Development of Empathy in a Rehabilitation Engineering Course

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Students’ Development of Empathy in a Rehabilitation Engineering Course

Abstract

Having empathy is an important skill that allows engineers to design for users with a variety of different wants, needs, and perspectives. The purpose of this study was to examine changes in engineering students’ development of interpersonal empathy as they progressed through a 10-week Rehabilitation Engineering course. Empathy is composed of five affective and cognitive constructs: affective response (AR), affective mentalizing (AR), self-other awareness (SOA), emotion regulation (ER), and perspective-taking (PT). These five constructs must co-occur to bring about the full expression of empathy. During the course, 24 students worked with clients from the local community to design a solution to meet their rehabilitation needs. In addition to the projects, student assignments included reflection prompts, four hours of community service, and several empathy “immersion” experiences (i.e., wearing a blindfold while trying to complete basic tasks). Seven students opted to participate in the study, all in their 4th or 5th year in either biomedical or mechanical engineering. Students completed pre- and post-course surveys aimed to measure changes in self-reported levels of empathy. One student participated in a personal interview, aimed at understanding the different ways in which the course activities influenced his development of empathy. All seven students who participated in the study reported an increase in empathy. Students’ perspective-taking and self-other awareness had the highest pre- to post-course increase. Despite the limitations of a small sample size, there is some indication that participating in a rehabilitation engineering course positively influences students’ development of empathy.

Background

The context for this study is a project-based rehabilitation engineering course, focused on the design and analysis of systems to assist people with disabilities. A main component of the course was a term-long project where students worked in teams to design or re-design a device to help a person with a disability perform an activity of daily life, a workplace function, or a recreational activity. Both the lecture topics and the project contexts were intentionally designed by the course instructors with the goal of promoting students’ development of empathy.

Prior Research

Employing empathy in engineering contexts has recently been explored as an opportunity for innovation. Couvreur and Goossens [1] argue that industrialized rehabilitation design solutions don’t approach the design with enough time to properly consider if a user need is satisfied, and also that there exists an economic incentive for companies to create a universal, rather than specific, solution for patients. In contrast, there is power in developing community-based rehabilitation solutions for people with disabilities; local solutions that reflect physical, emotional, and cognitive needs of a patient are often more effective. Local solutions involve horizontal innovation networks to create assistive technology that is modifiable by healthcare professionals and patients, not just the engineers that created the device. However, the ability to communicate between engineers, healthcare professionals, and patients requires empathy.

A number of other researchers have investigated the importance of developing empathy in their engineering courses. Mitchell and Light (2018) have incorporated initial challenger interviews, subject matter expert speakers or videos, stakeholder engagement plans, and reflection exercises to help students develop empathy in "EPICS," a first-year design course at Colorado School of Mines [2]. In another first-year program at the University of New Mexico students were asked to research the 2015 Gold King Mine spill and to reflect upon the roles and needs of community members, farmers, and government employees [3]. At another large state university, four different modules to promote empathy in a second-year mechanical engineering design sequence were developed [4]. In another second-year course at Lawrence Technological University in Detroit, Bell-Huff and Morano [5] report on a study that is perhaps most closely related to the work presented here. They had students work with a non-profit organization that helps people with disabilities in the workplace. Students did an accessibility simulation to promote empathetic design, and interacted with the customer five different times throughout the semester. Other authors have looked at developing empathy during capstone design [6] as well as an in ethics courses [7]. This work builds upon prior research by trying to understand which constructs of empathy are most impacted by a rehabilitation engineering course, as well as which course activities seemed to have the highest impact on students' development of empathy.

Defining Empathy

Empathy is the ability to be affected by and share the emotional state of another, to assess the reasons for the other's state and to identify with the other, adopting his or her perspective [8]. In human-centered engineering design processes, empathy is a critical skill for effective decision-making and successful product development [9]–[11]. Empathy helps individuals, including engineers, take on the perspectives of others, better understand their experiences, and respond to challenges in productive and compassionate ways that fully consider and reflect stakeholder needs. Hence, enhancing empathy has great societal relevance and is a critical skill, practice orientation, and professional way of being for engineers [10].

