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Where Empathy is Needed in Engineering Formation

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Where Empathy is Needed in Engineering Formation

Abstract

Engineers are called upon to solve the complex problems plaguing society. These problems are intellectually rigorous and steeped in societal, ethical, and geographic context, requiring social competencies to balance technical expertise with interpersonal, cultural, and environmental sensitivity. Empathy, an ability to understand others, experience their feelings, and behave responsively, is an essential skill and orientation for solving these complex engineering problems and holistically serving society. However, studies suggest engineers are not learning empathy during their collegiate years [1] and collegiate engineering culture can devalue social and professional competences [2]. This lack of empathy formation in college students prompted our research team to conduct focus groups where we asked ten engineering educators "What areas of engineering formation could be enhanced by greater empathy?" Participant responses were thematically analyzed in MAXQDA. The themes that emerged revealed five areas engineering educators feel greater empathy would benefit engineering formation: empathy for collaboration, diversity, individualized learning, professional practice, and understanding students. All participants expressed that empathy could enhance engineering formation. A reoccurring pattern in responses was participants describing an understanding of students that lead them to suggest empathetic actions. This response pattern demonstrates how educators began an empathetic process using cognitive empathy then proceeded to behavioral empathy. Our findings provide insight into how educators should be incorporating empathy into the curriculum, culture, and profession of engineering.

I. Introduction

Engineers are responsible for improving and maintaining the infrastructure and technology people interface with daily. To this end, the National Society of Professional Engineers state in their Code of Ethics that engineers are responsible for "…the safety, health, and welfare of the public" [3]. Since engineers greatly impact the wellbeing of others, it is vital for them to be able to consider the perspectives and values of the people who are using their creations. To effectively and holistically serve society, engineers must develop the professional skill of empathy, which can be described as a capacity "to perceive the internal frame of reference of another" [4]. Empathetic capacity allows engineers to understand the consumers or business partners who are impacted by their designs, respond to the needs of communities, and communicate effectively. During the last two decades, many articles have been published pushing for more empathy in engineering [5], [6], [7], [8], [9]. Some argue "that empathy… enables students to develop a nuanced critical understanding of the multiple perspectives which characterize contemporary engineering problems" [10]. Facilitating an environment for students to develop empathetic skills allows them to more holistically understand the problems they will encounter in their careers. Literature also suggests that "empathy can support effective communication and collaboration across disciplines and cultures, promote more useful and responsive solutions for users, and motivate engineers to incorporate humanitarian and ethical considerations into their solutions" [11]. Teaching future engineers the values of empathy would allow them to explain their solutions in a more nuanced and personal manner, which helps connect engineers with the people they are trying to help.

The practice of empathy can be divided into three distinct constructs: cognitive, affective, and behavioral. The cognitive construct of empathy refers to the mental ability to perceive the mindset of another. The affective construct relates to the “emotional response of empathy” [12], [13]. Finally, the behavioral construct can be viewed as the physical act of being empathetic. Figure 1 [12], [13] shows a redesigned model of empathy in engineering that mixes the constructs of empathy with the work that went into Walther, et al.’s Model of Empathy in Engineering [14]. The model breaks up the practice of empathy into three dimensions: empathy as a learnable skill, as an orientation of practice, and as a professional way of being [13], [14]. Empathy as a learnable skill encapsulates the portions of empathy that can be taught. These skills include affective sharing, self and other awareness, perspective taking, emotion regulation, and mode switching. Empathy as an orientation of practice in this model is described as “how engineers choose to utilize their various skill sets, and what course of thought or action they are predisposed to take” [14]. This portion of the model is broken up into epistemological openness, micro to macro focus, reflective value awareness, and commitment to values pluralism. The last dimension of the model, empathy as a professional way of being, reflects the commitment of engineers to be empathetic through their work and interactions. This dimension is then broken down into three sections: holistic service to society, engineers as a whole profession, and dignity worth of people and the natural environment.

