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RESEARCH ARTICLE

How Engineering Students Learn and are Impacted by Empathy Training: A Multi-year Study of an Empathy Program Focused on Disability and Technology

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Abstract

Purpose Measurable results of efforts to teach empathy to engineering students are sparse and somewhat mixed. This study's objectives are (O1) to understand how empathy training affects students' professional development relative to other educational experiences, (O2) to track empathy changes due to training over multiple years, and (O3) to understand how and what students learn in empathy training environments.

Methods Students in a multiple-semester empathy course completed surveys ranking the career development impact of the empathy program against other college experiences (O1), rating learning of specific empathy skills (O2), and ranking program elements' impact on empathy skills (O3). Intervention and control groups completed the Interpersonal Reactivity Index and Jefferson Scale of Empathy at four time points (O2). Cohort students participated in post-program interviews (O1, O3).

Results O1: Empathy training impacted career development more than several typical college activities but less than courses in major. O2: Students reported gains in four taught empathy skills. Cohort students showed significant increases in the Jefferson Scale while the control group did not. There were no significant changes in Interpersonal Reactivity Index scores. O3: interactive exercises had a significant effect on students' learning all empathy skills while interactions with people with disabilities had significant effect on learning to encounter others with genuineness. Students valued building a safe in-class community facilitating their success in experiential environments.

Conclusions This study highlights empathy skills' importance in engineering students' development, shows gains in empathy with training, and uncovers key factors in students' learning experience that can be incorporated into engineering curricula.

Keywords Empathy · Experiential learning · Service learning · Community encounters

Introduction

Biomedical engineers, particularly those working in rehabilitation and assistive technology, develop technology with and for people with disabilities. Engineers must understand the challenges people they serve face each day. This requires the ability to empathize. The role of empathy as a skill, practice orientation, and way of being as modeled by Walther and colleagues [1] is an emerging topic in engineering education. Arguments that empathy is a core skill for engineering professionals that should be explicitly taught in undergraduate curricula have developed over the past decade. This central argument was eloquently laid out by Walther and colleagues [2]. It goes like this: The engineering profession has placed an emphasis on teamwork and communication [3]. The most successful teams have high "average social sensitivity" [4] and have team members who share the belief that the team

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is a safe place for "interpersonal risk taking" [5]. Empathy is either a prerequisite or a direct analog to these traits of successful teams. However, empathy is not widely considered in undergraduate engineering programs. Instead, students become less concerned in public welfare as they progress through an engineering curriculum [6], a phenomenon Cech attributes to a culture of disengagement that values only technical concerns to the detriment of social concerns. To make matters worse, there is evidence in neuroscience suggesting that analytical and social cognitive tasks suppress each other [7]. In other words, increased analytical thought leads to diminished ability to reason socially. This all points to a call for greater prominence of empathy in engineering education.

This argument, although logical, has a sparse but growing base of evidence to support it and leaves key questions open. Proponents of empathy training in engineering are essentially preaching to the choir of people likely to accept these arguments. In order to drive change in engineering education, proponents of teaching empathy must

1. Show more concrete evidence that empathy is critical in the formation of successful engineers, especially relative to other knowledge and skills that may compete for instructional time.
2. Show that proper instruction leads to gains in empathy.
3. Identify useful methods for teaching empathy and ways to implement them in engineering curricula.

While there is growing evidence that engineering practice values empathy [8], professional and student engineers score lower on numerical scales of empathy and tend to be perceived as less empathetic than other professionals. Engineering students scored lower than students in social work and psychology on subscales of the Interpersonal Reactivity Index [9]. STEM majors scored lower than non-STEM majors in the Empathizing/Systemizing Quotient [10] [10]. These numerical scales support the general perception of the engineering profession as lacking empathy [11, 12]. A central explanation for this is that the culture of engineering education does little to promote the development of empathy and perhaps deters those who are more inclined to value empathy from joining the field [12]. A survey of engineers working in industry revealed that "collegiate experiences of years past have been particularly ineffective at instilling these [empathy] skills/dispositions" [8]. Although empathy is indeed valued, it's unclear what that value is relative to other educational priorities.

Empathy can be learned [9, 13, 14], but the measurable results of efforts to teach empathy in engineering students are rather sparse and somewhat mixed. The most common tool used to measure empathy in engineering is the Interpersonal Reactivity Index [15], a self-reported scale across four subscales: (1) perspective taking: "the tendency to spontaneously adopt the psychological point of view of others," (2) fantasy: "taps respondents' tendencies to transpose themselves imaginatively into the feelings and actions of fictitious characters in books, movies, and plays," (3) empathic concern: "assesses 'other-oriented' feelings of sympathy and concern for unfortunate others," and (4) personal distress: "measures 'self-oriented' feelings of personal anxiety and unease in tense interpersonal settings." Studies of empathy in engineering have shown increases, decreases, and no change in one or more subscales. In a study of 103 first-year students in a design course with explicit empathy instruction, the elements of the Interpersonal Reactivity Index either went down (empathic concern and personal distress) or were unchanged (fantasy, empathic concern) for students over an eight-week period [16]. In a large multi-phase study (109 students in one phase and 235 in the other) of students in a community-based learning course, students in the early phase without explicit empathy instruction saw an increase in emotional regulation and personal distress [17]. Students in the same study saw increases in Perspective Taking, Emotion Regulation, Interpersonal Self Efficacy, Personal Distress, and Fantasy in a later phase where empathy instruction was explicitly introduced. Another larger study of 41 graduate students across 16 institutions in a multi-disciplinary design thinking course with no explicit empathy instruction showed an increase in perspective taking [18].

A likely reason for these mixed results is the variety of methods used by early adopters to teach empathy. Two primary venues for teaching empathy are in design courses and community-based learning or service-learning courses. Community-based learning courses, whether they be in international locations [19] or in the local community [17, 20], potentially promote empathy by providing opportunities for personal reflection and for regular interactions between team members and with stakeholders in their environments. Design courses [2, 16, 18, 21] offer similar opportunities but typically span a longer time period and occur in more controlled environments that are familiar to students. Empathy has also been taught in more standard lecture type courses (e.g., fluid mechanics example in [22]) or as an element of teaching professional ethics [23]. Perhaps the most prevalent method for explicitly teaching empathy is the use of role-playing exercises, class discussions, and reflections developed at the University of Georgia [2, 17], and intentionally proliferated to other institutions [22]. Other teaching methods include merely taking part in service learning and reflection [19], employing user-centered design [20], taking part in an activity to identify stakeholders' perspectives [23], and instruction that included completing an empathy map, completing a journey map, a lecture on the importance of empathy in engineering design, discussions exploring the role of empathy, lecture and discussion on cognitive and affective aspects and the four parts of

the Interpersonal Reactivity Index, and 1-page reflection on students' own empathic development [16].

To respond to the needs enumerated above the objectives of this study are to (1) better understand the role of empathy training in students' overall professional development relative to other educational experiences, (2) provide quantitative evidence of changes in empathy due to empathy training over multiple years rather than over a brief period of training, and (3) better understand what students learn and how they learn it in empathy training environments. Via achieving these objectives we provide some recommendations on integrating empathy training into engineering curricula. To explore these research questions, we studied three cohorts of students taking part in a two-course empathy training program.

Positionality Statement

The first author is an able-bodied researcher who develops assistive technology in partnership with people with cervical spinal cord injuries. He has been frustrated that the demands of an academic position limit his ability to prioritize spending more time with people with lived disability experience. Therefore he created the empathy program as a way for he and his students to gain that experience as part of their normal responsibilities—teaching or taking a course—rather than as an outside activity viewed as unproductive by others. The second author is a Ph.D candidate who was able-bodied during the course of the research activities described, but experienced temporary tetraplegia due to Guillain-Barre Syndrome prior to this manuscript's submission. In addition to his training in engineering, he is interested in the role of empathy in the development of socially conscious engineers and believes it to be a critical yet absent component of the majority of engineering education programs. The third author is an able-bodied PhD student in Counseling Psychology, who is committed to justice broadly. She practices communicating empathy daily in her clinical work, and researches factors related to college students' identity development and well-being. She is invested in fostering empathy and effective communication skills in students and in the clients she works with in therapy. She acknowledges that the field of engineering is often perceived as one where skills working with others are not a prerequisite which can serve as a barrier to involvement in the field for many individuals.

Methods

To achieve these three objectives, we used a mixed-methods approach to study how students participating in a multi-semester empathy training program learned empathy. Data collected (Fig. 1) included interviews with students (orange box), students' survey responses at various points in the program (purple boxes), and students' responses to validated scales of empathy (green boxes).

Description of the Empathy Training Program

We followed three cohorts of students participating in an empathy training program at a public research university in the midwestern United States. The overarching purpose of the program was to teach students how to develop lasting relationships with people with disabilities and others who might have experiences that differ from their own. The desired result is that students use these skills to partner with people with disabilities in their professional roles. Participation in the program partially fulfilled the university's general education requirement in U.S. diversity. Students voluntarily chose the course from several other U.S. diversity courses that satisfied the general education requirement. The three-year program included a one-credit introductory course called Disability, Empathy, and Technology I (DET I), a two-credit follow-up course called Disability, Empathy, and Technology II (DET II), and the option to complete a disability-focused capstone project within their own majors. The first author of this paper taught both courses and acted as the faculty advisor for capstone projects.