There are several affective and cognitive constructs that together make up the phenomenon of empathy [8]: affective response (AR), affective mentalizing (AM), self-other awareness (SOA), perspective-taking (PT), and emotion regulation (ER):

> **Affective response**: This can be described as our immediate reaction to an input. For example, seeing, hearing, or even thinking about another person in distress might trigger a strong affective response, often an unpleasant one.
>
> **Affective mentalizing:** Once an affective response is triggered, we begin to appraise the emotional state of the other person (i.e., through non-verbal cues) and try to make sense of what is happening.
>
> **Self-other awareness:** This can be described as our ability to identify with another person while still maintaining our sense of self. In other words, this is the capacity to distinguish ourselves as separate from others.
>
> **Perspective-taking**: Once we have appraised the emotional state of another but also determined that we are *not* the other, we can then engage in perspective-taking. This is

the ability to imagine what it might be like to experience the other's situation. We may also be starting to think of actions to take to help another person.

Emotion regulation: This is the ability to react to another's situation and to process his or her feelings without becoming overwhelmed or enmeshed in those feelings. Increased emotion regulation leads to the ability to respond to other people in empathic ways. For empathy to occur, we need to be able to distinguish our own feelings from other people's feelings so that we don't become emotionally overwhelmed.

Teaching Empathy

The five constructs of empathy need to co-occur for the full scope of empathy to manifest. One of the preliminary hypotheses of this study was that students would enter the rehabilitation engineering course with different levels of these empathy constructs. This hypothesis was based on prior research that reinforces that people have "variably developed empathic capacities" [10]. For example, an incoming student might have strong affective mentalizing abilities but weak perspective-taking abilities. Over the ten weeks of the course, however, perhaps the student's perspective-taking capacity would increase with opportunities to practice this skill through the various course activities that required students to "walk a mile in someone else's shoes."

Although students have different empathic capacities and experiences, "empathic skills are concretely teachable" [10]. Outside of engineering, disciplines such as social work explicitly teach empathy and utilize it on a regular basis to make their students successful in this field, again showing evidence of the ability for educators to design learning environments to help students develop empathy and apply it to their chosen careers [12]. As stated by Walther, Miller, and Kellam [13], three challenges of designing learning environments to teach a trans-disciplinary content such as empathy are: "(i) the danger of disciplinary separation of content, (ii) the challenges of students' gradual transition to accepting a concept such as empathy as relevant to engineering, and (iii) the role of epistemological differences for both students and instructors." Further research needs to be performed to understand how different learning activities and environments affect students' ideas about empathy. Therefore, this study aimed to identify the constructs of empathy that were most salient in students before and after the rehabilitation engineering course.

Study Context

The rehabilitation engineering course was piloted in Spring 2017. Preliminary research showed that students developed aspects of design empathy, as well as recognition of the importance of accessibility and universal design [14]. The course was offered again in Fall 2019 and enrolled 24 fourth- and fifth- year biomedical engineering and mechanical engineering students. The course was co-taught by Dr. Lauren Cooper and Dr. Brian Self, mechanical engineering faculty at California Polytechnic State University. Both Dr. Cooper and Dr. Self have experience with project-based learning, rehabilitation engineering, and disability studies.

The research subjects for this study were a portion of the students who were enrolled in the Fall 2019 course. The course met for ten weeks and consisted of three hours of lecture and three hours of lab per week. The combined lecture and lab learning objectives (LOs) were:

- LO1: Describe how different disabilities affect activities of everyday life.
- LO2: Explain how the ADA and standards in assistive technology have improved the lives of those with disabilities.
- LO3: Compare and contrast the principles of universal design with those of the traditional design process.
- LO4: Design or re-design a device to help a person with a disability perform an activity of daily life, a workplace function, or a recreational activity.
- LO5: Analyze adapted designs for functionality, adaptability, and function.