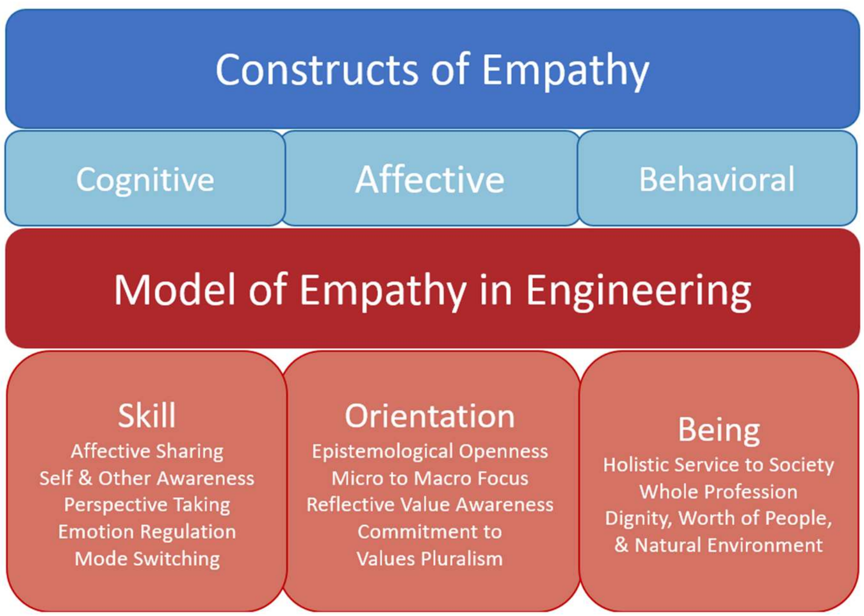

Figure 1: The constructs and model of empathy in engineering redesigned by Vaughn, et al. [13] from the original model of empathy in engineering published by Walther, et al. [14].

The growth in literature related to empathy shows a growing awareness of the relevancy of empathy to the engineering discipline. However, recent publications echo a lack of empathy in engineering formation. One of which goes as far as stating engineering students become less empathetic as they advanced through their degrees [2]. This study tracked 326 engineering students over the course of their college and early career experience. Periodically the “students were asked to rate the importance of ‘professional and ethical responsibilities,’ ‘understanding the consequences of technology,’ and ‘understanding how people use machines’” [2]. The results suggested that there was a “culture of disengagement… in place at these schools and that this culture is related to the students' weak commitment to public welfare consideration [2]." The disconnect between the cultural shift of engineering and the lack of empathy in engineering formation raises the question of where empathy should be included and taught to improve engineering formation.

Our team seeks to answer the research question: "What areas of engineering formation could be enhanced by greater empathy?" By eliciting and analyzing the responses of engineering educators, we aim to provide impactful narrative perspectives and meaningful implications for cultural and systemic changes in engineering education related to empathy. Participant responses were thematically analyzed and ordered into five unique themes: diversity, individualized learning, understanding students, professional practice, and collaboration. Each theme contained two unique sub-themes; diversity has inclusion and cultural awareness, individualized learning has programmatic modifications and personalized modifications, understanding students has professor to student and peer-to-peer, professional practice has end-user consideration and serving society, and collaboration has teamwork and external partnerships. Based on the narratives of these engineering educators, we suggest empathetic practices to be added to engineering education.

II. Methods

A. Data Collection

1. Participant Selection

Our research team conducted focus groups, in accordance with our Institutional Review Board (IRB), with 10 engineering educators to understand where educators felt empathy would best serve engineering formation. Educators were recruited through emailing a brief introduction to the research and a screening survey to the administrative contact faculty member for two engineering departments at state universities in each state (except in states that did not have two state universities with engineering programs) and 13 historically black colleges. The pre-screening survey requested initial consent, contact information, demographic data, engineering discipline, and years of experience. Additionally, a link to a pre-screening survey was posted on LinkedIn and a QR code to the survey was placed on posters when the idea for this work was being presented at engineering conferences. The results presented here are from 10 participants who consented to partake in our study. The demographics of these participants are shown in Table 1, which lists their identification code, gender, race/ethnicity, discipline, and years of experience. It should be noted that all the data presented, besides the identification code, in this chart was provided by the participants.

2. Focus Groups

We conducted five focus groups with the 10 engineering educators from April to May of 2024. Focus groups consisted of one to three participants each and were conducted virtually through Zoom. The participants were asked a total of six questions, but this work focuses only on the last question: "What areas of engineering formation could be enhanced by greater empathy?" For each focus group, at least two members of our research team, one an engineering educator and the other an empathy expert, were present to ensure consistency of protocol delivery. Following each focus group, present group members discussed notable responses and connections to empathy constructs and the model for empathy in engineering. The first author confirmed the accuracy of the Zoom translations and removed any identifiable data from the transcription.

Table 1: Demographic Chart of Engineering Educator Participants

ID	Gender	Race/Ethnicity	Discipline	Years of Experience
EE1	Male	White/Caucasian	Electrical Engineering	25+ Years
EE2	Female	White/Caucasian	Mechanical Engineering	6-15 Years
EE3	Male	White/Caucasian	Biological Engineering	25+ Years
EE4	Female	Black/African American	Mechanical Engineering	25+ Years
EE5	Male	White/Caucasian	Mechanical Engineering	6-15 Years
EE6	Male	White/Caucasian	Mechanical Engineering	6-15 Years
EE7	Female	White/Caucasian	Industrial Engineering	16-25 Years
EE8	Male	White/Caucasian	Chemical Engineering	0-5 Years
EE9	Female	White/Caucasian	Engineering Dean	25+ Years
EE10	Female	Black/African American	Civil Engineering	6-15 Years