The two courses taught four specific empathy skills: (1) encountering others with genuineness, (2) self and other awareness, (3) affective sharing and responding, and (4) switching between empathic and analytic modes of interaction. These skills were taught using the following program elements: (1) classroom exercises designed to practice specific empathy skills, (2) interprofessional cohorts, (3) visits to the homes of people with disabilities, (4) in-class discussions with people with disabilities and professionals who work with them, (5) weekly reflection assignments, and (6) lectures on disability and the empathy skills.

The classroom exercises were largely modeled off the approach developed at the University of Georgia [2] and implemented with initial consultation with those researchers. The Georgia group of Walther and colleagues described specific empathy *skills* which the empathy courses explicitly taught, an *orientation* towards practicing those skills that leads to a person's epistemological openness, micro to macro focus, relative value awareness, and commitment to values pluralism, and a person's *way of being* including recognizing the dignity and worth of persons and the natural environment, holistic service to society, and seeing oneself as a whole professional [1]. These included exercises where students explored the effects on personal comfort of physical closeness, eye contract, and relative height, scenarios where students took turns telling and listening to personal stories while practicing expressing and responding to emotions both verbally and nonverbally, and scenarios where

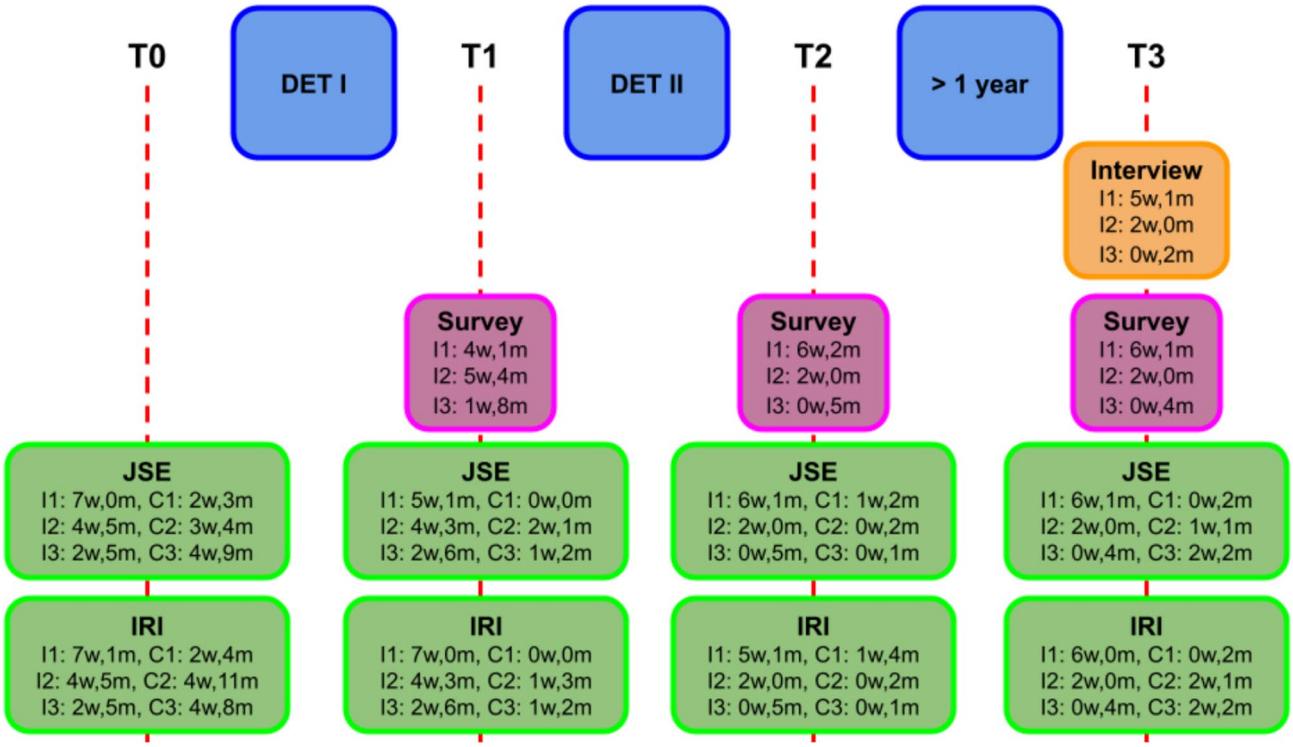

Fig. 1 Study design—a different color represents each instrument. "IX" means the Xth intervention cohort and "CY" means the Yth control cohort (e.g., I2 is intervention cohort 2). "w" and "m" indicate the number of women and men who completed each instrument

students were asked to play specific roles while practicing the empathy skills.

The empathy program was designed to be taken over multiple semesters by a cohort of students from various academic majors. There was no specific instruction on cross-disciplinary collaboration, but the instructor intentionally mixed students from different majors in assigning groups for class exercises and home visits.

Students were matched with a host who has a disability for one home visit during DET I and three home visits during DET II. The home visit during DET I asked students to interview their host in order to give a short presentation to the class that introduced the host as a person (e.g., family relationships, line of work, personal interests) and described how disability affects the host's daily life. The three home visits during DET II were designed for the students to collaborate with their host to propose a project that would benefit the host. The first visit was designed for students and host to informally get to know each other and to define the parameters of future meetings. During the second visit students observed one or more tasks that the host identified as challenging or would like to do differently. During the third visit the host and students brainstormed potential ways to improve the host's satisfaction in completing that task. After the three visits students proposed a project with specific objectives and a budget. In some cases the project could be immediately completed (e.g., a small purchase). In other cases the students might work on the project as part of their capstone course, or the project was given to CSU's volunteer organization to serve hosts with disabilities. The hosts were not directly paid for participating but often received equipment as a result of the course project paid from the course budget.

In-class discussions with people with disabilities and professionals began with a panel discussion where each guest introduced themself while students asked questions. The panel was followed by informal discussions where 3–4 students joined one guest. During DET II the informal discussions included sharing a meal provided by the course budget. In some cases guests with disabilities also worked as professionals serving others with disabilities. Guests were not paid for participating but received free parking.

Lecture topics included brief introductions to each of the four specific empathy skills before giving students opportunities to practice them. The introductions to the exercises were framed by the empathy model developed by Walther and colleagues [1]. There were longer lectures on an overview of disability, safety in home visits, examples of assistive technologies, and conceptual models of disability (e.g., medical model, social model, moral model, human rights model). Weekly reflection exercises asked students to write 500 words to prompts related to the

exercises, home visits, and lectures including pointing out specific examples of classmates effectively communicating or responding to emotions, changes in their thinking after home visits, creation of their own model of disability, and analysis of the usefulness of various assistive devices. The course instructor attempted to not endorse a specific model of disability but to introduce various models and challenge the students to experience disability from a disabled person's point of view and to practice empathy toward that view.

The capstone projects were taught according to the practices of the individual disciplines and did not explicitly include empathy instruction. Students (3 of 16 students who participated in end of program evaluations) who completed the optional disability-focused capstone project did so within the two-semester engineering senior capstone design course. Typically, one or two students who had taken DET I and DET II conceived of a project together with a person with a disability with whom the students had developed a relationship during the Disability, Empathy, and Technology courses. Those students then invited other students who had not taken those courses to also participate in the project. Example projects include working with a person with paralyzed hands to design an automatic door opening system and with a person with limited dexterity and non-typical speech patterns to allow for gross arm movements to activate functions on a smart phone. These projects were an alternative to more typical industry-sponsored senior design projects. The first author of this paper acted as the faculty advisor for projects related to disability but was not the main instructor for senior design.

Ethics, Consent, and Permissions

Students who participated in the empathy training program were invited to participate in a research study to evaluate the program. Students gave written consent to participate in the study under protocol IRB-FY2019-48 approved by the Cleveland State University Institutional Review Board. Table 1 lays out the academic major of students in each cohort.

Consent to Publish

Consent to publish was obtained from students who participated in the study.

Objective 1: Better Understand the Role of Empathy Training in Students' Overall Professional Development Relative to Other Educational Experiences

Students who consented to participate in the research study were asked to take an online survey created by the course instructor three times (purple boxes at T1, T2, and T3 in Fig. 1)—once at the end of Disability, Empathy, and Technology I, again at the end of Disability, Empathy, and Technology II, and a third time at least one year after completing

Table 1 Academic majors of students participating in the study

Major	# of Students who completed Pre-DET I Instruments at T0				# of Students who completed Post-Program Instruments at T3			
	Cohort 1	Cohort 2	Cohort 3	Total	Cohort 1	Cohort 2	Cohort 3	Total
Mechanical Engineering	1	3	3	7	2	1	3	6
Civil Engineering	0	0	1	1	0	0	1	1
Mechanical Engineering Technology	1	0	1	2	1	0	1	2
Computer Engineering	0	1	0	1	0	0	0	0
Electrical Engineering	1	1	0	2	1	0	0	1
Chemical Engineering	1	0	0	1	1	0	0	1
Post-Bacc Engineering	1	0	0	1	0	0	0	0
Engineering Totals	5	5	5	15	5	1	5	11
Math	0	1	1	2	0	1	0	1
Biology	0	0	1	1	0	0	0	0
Music	0	1	0	1	0	0	0	0
Film	0	1	0	1	0	0	0	0
Psychology	0	1	0	1	0	0	0	0
Arts & Sciences Totals	0	4	2	6	0	1	0	1
Music Therapy	2	0	0	2	3	0	0	3
Pre Physical Therapy	1	0	0	1	1	0	0	1
Health totals	3	0	0	3	4	0	0	4

Disability, Empathy, and Technology II. We will refer to this instrument as "the post survey" throughout this article. One section of the post survey asked students to "rank each of the elements of your overall college experience in terms of their impact on your preparedness for a career after graduation." The students ranked these elements: the empathy training program, residential life, other general education courses, elective courses, required courses in your major, extracurricular activities such as clubs or sports, and internships or co-op experiences. These post surveys allowed us to examine students' placement of empathy among their other educational experiences and how this evolved over time.