Specific lecture topics included empathic design, disability etiquette, the ecological model of disability, adaptive physical activity, universal design, mobility impairment, the American Disability Act (ADA), vision and hearing assistive technologies, developmental disorders, seating and wheelchairs, prostheses and orthotics, and physical and occupational therapy. Guest speakers included a Certified Prosthetist/Orthotist, a universal design for learning specialist, and a fellow engineering student severely injured in a hiking accident who now uses a wheelchair due to paraplegia. As a class, students visited a local physical and occupational therapist office that serves clients ranging from newborn to young adult. Students participated in an ADA walk-through of several buildings and places on campus to learn to identify infrastructure that is (or is not) ADA compliant. Students also visited the campus Recreational Center that hosts "Friday Club," a program that offers a variety of adapted physical activities (basketball, golf, dart throw, etc.) to members of the community who have a disability. The adapted devices were all designed by previous kinesiology and mechanical engineering students and faculty over the past two decades.

Additionally, student assignments included a variety of reflection prompts, four hours of community service (two of which had to involve direct contact with people with disabilities), and an enrichment activity in which students attended a public talk, event, or watched a movie related to disability and rehabilitation engineering. The course also featured three different empathy-building experiences. One empathy-building experience involved students wearing blindfolds while trying to complete basic mobility, meal preparation, and money exchange tasks. In another experience, each student tried to navigate around campus using a knee-scooter to try to simulate what it would be like to lose the function of one leg. In the last exercise, students met in teams to make dinner and watch the film *Rolling*, a free documentary created in partnership with four wheelchair users in Los Angeles. The challenge of this experience was that students had to spend the entire evening, including dinner preparation, with one arm tied to their torso to try to simulate the loss of their dominant arm. Of course, it was recognized and discussed among the instructors and students that these three empathy-building experiences could not truly emulate what it is like without vision or without one or more functioning arms or legs. However, the experiences did serve to make the lecture topics feel more real to the students while also encouraging peer-to-peer and instructor-to-peer bonding.

Perhaps the most significant element of the course was the projects that the students completed, each of which involved the design or re-design of a device to help a person with a disability perform an activity of daily life, a workplace function, or a recreational activity. Projects were supplied by local non-profit community partners, including Special Olympics of Southern California, California Children's Service (a state program for children up to 21 years with certain diseases or health problems), Achievement House (a non-profit agency providing vocational training and community living services and programs for adults with intellectual and physical disabilities), and one student's grandfather.

Students were matched with projects in the third week of class, giving them seven weeks to engage with their client and design, build, and test their rehabilitative device. The amount of student-client interaction varied greatly, mostly due to the clients' interest and availability. On one end of the spectrum, one team had a very involved client who was in frequent communication with them, took the team out to dinner, invited the team to his house to view the existing rehabilitation device that the team worked to repair. It should be noted that this client is the father to the boy for whom the team was designing. This team, "Team Joseph," is featured below in Figure 3.

On the other end of the spectrum, one of the teams, "Go Baby Go," experienced frustration and disappointment by the lack of communication from their client. Their client was the physical therapist to a young girl named Maria, whose family didn't speak English. Due to her work schedule and some family issues that arose, the client wasn't able to connect the team directly with the client until near the end of the project. As it turned out, Maria was extremely afraid of strangers, so the team wasn't able to spend time with her and develop a relationship with her family. Although the team did finish the project, they expressed feeling less satisfied with the project outcome. Between these two extreme cases, most students met with their clients 3-4 times throughout the course, or about every other week during the ten week quarter. With the exception of Go Baby Go's client, all clients (and in some cases their families) came to the Design Expo at the end of the quarter, where the students presented their rehabilitation devices and gave them to their clients.

The course modules that were intentionally designed to help students engage with their clients included empathic design, disability etiquette, and the ecological model of disability. The learning objectives of each module is described below, and authors of this paper will gladly share specific module curriculum upon request.

Empathic Design

- Discuss empathy and how it relates to engineering design.
- Compare and contrast emotional and cognitive empathy.
- Describe the consequences of only using an analytical state of mind when facing today's complex design problems.

