the way I think about how to use my knowledge in the future...I would like to continue to use my engineering skills to help others with disabilities to make their pains disappear as well as continue to

show the world that people with disabilities can make a difference in the workplace."

Anecdotal observations of the researchers also suggest a higher level of motivation to deliver a product that meets their identified customer needs when teams had face-to-face customer interactions. As a student, the ability to see the direct effect that your technical skills and know-how can have on someone's life can have a profound impact.

5.2 Study Limitations

A notable limitation, as outlined in the methodology, stems from the reliance on the EQ as the primary instrument for measuring empathy. Given the EQ's design, which does not differentiate between affective and cognitive empathy, our study may not have captured the full scope of empathy development. This limitation points to a gap highlighted by researchers regarding the need for multidimensional empathy assessments [10, 27].

Moreover, the adaptation to virtual service-learning due to the pandemic introduced an unforeseen variable. While our study managed to navigate this challenge, it presents an area for future research to explore the differential impacts of virtual versus in-person service-learning on empathy development [6].

5.3 Future Work

Future research should prioritize the development and utilization of multidimensional empathy measures that can capture the nuanced changes in both affective and cognitive empathy [10, 27]. Additionally, researchers are exploring alternative classroom interventions to help students develop empathy for their end-user in the early stages of the design thinking process to enhance students' empathetic self-efficacy. Investigating the longitudinal effects of service-learning experiences and classroom empathy-building activities have on empathy could provide valuable insights into the sustainability of empathy development over time.

Does trait empathy development in these educational contexts persist only in the educational setting in which they are experienced? This is particularly relevant given the transient nature of course-based interventions and the ongoing debate on the best practices for embedding empathy into engineering education [7, 11, 12].

In summary, our findings contribute to the body of literature advocating for the inclusion of service learning and empathetic design in engineering education. By reinforcing the importance of empathy in engineering practice, our study aligns with the objectives of the Kern Entrepreneurial Engineering Network (KEEN) and supports engineering curriculum design that not only imparts technical knowledge but also aims to cultivate the empathetic and entrepreneurial mindsets essential for addressing the multifaceted challenges of our time [15].

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