We conducted the following numerical analyses, which are similar to those described in [24] to determine the importance of the empathy training relative to other college experiences in terms of impact on students' perception of their career preparedness. Across all students and program time points we computed the mean rank for each student experience. We fit the ranking data to a Plackett–Luce model [25] in the R-software environment [26] to compute the model-defined "worth" and its statistical significance for each student experience as it relates to career preparation. A higher worth value corresponds to a ranked item being deemed more important and therefore ranked as such. Worth for each item was computed relative to the worth of the empathy training program so that we could make direct comparisons between the importance of the empathy training program and each of the other educational experiences. We also tested the significance as covariates in the Plackett–Luce model of the cohort a student was in and of the time point (end of DET I, end of DET II, one-year post-program) at which the survey was completed.

More than one year after the conclusion of DET II for all three cohorts we conducted semi-structured interviews of 10 students (orange box at T3 in Fig. 1). We conducted the interviews at least a year after students completed the program both to see which elements of the program had a lasting impact and to get a better idea of where empathy fit into a student's larger undergraduate experience rather than just the time the student took the courses. Eight of the students were STEM majors, and two others were non-STEM majors. The interviewers were the coauthors who did not participate in the development or teaching of the courses in which the interviewed students were enrolled. The interviews were based on an interview guide and covered topics in both Objective 1 and Objective 3. Together, the three authors designed an interview guide to cover three topic areas relevant to Objectives 1 and 3: (1) benefits of learning empathy, (2) what students learned, (3) ways students learned. The authors wrote down specific questions they might ask related to each of the three topic areas. The interviewers were free to ask questions from the guide in any order, change the wording of questions, and ask additional questions depending on a person's responses. The following questions in the interview guide were most relevant to Objective 1:

- Can you tell me about your decision to take the class? What piqued your interest about the class?
- Did you switch majors after taking the empathy courses? Did the empathy courses affirm your choice?
- Have you changed the way you think about your profession?
- How do you see the role of empathy in engineering specifically?
- Talk about how the empathy program fit into your overall undergraduate education. How important was it relative to other things like clubs you were in, classes in your major, other gen ed classes, internships/practicals, etc.?
- Did this class make a difference in your career choices?

The interviews occurred over Zoom. The audio files were converted to transcripts with the Otter.AI (Mountainview, CA) software. The transcripts were then proofread by one of the researchers to correct any errors in transcription and anonymize the transcripts. The interview transcripts were augmented by open-ended responses to two survey questions at the end of DET I, DET II, and one year after DET II (purple boxes at T1, T2, and T3 in Fig. 1): (1) What was your most positive experience in the course? and (2) What was your most negative experience in the course?

Qualitative analysis of the transcripts and survey responses was done in the DeDoose software system [27]. The research team began with a preliminary set of codes derived from the interview guide (benefits of learning empathy, what students learned, ways of learning). The non-interviewer author who was also the instructor of the empathy courses read the transcripts and responses and took initial notes on them to create a set of subcodes. Relevant to Objective 1 the subcodes for "benefits of learning empathy" were "benefits in career," "benefits in personal life," "general importance of empathy," "influence on career path," and "other benefits." Within the software the author manually assigned codes to text in the ten transcripts and survey responses. During coding, if new subcodes surfaced (e.g., a new benefit of the program) the author revisited previous transcripts to add the new subcodes. The software aggregated lists of all quotes across each code. The researcher reviewed these quote lists and developed larger themes relevant to Objectives 1 and 3. These themes became the basis for the structure of the results section. The researcher then chose quotes that were most illustrative of the themes to be included in the text of the manuscript.

Objective 2: Provide Quantitative Evidence of Changes in Empathy Due To Empathy Training Over Multiple Years Rather than Over a Brief Period of Training

We measured changes in students' empathy over the time of program participation and compared their empathy scores to those in a control group who did not receive any explicit empathy training. Students in the empathy training program and the control group took the Interpersonal Reactivity Index [15] and a modified version of the Jefferson Scale of Empathy [28]. As the Jefferson Scale is designed for medical personnel, we changed references to "patients" to "clients" in questions asked of students in the empathy program. The Interpersonal Reactivity Index includes a total score and scores for each of four subscales: perspective taking (the tendency to spontaneously adopt the psychological point of view of others), fantasy (taps respondents' tendencies to transpose themselves imaginatively into the feelings and actions of fictitious characters in books, movies, and plays), empathic concern (assesses 'other-oriented' feelings of sympathy and concern for unfortunate others), and personal distress (measures 'self-oriented' feelings of personal anxiety and unease in tense interpersonal settings). We include both scales as the Jefferson Scale measures empathy in professional settings, and the Interpersonal Reactivity Index measures empathy more generally. The empathy program aims to increase empathy in both spaces. Empathy program students (intervention group) completed each of the two scales via an online system on the first and last days of Disability, Empathy, and Technology I, on the last day of Disability, Empathy, and Technology II, and at least one year after the end of Disability, Empathy, and Technology II (green boxes at time points T0, T1, T2, and T3 in Fig. 1). DET I was targeted to second-year students, and DET II was targeted to third-year students. The control group was recruited from students taking a sophomore level engineering class in each semester in which a new cohort of empathy training students began Disability, Empathy, and Technology I. Rather than taking the two DET courses to fulfill the U.S. Diversity general education requirement, control group students took one of 30 other courses to fulfill the requirement. Of those 30 alternative courses, only one (Psychology of Women and Gender), mentions "empathy" in the course description. There are no other courses in the entire university catalog that include "empathy" in the course description. The choice of control group was intended so members of the control group did not receive explicit empathy training (although they could potentially develop those skills in other ways) and that both control group members and intervention group members began the study during their second year and completed the study near the end of their fourth year. The control group took the IRI and Jefferson Scale at approximately the same time points as the students participating in the empathy training program.

For the Jefferson Scale, the total IRI score, and each of the four IRI subscales we tested these null hypotheses:

Null hypothesis #1: Each of the individual empathy scores were the same across any two time points in the study for members of the intervention group.

Null hypothesis #2: Each of the individual empathy scores were the same across any two time points in the study for members of the control group.

Null hypothesis #3: The intervention group and control group had the same score for each of the individual empathy scores at the beginning of the program.

The alternative hypothesis for each case is that the scores were different between the groups or time points.

Each of null hypothesis #1 and null hypothesis #2 were, in practice, 36 individual hypotheses representing six comparisons of study time points (T0: pre-program vs. T1: post-DET I, T0: pre-program vs. T2: post-DET II, T0: pre-program vs. T3: post-program, T1: post-DET I vs. T2: post-DET II, T1: post-DET I vs T3: post-program, and T2: post-DET II vs. T3: post-program) for each of the six empathy scores (Jefferson, IRI total, IRI perspective taking, IRI fantasy, IRI empathic concern, IRI personal distress). In practice, null hypothesis #3 was six individual hypotheses comparing the pre-program (T0 in Fig. 1) empathy score of the intervention group to the corresponding score of the control group.

For each empathy score we compared pairs of time points rather than testing one hypothesis that the scores are unchanged over all time points (with post-hoc comparisons of individual time points). We made this choice because it was rare that an individual participant completed the empathy measures at all time points. Doing the individual tests allowed us to have larger groups for comparison and avoid eliminating data for participants who did not complete the empathy measures at all time points. For example, if a participant completed the empathy measures at T0: pre-program, T2: post-DET II, and T3: post-program we could include them in comparisons of scores at those time points rather than disregarding that participant's scores because they did not complete the measures for T1: post-DET I.

We used the Freidman test [29] for each hypothesis. The Friedman test is the nonparametric analog of a one-way repeated measures ANOVA which rank orders measures of the same variable (the empathy score for a particular individual) at different time points in computing the test statistic. We used the Friedman test because our data did not pass tests of normality.

The post surveys described above allowed students to evaluate their own learning of the four specific empathy skills (encountering others with genuineness, self and other awareness, affective sharing and responding, and switching between empathic and analytic modes of interaction) over

time. The post-surveys for DET II and at least one year after DET II asked students to score their learning of each skill on a five-point Likert scale. The scale included "the program made me much worse at this skill," "the program made me a little worse at this skill," "the program had no effect on this skill," "the program made me a little better at this skill," and "the program made me much better at this skill."