Disability Etiquette

- Provide examples of using first person disability language.
- Explain to a general audience why we don't use terms such as handicap, cripple, or "constrained" to a wheelchair.
- Discuss why certain behaviors or descriptions are appropriate (or inappropriate) – i.e., assuming someone who is deaf can read lips.
- Define quadriplegia, tetraplegia, paraplegia, hemiplegia, prosthesis, orthosis, and assistive device.

Ecological Model of Disability

- Define the ecological model of disability.
- Describe the concept of least restrictive environment.
- Identify the five social barriers to inclusion.

Each of the seven rehabilitation design projects is described below.

Team Name: Dupuytren's Device
Problem Statement: The goal of the design was to aid users affected by Dupuytren's Contracture, a condition in which knots of tissue form under the skin, creating a thick cord that can pull one or more fingers into a bent position. Since the users' muscles are still strong enough to contract, the device was designed to keep the hand open so the user will have more control over their hands. The final device was in the form of a brace designed to keep the fingertips/palms uncovered and is as discreet as possible (see Figure 1).

Team Name: Go Baby Go
Problem Statement: This project was designed for a two-year old with severe Spinal Muscular Atrophy to provide her with more agency and social interaction and was modeled after a program developed at the University of Delaware [15]. The ability to move independently is linked to numerous developmental benefits, and modified electric cards are a less-expensive alternative to electric wheelchairs (see Figure 2).

Figure 1: Dupuytren's Device

Figure 2. Go Baby Go

Team Name: Team Joseph
Problem Statement: The client has a specific subset of cerebral palsy known as spastic quadriplegia that completely renders him from controlling any of his muscles. In the past, the client has been able to participate in triathlons with the help of others. However, his existing water flotation device had many issues. The project goal was to make modifications to his device to enable him to safely and comfortably compete in swimming competitions again (see Figure 3).

Team Name: Adaptive Potting Station
Problem Statement: Achievement House needed an improved potting station designed to be inclusive to all of their individuals, some of whom have mobility impairments. This project designed a station with improved layout, including seating and standing workspaces along with appropriate tool storage (see Figure 4).

Figure 3: Team Joseph

Figure 4. Adaptive Potting Station

Team Name: Porta-Steps
Problem Statement: The client for this project was a local high school student who needed a device to help her independently get in and out of her wheelchair and bed when she travels with her family. The device also needed to be lightweight, portable, easy to assemble, and aesthetically-pleasing to the client (see Figure 5).

Team Name: Friday Club Equipment Repair
Problem Statement: The project goal was to restore the basketball launcher used by Friday Club to working condition by replacing the worn-out and broken pieces, as well as to redesign the pull lever to be a more ergonomic push lever (see Figure 6).

Figure 5: Porta-Steps

Figure 6. SOSC Basketball Launcher

Team Name: Dressing Aid

Problem Statement: The client was a 10-year old boy with Spina Bifida who has trouble getting dressed independently. He can put on shirts by himself but has a hard time reaching all the way down to his feet to put his pants and shoes on. He needed a way to do these things independently, especially when he is at school and needs to use the bathroom. The team designed a wheelchair attachment that slid out from underneath the client's seat and provided leverage and reduced the reach distance to his feet.

Figure 7: Dressing Aid

Research Methods

Quantitative methods consisted of pre- and post- course surveys to measure changes in students' self-reported levels of empathy, as measured by The Empathy Assessment Index (EAI). The EAI is a validated assessment instrument with 22 Likert-type questions, commonly used to compare before and after empathy interventions. Demographic questions were also included in the pre-course survey. The full empathy survey, along with instructions for interpretation, is published in the book, “Assessing Empathy” [8].

Post-processing of the raw data resulted in the formation of two independent variables and one dependent variable. The two independent variables were the **empathy construct** and the **individual student**. The dependent variable was the **empathy score**. Once these variables were formed, quantitative analysis involving two-way ANOVA and Tukey tests were used to determine:

1) If there was a significant difference in the dependent variable (students’ empathy scores);
2) To what degree that difference was attributed to each of the two independent variables (the empathy construct and the individual student).

Qualitative methods consisted of one personal interview a student, conducted approximately one month after the course was finished. The interview was 30-minutes long and focused on questions aimed to understand the different ways in which the course activities influenced the development of empathy in this student. The authors are well-aware of the limitations of having only one qualitative data point and hence consider the results of the interview to simply inform future qualitative work that can be done in this area.

Quantitative Results

The seven students in the study demonstrated an increase, on average, in all five empathy constructs. These results are denoted PRESCORE and POSTSCORE, respectively. The change in empathy score is denoted DIFFSCORE.

Figure 8 presents paneled histograms of PRESCORE and POSTSCORE for each empathy construct, reading from left to right: Affective mentalizing (AM), Affective response (AR), Emotion Regulation (ER), Perspective-taking (PT), and Self-other awareness (SOA). Essentially, the histograms show the percentage of occurrences where a student “strongly agreed” with statements about empathy, across the five different empathy constructs. For example, the four statements about affective response were:

- When I see someone receive a gift that makes them happy, I feel happy myself.
- When I see someone being publicly embarrassed I cringe a little.
- When I see someone accidentally hit his or her thumb with a hammer, I feel a flash of pain myself.
- When I am with someone who gets sad news, I feel sad for a moment too.
- Hearing laughter makes me smile.

If a student had “strongly agreed” with all five statements pertaining to affective response (AR), this would have correlated to an AR score of 1, meaning that the student strongly agreed with AR statements 100% of the time. As seen in Figure 8, there was only one occurrence when a student “strongly agreed” with all statements about self-other awareness, and this occurred after the course (POSTSCORE, SOA).

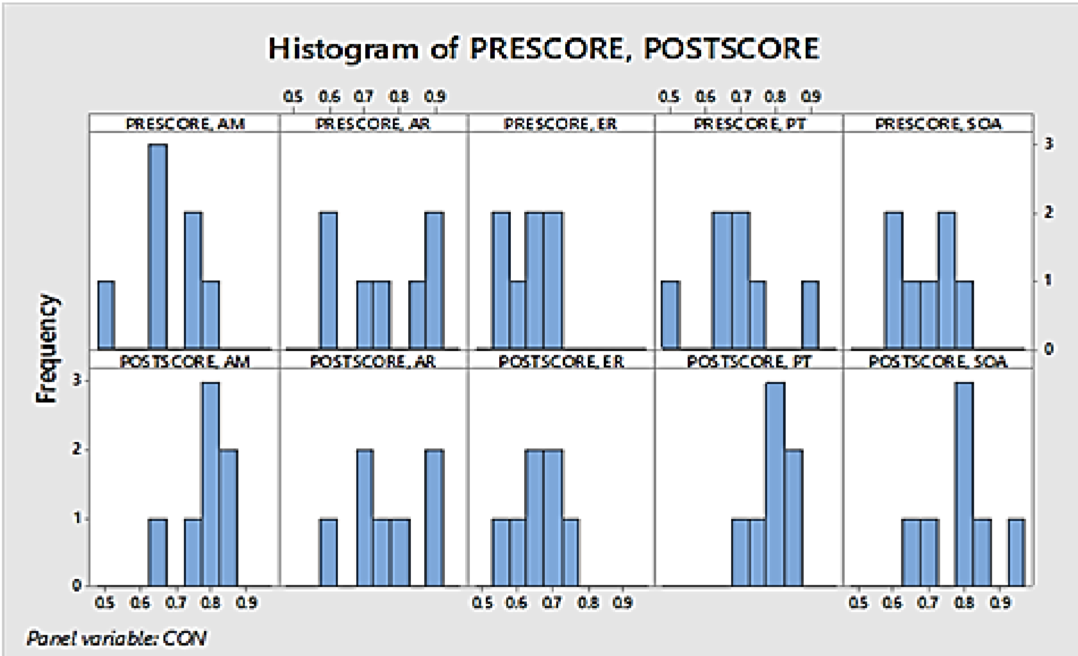

Figure 8: Paneled histogram of pre-course and post-course empathy construct scores

Table 1 presents descriptive statistics for the three variables PRESCORE, POSTSCORE, and DIFFSCORE, followed by a summary of the most important results.