To analyze the Likert scale data, we computed the frequency of each of the five responses for each of the four empathy skills. We also fit an ordinal logistic regression model to the data using the MATLAB (Mathworks, Inc, Natick, MA) function fitmnr(). The ordinal logistic regression model tested for the effects of two independent variables (cohort—three levels and time in program - two levels) and one ordinal dependent variable (Likert score).

Objective 3: Better Understand What Students Learn and How they Learn it in Empathy Training Environments

In surveys at the end of DET II and at least one year after DET II (purple boxes at times T2 and T3 in Fig. 1) we asked students to rank the empathy training program elements (classroom exercises designed to practice specific empathy skills, interprofessional cohorts, visits to the homes of people with disabilities, in-class discussions with people with disabilities and professionals who work with them, weekly reflection assignments, and lectures on disability and the empathy skills) in terms of their effectiveness in students' learning each of the four empathy skills (encountering others with genuineness, self and other awareness, affective sharing and responding, and switching between empathic and analytic modes of interaction).

We conducted the following numerical analyses to determine which empathy program elements aided most in learning each empathy skill. We computed the mean rank for each program element for each empathy skill. For each empathy skill we fit the data to a Plackett–Luce model [25] in the R-software environment [30] to compute the model-defined "worth" and its statistical significance for each program element as it relates to learning the specific empathy skill. Worth for each item was computed relative to the mean worth. We also tested the significance as covariates in the Plackett–Luce model of the cohort a student was in and of the time point (T2: end of DET II, T3: one-year post-program in Fig. 1) at which the survey was completed.

We also used the semi-structured interviews (orange box at time T3 in Fig. 1) and end of course surveys (purple boxes at T1, T2, and T3 in Fig. 1) previously described in Objective 1 to understand what and how students learned in the empathy program. Questions from the interview guide especially relevant to Objective 3 were:

- Speaking candidly, how do you feel about the class in hindsight?
- What did you tell your friends or family about the class?
- Do you find yourself using any of the skills you learned in the class?
- Can you talk about a time when you used a technique you learned in class during your time in college? Your career?
- What were your favorite parts of the class, why?
- What did you find the most helpful?
- What did you find the least helpful? How would you improve them while still teaching the same skill?
- This isn't meant to feel like a quiz, but can you talk about the skills you learned?
- Can you define empathy in your own words?
- Tell me about the home visits. How did you feel about them? How did you feel before the first one?
- Talk about the effect of taking DET I and DET II in separate semesters.
- Do you think you would've learned this stuff anyway?

The first author coded responses under the main code "what students learned" with subcodes representing the four empathy skills taught in the courses (encountering others, affective sharing/responding, self and other awareness, mode switching) and a subcode for "other things learned." After the initial coding, it became obvious that interview excerpts under "what students learned" could be aligned with the model of empathy proposed by Walther and colleagues [1] described earlier. After having looked at the qualitative data, we inductively adopted the "skills," "orientation," and "way of being" elements of the Walther model as the themes of our analysis. The main code "Ways of learning" had subcodes for the six program elements (class exercises, interprofessional cohorts, special guests, home visits, class lectures, reflections) and for "facilitators of learning," "two-semester effect," and "Could you learn empathy some other way?"

Results

Objective 1: Better Understand the Role of Empathy Training in Students' Overall Professional Development Relative to Other Educational Experiences

Our post-course surveys and one-year-out survey (purple boxes at T1, T2, and T3 in Fig. 1) asked students to rank various educational experiences, including participating in the empathy program, in terms of impact on career preparedness. According to mean ranking, students rated "required courses in major" as most impactful followed by "internships and co-ops," the "empathy training program,"

"elective courses," "extracurricular activities," "other general education courses," and "residential life." The empathy training program was the third most impactful of the seven experiences.

In the Plackett–Luce model fit to the survey data (Fig. 2), the empathy program had statistically significantly greater worth in terms of perceived impact on career preparation than "residential life" ($p = 2e{-}10$), "other general education courses" ($p = 0.0006$), "elective courses" ($p = 0.02$), and "extracurricular activities" ($p = 0.0002$). Empathy had significantly less worth than "required courses in major" ($p = 0.003$). There was no significant difference in worth between the empathy program and internships and co-ops ($p = 0.34$). The empathy program was second most likely to be ranked most impactful by students (18%) behind only "required courses in major" (37%).

The Plackett–Luce model is considered to fit the ranking data very well with a residual deviance of 774.14 on 1065 degrees of freedom ($p = 1$ where low values indicate poor fit and high p values indicate good fit). Cohort and time point were both not significant covariates—i.e., students' rankings did not differ significantly for different cohorts and did not differ significantly depending on the point during the program (T1: post-DET I, T2: post-DET II, T3: one-year post-program) in which students assigned the rankings.

The qualitative interview responses shed light on the nature of the value of empathy on their professional development. A summary of codes and frequency of responses with each code is included in Fig. 3. Below we focus on the career benefits students believed empathy training provided and how the empathy training influenced their career paths.

Seven of ten interviewed students (Fig. 3) described empathy as a skill that could benefit them in their careers. Empathy allows them to develop relationships with clients and coworkers that will have engineering impact (idea generation, team dynamics in college projects, professional relationships). One student commented:

> Engineering is inherently political, engineering inherently needs to like, you know, you're building things for people. So, you cannot *not* take people's feelings into account. (Participant 9)

This sentiment manifested in students working through disagreements on their senior design teams, interacting with coworkers in internships, and connecting with clients. These comments came on different levels from pure emotional connection:

> I think it's more like a posture of the heart too of how you're viewing your client. (Participant 4)

to a general connection between understanding another and an engineered product:

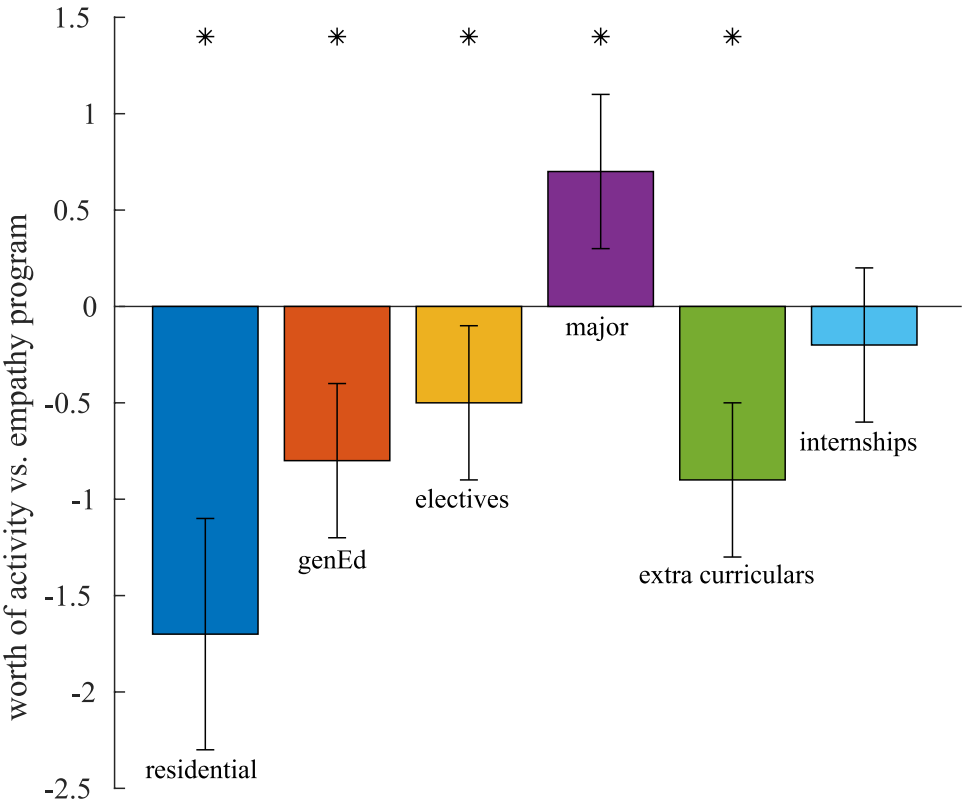

Fig. 2 Plackett–Luce model worth of various activities relative to the empathy program in terms of impact on a student's career preparation. Asterisks represent statistically significant differences. Error bars represent the standard error of the mean