Table 1. Descriptive statistics for PRESCORE, POSTSCORE, and DIFFSCORE.

	PRESCORE		**POSTSCORE**		**DIFFSCORE**	
CONSTRUCT	**Mean**	StDev	**Mean**	StDev	**Mean**	StDev
Affective Mentalizing (AM)	**0.6786**	0.0994	**0.7857**	0.0690	**0.1071**	0.1205
Affective Response (AR)	**0.7486**	0.1238	**0.7657**	0.1118	**0.0171**	0.0605
Emotion Regulation (ER)	**0.6286**	0.0636	**0.6571**	0.0673	**0.0286**	0.0636
Perspective Taking (PT)	**0.6857**	0.1118	**0.7943**	0.0428	**0.1086**	0.1280
Self-other Awareness (SOA)	**0.6929**	0.0787	**0.7929**	0.0976	**0.1000**	0.0707

- Before the Rehabilitation Engineering course, students' **emotion regulation (ER)** was the **weakest empathy construct**. Although it did increase over the ten weeks of the course, it remained the weakest construct.
- **Before the course**, students' **affective response (AR)** was the **strongest empathy construct**.
- **After the course**, students' **perspective-taking (PT)** was the **strongest empathy construct**, followed closely by self-other awareness (SOA).
- Students experienced **gains** in **all** five **empathy constructs**.

Results of the two-way ANOVA are presented in Table 2. The **p-value of 0.010 for ID** indicates that at least one mean value of students' DIFFSCORE was different than the other means. Hence, a portion of the model variance can be attributed to the individual differences among students. The **p-value of 0.066 for CON** suggests that DIFFSCORE does not vary by empathy construct. It is close, but not significant at the 0.05 level. **Together**, the factors **ID and CON** account for **57.3%** of **model variance**.

Table 2: Results of the 2-Way ANOVA

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
ID	6	0.12534	0.020890	3.68	0.010
CON	4	0.05776	0.014440	2.54	0.066

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0753658	57.32%	39.54%	9.24%

Post-hoc analysis using a Tukey test was performed to determine which variables in the data were likely contributing to differences in means as indicated by ANOVA. Means that do not share a letter are statistically different, with a 95% confidence interval.

Table 3. Tukey test to determine construct grouping

	PRESCORE		POSTSCORE		DIFFSCORE	
CONSTRUCT	Mean	**Group**	Mean	**Group**	Mean	**Group**
Affective Mentalizing (AM)	0.6786	**A**	0.7857	**B C**	0.1071	**D**
Affective Response (AR)	0.7486	**A**	0.7657	**B C**	0.0171	**D**
Emotion Regulation (ER)	0.6286	**A**	0.6571	**B**	0.0286	**D**
Perspective Taking (PT)	0.6857	**A**	0.7943	**C**	0.1086	**D**
Self-other Awareness (SOA)	0.6929	**A**	0.7929	**C**	0.1000	**D**

The Tukey tests show that none of the PRESCORE means are significantly different from each other. In other words, even though emotion regulation was the lowest PRESCORE empathy construct, we cannot be certain whether that low score was a result of students truly having weaker emotion regulation skills, or because of variance in the data. The same applies to the single grouping of DIFFSCORE; even though the average differences from pre-course to post-course are different, they are not significantly different from each other. However, the Tukey tests show that, on average, POSTSCORE perspective-taking and self-other awareness are different from the other constructs. This indicates that perspective-taking and self-other awareness may have been influenced more than the other empathy constructs.

Qualitative results

One student, Jeremy, was interviewed about his experiences in the course and their relationship to empathy. Although a single interview will not provide generalizable results, it can provide insight into certain aspects of this single student's development of empathy. Jeremy did not feel that his definition or understanding of empathy changed throughout the course, but that, as a student in the course, "you learn different ways to apply it [empathy] as you're learning more about people with disabilities." He viewed the main purpose of empathy in engineering as an important part of understanding the problem. This viewpoint was demonstrated when he said, "engineering is like coming up with solutions through design to solve the problem. So if you don't fully understand the problem, you can't come up with a good solution, because then how do you know that you're fully solving the problem?"