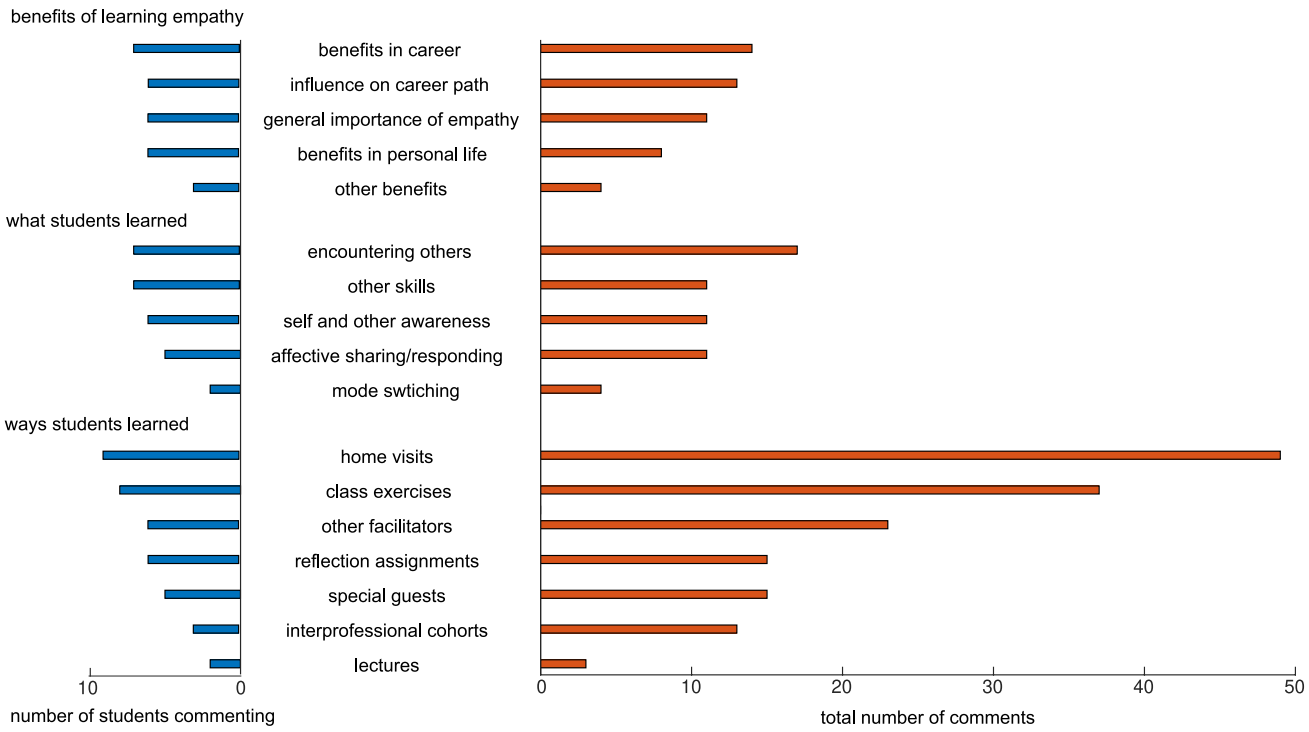

Fig. 3 Summary of qualitative results. The blue bars on the left represent the number of students out of ten interviewed students who responded with at least one comment that received the given code. The red bars on the left represent the total number of excerpts from student interviews and open-ended course survey responses that received the given code

> Empathy opens up the door to, you know, get to know them a little better, understand their needs. It's like if you're developing something and you're giving them a product that suits their needs, because you understand them. (Participant 7)

to a specific example of connecting with coworkers:

> I tried to make the most of it and talk to all the plant operators and get their one-on-one on what they're doing … And I remember thinking I was probably being my shy self. I probably wouldn't have gotten on my way to do that, if I didn't sort of learn to go to the source of information from the class. (Participant 6)

Six of ten students credited empathy training as influencing their career paths (Fig. 3). Two students said the empathy training made them more selective based on their values in choosing employers, even citing a case where a specific prospective employer was ruled out. Other students cited the empathy class as a springboard for pursuing new areas of their fields that related to working with people. For example,

> It made me discover that I wanted to assess other areas of application in terms of math and applied statistics to focus on social issues and studying issues pertaining to minority groups. (Participant 2)

> I took the course in the spring, and then in the fall for the second round, and then in between there for the summer, actually co-oped at [employer]. And it was a quality job. So I was behind the desk. And I really didn't like it. So everything I thought I wanted I didn't really like. And so I think having the class actually sort of sandwiched in between it solidified the fact that I knew I wanted to work with people. And I want to do some more hands-on chemical engineering. Unfortunately, it was probably not the best decision I made, but I went through with it. And then I came across biomedical engineering with other opportunities throughout my undergrad that I think the course definitely solidified. (Participant 6)

Six of ten students (Fig. 3) discussed the general importance of empathy in professional settings with four of those students citing a lack of empathy in the engineering profession. Six of ten students (Fig. 3) mentioned various benefits in their personal lives including the program offering a way for socialization during the COVID-19 pandemic and being able to support friends in difficult times like the death of a loved one and being able to manage conflict. Other benefits included having more courage to help people in public, getting to know people with disabilities, and having camaraderie within the cohort.

Objective 2: Provide Quantitative Evidence of Changes in Empathy Due to Empathy Training Over Multiple Years Rather than Over a Brief Period of Training

Students in the empathy program showed a significant increase (109 to 116, 9/10 students increased, $p = 0.01$) in the modified Jefferson Scale of Empathy scores over the entire duration of the empathy program. This shows a quantitative increase in empathy for program students measured from the first day of the first empathy course to at least one year after completing the second course in the program. The range of possible scores on the Jefferson Scale is 20–140. In multiple studies around the world the mean Jefferson score was typically around 112 with a standard deviation of 12 [31]. Given this distribution, moving from a score of 109 to 116 is like moving from the 40th percentile on the Jefferson Scale to the 63rd percentile.

Differences in Jefferson scores between program time points other than the pre-program/ post-program comparison were not significant, although the largest difference in mean scores (111 to 114, 12/18 students increased, $p = 0.16$) was observed over the period of the initial empathy program course. This suggests that the overall gains in empathy occurred for different students at different times during the program rather than all students benefiting most from a particular part of the program.

Jefferson scores for students in the control group did not see a significant change over the time during which their peers participated in the empathy program ($p = 0.78$). There was not a significant difference in Jefferson scores between the control group and intervention group at the time of enrollment in the study ($p = 0.45$). Therefore, despite no initial significant difference between the peer control group and the empathy program students, the intervention group students' Jefferson scores increased while the control students' scores did not increase.

There was not a significant difference in the Interpersonal Reactivity Index or any of its subscales between the control group and intervention group at the time of enrollment in the study ($p = 0.45$). Students in the empathy program did not show a significant change in the total Interpersonal Reactivity Index or any of its subscales over any period of the program. The same is true for the control group.

At the end of DET I and one year after completing the empathy courses, students in the empathy program overwhelmingly self-reported improvements in each of the four empathy skills explicitly taught in the program (Table 2). A majority of students reported being "much better" at the skills of "encountering others with genuineness," "self and other awareness," and "affective sharing and responding" with all students reporting being at least "a little better" at these skills. For the "mode switching" skill 3 of 29 students reported "no change" with the remaining responses split evenly (13 each) between "a little better" and "much better." Fitting the Likert Scale data to an ordered logistic regression model did not result in significant effects of the time the survey was taken or the student's cohort.

Objective 3: Better Understand What Students Learn and How they Learn it in Empathy Training Environments

At the end of Disability, Empathy, and Technology II (T2) and one-year post-program (T3) students ranked the program elements in terms of the elements' impact on students' learning of the four empathy skills. According to mean ranking, students rated the home visits highest in learning the skill "encountering others with genuineness" followed by class exercises. For the remaining three empathy skills, students ranked class exercises first followed by home visits. Interactions with classmates and in-class panel discussions of people with lived disability experience and professionals working with people with disabilities typically were third and fourth highest ranked. In-class lectures had either the fourth or fifth highest mean ranking across the four empathy skills. Reflection exercises received the lowest ranking for each of the four empathy skills indicating that students found the reflections the least impactful program element on their learning.

We fit a Plackett–Luce model to the survey data (Fig. 4). The Plackett–Luce model assigns a "worth" to each program element relative to the mean worth across all elements for each of the four empathy skills. The only program element

Table 2 Students' self-reported change in each empathy skill

Skill change ($n = 29$)	Much worse (%)	A little worse(%)	No change(%)	A little better(%)	Much better(%)
Encountering others with genuineness	0	0	0	34	66
Self and other awareness	0	0	0	45	55
Affective sharing and responding	0	0	0	38	62
Mode switching	0	0	10	45	45

that had significantly greater than average worth for learning all four empathy skills were the class exercises where students practiced empathy skills with each other. The home visits and panel discussions had significantly greater than average worth in students learning to encounter others with genuineness but not for the three other empathy skills. The written homework reflection exercises had significantly less than average worth for students' learning of all four empathy skills. Lectures on the empathy skills had significantly less than average worth in students learning self and other awareness, affective sharing and responding, and mode switching.

Our Plackett–Luce model is considered to fit the ranking data very well ($p = 0.9998$ where low p values indicate poor fit and high p values indicate good fit). Cohort and time point were both not significant covariates—i.e., students' rankings did not differ significantly for different cohorts and did not differ significantly depending on the point during the program (T2: post-DET II, T3: one-year post-program) in which students assigned the rankings.

What They Learned

The themes that emerged closely matched a model of empathy [1] as a set of skills, an orientation, and a way of being.

Theme 1: Empathy Skills

In post-program interviews students mentioned learning many things related to the four core empathy skills. Students mentioned managing tone of voice, eye contact, and posture which were part of lessons on encountering others with genuineness. Students became more aware of themselves, more aware of others and their perspectives, and more aware how people perceive personal space differently. On several occasions, students mentioned skills related to expressing emotion and responding to other's emotions (affective sharing and responding). One example is understanding when sharing common experiences is helpful to affirm another's experience and when it is not. A second example is responding with body language to another's story:

> One of the things I didn't realize is that I usually have a very stoic expression. If I'm listening, even if I'm like, really, you know, listening and like taking in what you're saying. And then I feel like when I took that class I learned to kind of show this, some type of reaction, whether it's like nodding your head or making your face show excitement or whatever, things that I definitely picked up from the class. (Participant 2)

One student briefly mentioned mode switching as a skill but did not provide a specific example.

Students mentioned a number of other communication skills—speaking, active listening, storytelling, focusing on the other, and managing difficult conversations.

> DET II has made me feel more comfortable expressing empathy. I have a lot of difficulty with expressing empathy, especially verbally, and DET II put me in situations where I can practice getting better at those skills. (Participant 2—End of DET II)

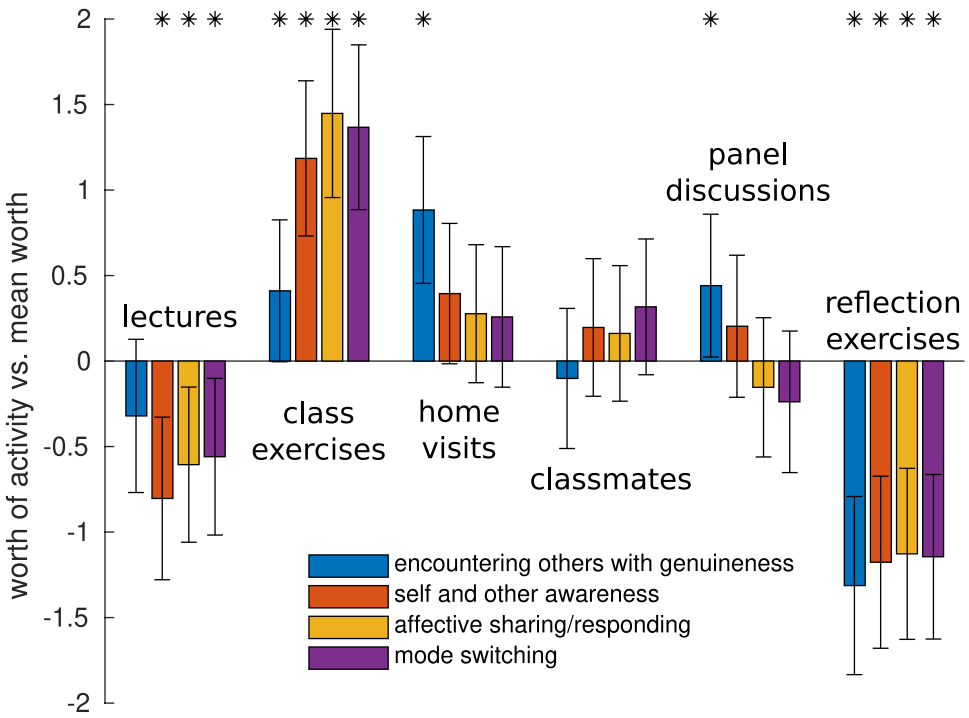

Fig. 4 Plackett–Luce model worth of elements of the empathy program relative to mean worth in terms of impact on students' learning of the four empathy skills. Asterisks indicate statistical difference from the mean worth.

One student mentioned an increase in her own confidence:

> Okay, much shyer when I came to college than I am now. Now, I'm way more involved, which is like a 180 from when I started my undergrad [when I] was much shyer … And taking that class, I think it was a nice push for me to sort of get out of my comfort zone and also just feel confident with talking to people and listening to people and communicating. (Participant 6)

Several students expressed an increased ability to interact with people who are different than them, especially those with disabilities. These interactions lead to forging relationships and deeper understanding of the challenges people face. For instance,

> I also had a lot of opportunities to interact with people with disabilities after that. And I think that having that class and like I said, eliminating the taboo about talking to people about their disabilities helped a lot. We also worked on a project for this guy who owns a bike park. And I think that I didn't even know him. And neither did any of the people that I was working on the project with originally. So we did a home visit, we went there, and we weren't sure what to expect. He showed us a bike that he wanted fixed. His humor is a little bit more intense. It's, you know, we're learning about his disability, but also learning how to navigate his humor. He said some things the first time we met that we were like, that was kind of crazy, but he's kind of cool … And then ended up being super cool. Like, at the end of the project, we had a dinner with him, and he was telling us about his experiences with the business and like his spinal cord injury, and all that kind of stuff. I think it allows you to get an idea even past like their disability, like I understand kind of how the medical field and insurance works for people with disabilities, and it's not great. And that stuff that I wouldn't have known if I didn't have these interactions with people with disabilities. So it's cool to see that. And now, even more than me wanting to help people with disabilities, I want to figure out a way to do it so that it also benefits them in terms of all of the tricky insurance things and how costly everything is. So yeah, it was great to have experiences with people with disabilities. And I think that the class helped a lot, making the interactions not super awkward. (Participant 5)

Theme 2: Orientation toward practicing empathy

Orientation refers to a person having skills and choosing to use them in everyday life. Students conveyed a sense that empathy is an action rather than merely a skill developed.

> Empathy is the ability to put yourself in another person's shoes and experience. And I think it does include having a humble view of your experience and values and being able to try on somebody else's for a moment. And like letting that perspective impact how you interact with them. So I do think it is tied to, there is an action attached to empathy. It's not just like, "Oh, I just feel this way towards this person," it does impact and ought to impact how you interact with them, and how you behave when you're with them. (Participant 4)

A majority of students mentioned the effect of the empathy class on their everyday life. Several students mentioned being able to genuinely connect with others, specifically people with disabilities:

> But then it was nice to kind of learn as I was interacting with people with disabilities that they want to talk about their disability. And it's not taboo to ask them questions. So that was nice. And then it makes it way easier to just become friends with whoever we're interacting with. (Participant5)

Another student displayed self and other awareness in recognizing that others aren't necessarily out to get you:

> That person was just a jerk to me, like body checked me. But so maybe you get mad about it. But also maybe you didn't realize there's a toddler with them and have nine groceries. It's like, oh, they're having a rough day … you know, it makes you more self-aware. Like maybe people aren't out to get you. They're having their own thing right now. (Participant 8)

Several students practiced affective sharing and responding in recognizing when friends or loved ones are struggling, for instance,

> And she had been through a lot of, I guess, I can say traumatizing such difficult events. And at the time, this class … allowed me to, in a sense, better understand and better communicate about those events and how they were affecting her. Um, just understanding how to communicate around them. (Participant 1)

Besides practicing the core empathy skills some students spoke of developing courage in entering relationships.

> I think it's given me a boldness to care for people out in public, even if they're complete strangers, like, I don't feel like, "oh, gosh, there's a person who is in a wheelchair" and I'm anxious, and I don't know how to interact with them. Like I feel much more comfortable. Letting them know, hey, if you need support, I'm willing to support you however you need. I'm not trying to assume that you need help, but I want to let them know that I am comfortable with that, like their existence.

> Does it make me uncomfortable? Um, yeah. But that's I think just a general perspective shift … And I can go into more depth, but bravery in the way of like, stepping out and taking a risk in pursuing a relationship with somebody who is different than me. And knowing that, most times, I can always apologize if I overstep or misstep. But not letting the fear of like, if I do misstep then I'm this kind of a person or whatever, but there needs to be some level of grace in order to take that step towards somebody who's different than you. And I think people with disabilities it just for some reason, feels like a steeper risk. (Participant 4)

Theme 3: Empathy as a Way of Being

Some students began to make connections between the empathy skills and who they are. One student eloquently connected exercises on body positioning with who she is in her professional role as a music therapist:

> It is a physical exercise, but I think it's more like it's a posture of the heart too of how you're viewing your client. Like, it's deeper than just how you are positioning your body and like in context to them. (Participant 4)

In the interviews, students gave a number of reasons for taking the class: taking an advisor's recommendation, being attracted to a general education course offered in engineering, or taking the class as a break from the grind of an engineering curriculum. Other students came to the class with specific interest in disability or a general interest in using engineering to help people.

One student used the empathy class as a step to find ways to fulfill what she really wanted to do, which, in her mind, was off the beaten path in engineering:

> Yeah, I think honestly, I think the disability empathy and tech class was like the beginning of the support. Because I didn't know how to find people in engineering that were doing things that I wanted to get involved in. Because I had great professors, but I'm not interested in fluid mechanics and stuff like that. But I think meeting [course instructor], and since he's engineering, but he was doing the disability empathy and tech class, I think that that was like the perfect meeting to start to get that support. (Participant 5)

Another student described a change in the kind of work she wanted to do:

> And I didn't necessarily see myself in a role working with people. Because that course at the time was very, like working-with-people oriented. I think that's sort of the point of the course, too. But I didn't really see myself in that role. I sort of saw myself just working at a desk maybe the rest of my life. (Participant 6)

How they learned

Theme 4: Importance of Building Community Among Classmates

Getting to know each other and feeling part of a community within the class allowed students to feel safe in venturing into more challenging elements of the course. The smallness of the class (10-15 students) and the heavy reliance on discussion and personal storytelling allowed students to be honest with each other, grow closer, and form friendships. This facilitated an environment where students could give honest feedback and criticism as the students learned the empathy skills together:

> I liked those exercises a lot. Because we were also very brutally honest. I think, because we knew each other too. So we actually gave each other feedback. It wasn't just like, "Oh, you did really good, but you were quiet." You know, we actually gave good feedback. (Participant 6)

The empathy training itself—learning to take on a listening posture rather than jumping to problem solving—led to building relationships within the class that facilitated facing challenging elements of the course together.