Jeremy identified several key activities in the course that he felt helped him to see people with disabilities in a new way. He thought the guest speakers "were great," especially his fellow student with paraplegia. He especially appreciated that “the way he talked about it [his disability] made it not uncomfortable at all,” especially how “he was funny. He was just a regular dude. Just talking and making jokes. He didn’t have to pretend like he didn’t have a disability.” Additionally, Jeremy explained that exploring the needs of his project client helped him to feel empathy for her and want to design a device that would fit into her lifestyle. He seemed to recognize the importance of “being able to put yourself in the place of that person in order to fully understand the problem and design to that problem.”

The final activity that Jeremy cited as helpful was the knee-scooter activity. He felt that he experienced some of the “extra attention” that people who use mobility assistance devices experience. However, he felt that because he was not truly injured or needed the device, he did not experience the same sorts of problems that people who use mobility assistance devices would experience and that “if I actually had to use an assistive device I think I’d be a little more self-conscious about it.” In addition to his experiences in the course, Jeremy was able to recognize out-of-course experiences that have helped him to develop empathy. In particular, he credited his experiences with an aunt with autism with helping him to develop empathy by seeing life from the point of view of someone with a disability as he was growing up.

Discussion

The purpose of this study was to investigate how course participation influenced students’ development of empathy. The results of the study show that students increased their levels of empathy in all five areas: affective response (AR), affective mentalizing (AM), self-other awareness (SOA), perspective-taking (PT), and emotion regulation (ER). These results are congruent with the work of Walther, Miller, and Sochacka [10], who showed that empathy is a teachable skill. Our work also shows the positive effects on empathy development in a rehabilitation engineering course. It may be the case that the skills of self-other awareness and perspective-taking were most positively influenced by the course activities. This makes sense, since most of the immersion and reflection activities required students to use self-other awareness and perspective-taking.

The observed increase in empathy provides evidence that, while the clients indeed benefited from the products that the students produced, the students also benefited by interacting with their clients. Through the project experience, students learned that their client, and by extension other people with disabilities, have personalities, wants, and needs similar to their own. The students were able to have direct interaction with people with different disabilities, through guest speakers, their clients, and their volunteer work. These immersive experiences provided students a new lens through which to consider disability, which is an important aspects of empathy development [8].

These quantitative findings are also reflected in Jeremy’s interview responses. While this is a single data point, the authors noted that Jeremy’s interview responses were echoed in many of the students’ course evaluations and reflections. Assignments and activities that contributed to perspective-taking and self-other awareness seemed to stand out the most to the majority of students. Students seemed to understand that empathy is important in engineering, especially in fully understanding the problem and the needs of the user, which is an important realization for future engineers [10]. Although including the specific results of the instructors’ course evaluations and written feedback is beyond the scope of this study, we would like to share that the evaluations from students were overwhelmingly positive, and we are eager to teach this class again in Fall 2020.

The next offering of this class will likely be quite similar to the Fall 2019 version. Improvements may include:

- More thorough client onboarding process to explain expectations about how often clients should meet with student teams.
- Require students to complete their volunteer hours and enrichment activity in phases. Many students left these two assignments until the end of the quarter, resulting in many students opting to watch a movie instead of attending in-person events, the latter being arguably more enriching. Students who left their volunteer hours for the end of the quarter wound up completing volunteer assignments that were loosely related to rehabilitation engineering and/or did not meet the two hours of direct contact with a person with a disability requirement.

The high-impact activities that will be retained include the three empathy immersion activities, the guest speakers and, of course, the student projects and culminating Design Expo.

In terms of study limitations, one obvious limitation is the small sample size. The small number of participants may have masked effects that would have been statistically significant for a larger number of participants. Another notable limitation is self-selection bias. As the study was voluntary and not incentivized, it is reasonable to assume that students who were more impacted by the course were more intrinsically motivated to participate. Most of the study participants were female, despite a nearly 50/50 female/male split in the class.