> My most positive experience was when we had to share stories with classmates of something that wasn't super good that happened to us. Even though the stories weren't about a positive experience, learning how to respond to a story like that and having people not offer unhelpful solutions was a good experience for me. I feel like this was one of the moments I got closer with my classmates. (Participant 12—End of DET I survey)

Part of that togetherness was facing the same challenging situations together,

> I think trying to make it slightly uncomfortable to the point that we're all in the discomfort together. And we understand that we're humans in this discomfort, like, that helped to make things more comfortable, you know, because I feel like if you're in a situation that's difficult with people, you're more likely to bond with them. So I think that's kind of how it worked. (Participant 5)

Students mentioned structural parts of the course that led to community building. These include the two-semester format providing a more leisurely pace and the chance to get to know classmates, the emergence of a student leader

who modeled empathic behavior, and the instructor regularly mixing groups of students so that all got to know each other.

Besides setting up the students for learning, students cited building connections with classmates as one of the important benefits of the course. 8 of 21 students mentioned sharing stories and getting closer to classmates as the most positive experience in DET I (second to home visits in frequency), 4 of 16 in DET II (second to home visits), and 2 of 16 a year after DET II.

Theme 5: Scaffolding to build students' confidence to face challenging environments in which to grow empathy

The quantitative data points to the class exercises and home visits as central to students' learning (Fig. 4). The class exercises and home visits were also most often mentioned in student interviews and class surveys (Fig. 3). Sharing personal stories with classmates, meeting people with disabilities in the classroom, and, eventually, being invited into the homes of people with disabilities presented students with challenges. Given the foundation of a strong class community mentioned above, students could slowly build their confidence to face increasingly challenging environments and reap the benefits in their empathy growth.

The visits to the homes of people with disabilities and the informal class visits from people with disabilities were central to many students' experiences. This manifested in the end of class survey responses to the questions: "What was your most positive experience?" and "What was your most negative experience?" After DET I, 11 of 21 students answered "home visits" as the most positive experience, the most frequent response. After DET II, 7 of 16 students answered, "home visits" (4) or "panel discussions with people with disabilities" (3) as their most positive experience. One year after finishing DET II, 10 of 16 students listed "home visits" (6), "class dinners with people with disabilities" (3), or "resiliency of disability partners" (1) as the most positive experience. Some mentioned negatives of the home visits and visits from people with disabilities including being nervous about home visits, feeling uncomfortable during the visits, mentioning specific comments made by disability partners or family members that students were offended by, or a student's regret in not following up with a disability partner after the course ended. The personal encounters with people outside of class came with some risk, but in many cases offered significant rewards in students' learning.

The home visits provided many students a sense of purpose and a chance to turn theory into practice:

> And we would just talk and we're like, friends now. So that's the cool thing, I think that came out of home visits. And we got to have a purpose in our senior design project, which senior design isn't always the best experience. And it wasn't easy, but I think that having the purpose and knowing this is my person that I'm making this for, and she likes to do this, and she likes this. And we're similar in all these ways. And I wanted to help, you know, make something easier in her life, because she's my friend. So I think that was really cool about the home visits, like putting into practice everything that we learned, but then also coming out of it with friends and opportunities to help where we can. (Participant 5)

The home visits also uncovered the nuance and complexity of the problems people face that go well beyond the technical problems typically solved by engineers. Students were faced with the reality that designing or building something is not always the hard part.

> It was interesting to see like, where people live. And you know, I remember seeing this one person and she had a flight of stairs to go upstairs, but she couldn't. So she just basically lived downstairs. And they just had a bed set up down there. And it was just interesting to see that not everybody can afford to buy an accessible home. Yeah, even have accessible things put in. And I didn't, I was just like, Okay, well, aren't there resources for these people? And there are, but not everybody qualifies for all of the resources, or has the help that they need or even the knowledge to find those resources. And I know at the time, I didn't have the knowledge to find all those resources. There's so many, but which ones are applicable to who? And it was just, yeah, eye opening. (Participant 3)

Students identified home visits as highly valuable to their learning. However, extracting this learning required students to work through anxiety.

> But the first time we did it during my freshman year, I was definitely terrified, just because I really was like, I'm not ready to do what you're telling me to do, or what we're expected to do. I just didn't really feel ready. And then I of course, like most things, you're more ready than you think. But I definitely was nervous again, because I was also just very shy at that point. So I was sort of freaking out. But it was nice to have it with a group. It was like there were three of us in a group three, including me. And it was definitely nice to have the two other people there with me doing it. So it was nice to have their support team. (Participant 6)

> I definitely felt nervous. I think the person that we met with was in a nursing home, but we were still in their space. Like, it wasn't a public area that we were meeting them. They were sitting in bed. Um, so yeah, I

> felt nervous. I felt I was excited, because I just enjoy people and working with people. And that's like, why I chose this profession. Um, and I remember being a little bit nervous too, because I was with [course instructor], and then our contact person who was at the site, and then also, I think, a couple other my classmates. So it just felt like a lot of people. We're all here for this one person who's laying in their bed and living their life. And being a little bit nervous of like, what if somebody else says something stupid? And then I'm lumped in with this whole group, you know, but nobody did. It was totally fine. Like, it was actually very enjoyable. But yeah, definitely had the nerves beforehand. I felt like a child, but I had the knowledge, it's just a matter of like putting it into practice. (Participant 4)

The class exercises also caused students discomfort. Working through discomfort in the more familiar classroom environment allowed students to more confidently face the challenge of meeting people with disabilities in their homes. In many cases, students who expressed their discomfort ended up enjoying and benefiting from those exercises. This was evident in students' comments:

> Sometimes some of the exercises we did were a little uncomfortable but that's also a reason why we did those exercises to confront the uncomfortable feeling and work on it. (Participant 11—End of DET II)
> [Most positive experience] Being able to share some of the stuff I wanted to say to others, as well as better understanding affective listening … [Most negative experience] kind of the same thing as the most positive I guess. I felt really uncomfortable during roleplay exercises. (Participant 13—End of DET II)

The negative feelings about being uncomfortable in the class exercises were a theme in the end of course survey responses as 5 of 18 students after DET I and 4 of 12 students after DET II mentioned this. However, one year after the end of DET II no students mentioned the class exercise as a negative experience.

The informal in-class dinners with visitors with disabilities provided a comfortable environment where students could connect and feel vulnerable with the guests helping them to prepare for the home visits later in the course. Many students mentioned the benefits of these dinners including the relaxing setting and the chance to find common bonds and begin to develop friendships.

> We actually had a few individuals come into our class from different backgrounds. So one was working with people with disabilities, one person had a disability, and one was a family member of someone who had a disability. And that was awesome. That was like, we had dinner with them. [Course instructor] provided dinner. So we all got to sit around, have dinner with them, and talk to them and get to know them and their roles and their caregiving life and just how they do different things. And I thought that was probably one of the best classes we had, if not the best one. Because it was really, like, personal and vulnerable for them. And for us, to be honest, because we also learned different things about one another that we hadn't really shared before. (Participant 6)

Other Themes

Students stressed the importance of using multiple learning methods: some saw the repetition of certain exercises as tiresome and that facilitating discussions in the same way each time was not helpful; two end of DET I survey responses mentioned lack of variety in ways to practice empathy as a negative experience; another student mentioned that the variety of environments—going into the community, having people come to us, exercises and role plays, and having discussions—prevented burnout.

The conversational style of the class was a welcome respite from students' engineering curricula. Students stressed that hearing individual stories was more effective than learning from textbooks and lectures.

> I still remember specifically, a lot of the people that I met, and just their stories, and I don't think that that's really replaceable, like meeting one specific person. So that was something that was really cool to me versus it just being more of an informational slideshow, like lecture type thing, which is what all my other classes were. (Participant 9)

The weekly reflection writing exercises were instrumental in some students' learning and a major negative for other students. For some, the assignments were a chance to dig deeper into the exercises from class and important for improving their skills. One student commented on risk-free vulnerability.

> Sometimes it's hard to be forward about how the experience was because it's vulnerable. So that might be part of it. And I, over my college career, I've increasingly liked vulnerability more. So I think that was a good opportunity to be vulnerable without having to be vulnerable with someone's face. So that probably played into why I enjoyed them. (Participant 5)

Other students saw the reflections as repetitive, lacking impact because they chose to do all the reflections at the end of the semester, or were more helpful in developing writing skills rather than empathy skills. In end of course surveys, 3 of 12 students in DET II and 2 of 11 students a

year after DET II mentioned the reflections as their most negative experience.