Conclusion and Future Work

This study provides insight into students' development of empathy by suggesting that participation in a rehabilitation engineering course does have a positive effect on empathy. We conclude that **perspective-taking** and **self-other awareness** were most influenced by course activities, especially the high-impact activities as noted above. Although the results of this study represent only a small group of students, this research demonstrates that rehabilitation engineering courses have potential for the development of empathy in engineering students and are an area worth further study.

In the next iteration of this study, the study will be included as part of a class assignment to ensure that most, if not all, students participate. A similar mixed-methods approach will be used (with a larger sample size) to more deeply understand the nuances between the different constructs of empathy and how they are developed over the course, as well as qualitative analysis to better understand the students' perspectives of their empathy development and the specific activities and aspects of the course that helped them to develop empathy. In future work it may also be beneficial to engage the clients with evaluating the students with respect to empathy in practice (i.e., listening, responding to feedback, forming a connection, etc.) Long term, the researchers would like to develop open-source modules on the development of empathy in engineering students that could be available through a creative commons platform.

Works Cited

[1] L. de Couvreur and R. Goossens, "Design for (every)one: Co-creation as a bridge between universal design and rehabilitation engineering," *CoDesign*, 2011.

[2] L. Mitchell and L. Light, "Increasing student empathy through immersive user empathy experiences in first-year design education," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2018.

[3] J. O. James, V. Svihla, C. Qiu, and C. Riley, "Using design challenges to develop empathy in first-year courses," in *ASEE Annual Conference and Exposition, Conference Proceedings,* 2018.

[4] J. Walther, S. E. Miller, N. W. Sochacka, and M. A. Brewer, "Fostering empathy in an undergraduate mechanical engineering course," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2016.

[5] C. Bell-Huff and H. L. Morano, "Using simulation experiences, real customers, and outcome driven innovation to foster empathy and an entrepreneurial mindset in a sophomore Engineering Design Studio," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2017.

[6] E. Schmitt, E. Kames, B. Morkos, and T. A. Conway, "The importance of incorporating designer empathy in senior capstone design courses," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2016.

[7] J. L. Hess, J. Strobel, and A. O. Brightman, "The Development of Empathic Perspective-Taking in an Engineering Ethics Course," *J. Eng. Educ.*, vol. 106, no. 4, pp. 534–563, 2017.

[8] E. Segal, K. Gerdes, C. Lietz, M. A. Wagaman, and J. Geiger, *Assessing Empathy*. 2017.

[9] M. Kouprie and F. S. Visser, "A framework for empathy in design: stepping into and out of the user's life," *J. Eng. Des.*, vol. 20, no. 5, pp. 437–448, 2009.

[10] J. Walther, S. E. Miller, and N. W. Sochacka, "A Model of Empathy in Engineering as a Core Skill, Practice Orientation, and Professional Way of Being," *J. Eng. Educ.*, 2017.

[11] C. B. Zoltowski, W. C. Oakes, and A. E. Cardella, "Students' ways of experiencing human-centered design," *J. Eng. Educ.*, vol. 101, no. 1, pp. 28–59, 2012.

[12] K. E. Gerdes, E. A. Segal, and C. A. Lietz, "Conceptualising and measuring empathy," *Br. J. Soc. Work*, 2010.

[13] J. Walther, S. E. Miller, and N. N. Kellam, "Exploring the role of empathy in engineering communication through a transdisciplinary dialogue," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2012.

[14] B. P. Self and J. Widmann, "Access for all: Promoting universal design thinking in a rehabilitation engineering course," in *Proceedings of the 8th Research in Engineering Education Symposium, REES 2019 - Making Connections*, 2019.

[15] D. S. Kumar, D. S. Reisman, and J. C. Galloway, "Go baby go café: a case study on an

immersive rehabilitation environment to improve functional outcomes and quality of life," *Disabil. Rehabil.*, 2018.