Just as with the reflection exercises, students had mixed feelings toward the video recorded interactions with classmates that were used for feedback on students' ability to affectively share and respond. One student saw it as helpful in really understanding how they were sharing and responding in order to improve. Another student describes a key barrier to this being effective—students not being able to act naturally because they are being recorded, something akin to the Heisenberg uncertainty principle:

> I vividly remember how terrified I was … I don't like being recorded and having to watch it back for sure. Because that was the whole point of the exercise, to watch yourself back and then get feedback. And like I said, I was very shy, especially in that first year. And I couldn't not smile, or you can tell I was sort of like stage fright mode, where I was constantly and like just, I looked one way so all those empathy skills of facial expression and tone, everything was gone. Like thrown out the window the moment the camera was there, which of course there is not a camera there when you're actively doing a job, but it was different. And you sort of realize that even though you might know it by the book, you have to put into action. (Participant 6)

Other negative experiences students mentioned had largely to do with practical circumstances. These include Covid-19 restrictions, classmates not following through on project responsibilities, lack of clarity in course instructions. class being in the evening because of the difficulty in scheduling a class for students from different majors, and the optional capstone project not working in students' course progression.

Discussion

We set out to understand the role of learning empathy in engineering students' career development, how empathy training affects students actual learning of empathy skills relative to a control group without empathy training, and what elements of an empathy training program have the most impact on students' learning of specific empathy skills.

Overview of Findings

Students saw empathy training as more important in their career development—second to required courses in a student's major—than several other typical parts of the college experience. To our knowledge no other studies have examined the relative importance of empathy training to other curricular, co-curricular, and extracurricular activities. Studies have investigated the importance of various activities [32–34] but never specifically for empathy and not in relation to a gamut of college experiences.

The rather comprehensive training program described here resulted in, at best modest in the case of the Jefferson Scale, and at worst non-existent, changes in validated quantitative measures of empathy. However, students self-reported gains in the four empathy skills explicitly taught in the class. Other studies have shown mixed results with some showing no change or even a negative change in the Interpersonal Reactivity Index [16] and some showing modest improvements [17] as highlighted in the introduction. Why do we not see more progress on the quantitative scales, especially the Interpersonal Reactivity Index? It may be that the IRI does not measure what is taught in class and the Jefferson Scale or some other measure is a more accurate measure of what is being taught. To our knowledge, our study is the first to adapt the Jefferson Scale, which was designed for the medical professions, to a group of engineering students. Another potential explanation could be that interventions like empathy training are effective for some students but not for others. Is there an aptitude for empathy learning, an "empathy potential" of sorts, that some students possess more than others? In our own study it was clear that some students made great progress on the quantitative scales and could explain what happened for them in the interviews, some students did not make quantitative progress, and their interview responses were fairly superficial, and some students had high empathy scores from the start. Finally, it could be that this instructor and others who have tried are not terribly good at teaching empathy. For instance, the instructor in this study does not have any specialized training in teaching empathy.

Our mixed-methods approach was designed to capture the nuance that might not be evident in the quantitative results. Given that this empathy program is new, the qualitative data we gathered is critical for educators at other institutions to understand what happened with this group of students and be able to adapt the program given their particular situations. We highlight these nuances below.

Variations of the empathy training exercises developed at the University of Georgia were central to students' learning but critically supplemented by experiences with stakeholders outside of the classroom. Experiences such as the home visits to people with disabilities and visits to the classroom from people with disabilities and service providers provided students with a sense of purpose in the class and an understanding of the complexity of challenges facing people with disabilities. Many students reported anxiety in these potential high learning settings. Over the years we have learned ways to reduce that anxiety and to help students work through it. This included identifying a group of trusted hosts that especially enjoy working with the students and having multiple home visits with the same host to build familiarity.

To give the students a taste of the depth of the home visits we made the in-class visits from people with disabilities more casual and intimate by providing a meal to share. We also provided students with more structure for the home visits including clear objectives for the students for each visit. Empathy has been taught primarily in community-based learning settings [17, 19, 20], design-based courses [2, 16, 18, 21], and ethics courses [23]. Our findings highlight the importance of both explicitly teaching empathy skills and practicing them in relevant real-world settings.

The study highlighted that creating a community in which students can face difficult and uncomfortable scenarios in the real world enhances students' ability to grow in empathy. The classroom exercises, which the students rated as having the most impact on their learning, were instrumental to community building. The class exercises often included students telling each other personal stories which allowed them to get to know each other. Practicing empathy by listening to these personal stories facilitated trust and connection between students that was consistently reinforced as students spent multiple semesters together as a cohort. These results reinforce the recent interest in forming cohorts and communities of practice in engineering [35, 36] and higher education in general [37].

Limitations

This study has a number of limitations. First is the number of participants, especially in the control group. Depending on the instrument (surveys, IRI, Jefferson, interviews) there were typically between 10 and 20 respondents compared to larger studies with at least 100 participants [16, 17]. The intervention group included 16 of 18 students who completed both courses, so it is a nearly complete sample of the population who took the courses, and we are confident in reporting results as they apply to this program. The control group was a rather small sample of the entire population of engineering students at the institution. In all cases of the control group we failed to reject the null hypothesis that empathy scores do not change over time. It is possible that they really do change over time and that we might observe that change with a larger sample. However, that is rather unlikely given the p values (0.78 for Jefferson and 0.45 for IRI) were not close to the significance level. Although our study represents a rare occurrence of collecting data at multiple time points from a control group that did not receive empathy training, collecting that data was rather difficult as shown in the number of control group participants decreasing over time as the study progressed (Fig. 1). Despite thoroughly sampling the population of students in the empathy program, it is unclear what would happen in different populations of students taking the same courses at a different institution with a different instructor. A prime example are the quantitative results showing the relative importance of various college experiences. The institution where the study was conducted has a high commuter population. It is possible that residence life and extracurricular activities might be of more importance at schools where students typically live on campus. It should be noted, however, that empathy had roughly equal worth as internship and co-op experiences, which are prevalent at the institution where the study was conducted.

Implications for Educators

This study and others have shown to various extent that empathy is valuable and teachable. It remains rather unclear how empathy training ought to be woven into an already packed engineering curriculum. If empathy is valuable, how do we get to the ultimate goal of having students practice empathy as a way of being [1]including recognizing the dignity and worth of persons and the natural environment, holistic service to society, and seeing oneself as a whole professional? Is teaching empathy explicitly as we and others have done really just a bandage on a lingering wound in the heart of engineering? In our interviews some students stated that they took the class because it was an engineering course that counted for a general education credit. They were simply not interested in a broader perspective and needed to be drawn in via an engineering course. Could the real solution be turning away from engineering education as technical training and the attitudes toward "non-useful" study of non-technical subjects that come with it, and instead turning toward better integrating engineering into a more holistic education in the liberal arts as some have suggested [38–40]. We may have destroyed the liberal arts for engineering students—if we hadn't, would we really need an empathy class?

Perhaps a pragmatic approach is to weave empathy into existing courses. Based on the results of this study a pragmatic approach might include the following: (1) ongoing community building within cohorts of engineering students: there should be spaces in regular courses for students to actually discuss their feelings with each other and to better understand lived experiences. This might happen as groups of students from different disciplines navigate a series of common design courses together throughout their curricula. (2) Explicit instruction in empathy skills akin to those developed by Walther and colleagues [2]: these can be taught and practiced in 30 minutes in most cases, which makes them easy to implement within project-based courses that do not have structured content to compete with. (3) Practicing empathy with real stakes; someone—a classmate, a client, a community member—needs to depend on the students to deliver. In our case, this was having to come through for a person with a disability, but other examples might include creating something that is on display at the university or

something that must be used by other students or by an industry partner.

Including People with Disabilities in Empathy Training

It is important to comment on the inclusion of people with disabilities and members of other marginalized groups. Their participation is vital to programs like the empathy program described here. For this to happen organically, the numbers of disabled people in faculty and student roles in engineering need to match those of the general population. Currently they do not, although several students with disabilities were students in our program. Although we have made strides in building a model for physically disabled students participating in engineering research [41], by necessity we still need to ask people from outside the university community to share their experiences. It is an ongoing challenge to find ways to ensure that this partnership is equally beneficial to our disability partners and to the university community. We cannot indefinitely ask people to donate their time and expertise. In some ways the program fell short. At times the program overpromised benefits to a home visit host. One group of students intended to build a ramp for a host, but that ended up requiring significant structural repairs to the home, and the host was very disappointed that the ramp was never built. In many ways the empathy program strengthened relationships and motivated change in our research community. Many students and disability partners formed relationships beyond the empathy program. Our home visit hosts have given paid lectures in other classes and served as paid consultants on research projects. For guidance on partnering with the disability community we recommend the Integrated Knowledge Translation Guiding Principles for Partnership [42] or Participatory Action Research [43].

Conclusions

We presented a mixed-methods study of students in a multi-year empathy training program that included a control group. This study highlights the importance of empathy skills in engineering student's development, shows quantitative evidence of gains in empathy with specific training, and uncovers key factors in students' learning experience. Students saw empathy as vital in both their professional success and in helping to determine their career paths. Our study highlights the importance of a holistic approach to learning empathy that includes building a community of trust among students, giving explicit instruction in specific empathy skills, and giving students opportunities to practice empathy in scenarios where there are real stakeholders. There is still much work to do in the community to optimize learning of empathy within engineering curricula.

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Data Availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code Availability Custom computer code used to analyze the data collected in the current study is available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare that they have no competing interests.

Consent to Participate Students gave written consent to participate in the study under protocol IRB-FY2019-48 approved by the Cleveland State University Institutional Review Board.

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