B. Thematic Analysis

We analyzed the transcripts using MAXQDA, a qualitative analysis tool. The analysis of our data was guided by the Braun and Clarke method of thematic analysis [15], [16]. This was an iterative process which required the analyzers to first become familiar with the data. Familiarization began with the first author reviewing the transcripts while listening to the focus group recordings. Before and during the analysis of our data the first author consulted existing literature to help give academic validation to the emerging and finalized themes. Insights from existing literature and initial themes were shared with the group during regular meetings. This allowed our research team to better define the themes and gave the chance to reexamine how themes were perceived among the authors. The first author developed the initial codes by identifying the broad areas within the discipline that educators were discussing as important or impactful in relation to empathy. The first author then reviewed the initial codes to find emerging themes in participant responses. These themes were then iteratively reviewed by the remaining authors who, in collaboration with the first author, renamed and defined the final themes and sub-themes from the focus group responses. This process occurred in weekly meetings over two months, focused on achieving consensus among our research team, as has been seen in other qualitative engineering studies [17]. These themes were then organized for clarity. Table 2 defines the themes, provides specific words or concepts coded for by the theme, and provides an example of each from the participants.

C. Limitations

A notable limitation of this work is the small sample size. This thematic analysis was conducted using 10 participant responses, which is approximately a quarter the entire scope of the data we hope to collect. As such, these are the initial findings from engineering educators concerning what areas of engineering formation could be enhanced by greater empathy.

III. Results and Discussion

During virtual focus groups, 10 engineering educators responded to the question "What areas of engineering formation could be enhanced by greater empathy?" Through analysis of these responses, five themes emerged: collaboration, diversity, individualized learning, professional practice, and understanding students. For each theme, subthemes also emerged. Table 2 presents these themes and subthemes, along with descriptors and an example quote. The descriptors are words and phrases participants said that prompted us to code their statements within each subtheme. The example quotes highlight a key sentiment of each subtheme. Many of the instances coded in our analysis had overlapping themes and subthemes, however, each observed subtheme highlights an area discussed by multiple participants in separate focus groups.

A. Understanding Students

Taking on the perspectives of others is the foundation of empathy. This allows educators and peers to understand the experiences of students and find ways to better help them succeed. Literature suggests that "empathy… enables students to develop a nuanced critical understanding of the multiple perspectives which characterize contemporary engineering problems [11]." Teaching students to understand the needs of others will greatly increase their perspectives when approaching solutions. In our analysis, we established this theme as the cognitive precursor to many of the other themes observed. Often the participants would discuss in some way a form of understanding that would develop into one of the other themes. In the focus group responses, the theme of understanding students was identified in the forms of professor to student understanding and then as peer-to-peer understanding.

1. Professor to Student

Professor to student understanding was used to code sections of the transcription where participants advocated for the benefits to engineering formation of a better understanding of students. Participant EE1 recalled his experience teaching a class over the fundamentals of engineering. He stated that some of his students did not "know what engineers do" and that "they might be discouraged… we kind of scare them away." This demonstrates a cognitive understanding of the perspective of his students. The participants also talked about students who had specific needs or outside obligations that would impact how they show up to the engineering classroom. EE1 described a situation where, "one particular student… came to me and she said… I spent four years in the Navy and I'm now working at Taco Bell wrapping tacos." Other participants discussed students with commitments outside of engineering, such as "taking care of siblings", EE8, and how COVID-19 impacted students' ability to adhere to deadlines, EE6. Understanding students not only applies to students in the classroom, but to other facets of engineering formation, like research and career preparation. EE8, also claimed "the undergraduates that do research with me… a lot of them didn't have research experience before, but they'd worked in restaurants, they'd worked actual jobs and they had a lot of resilience… I think… there's so many skills… and experiences that adds so much value beyond just the GPA." By developing a cognitive understanding of student struggles and strengths, engineering educators can then develop affective and behavioral strategies to better assist the students. EE9 summarized this by saying "Do we actually think maybe if we could understand what these people are going through, what's their changes, how we could do that, they could start identifying as an engineer."

2. Peer-to-Peer

The peer-to-peer understanding was used to code for instances when participants would discuss how to build a deeper understanding amongst their students. Some educators discussed how they would provide opportunities for connection in the classroom. For example, participant EE2 stated that she connected her students with "alumni to tell them, hey, I still don't really always know what I'm doing. That it's OK to not feel like you're perfect, to not feel like you know everything." Providing an environment to allow students to be empathetic towards one another helps them to develop better social networks and develop professional skills which will lead to a more successful career.

B. Diversity

Engineering educators should promote diverse principles within their curriculum. By increasing diversity within the discipline, emerging engineers will have broader perspectives on problems leading to better engineering solutions. In 2018, researchers at MIT published a study addressing the racial bias seen in a commercially available facial recognition software. They found that the software had a 34.7% error rate when analyzing "darker-skinned females" but only had an error rate of only 0.8% for "lighter-skinned males" [18]. This example is one of many that highlight how lacking diversity when considering a problem leads to poor design. Dewsbury et al. suggests educators adopt inclusivity into their classroom, which he defines as "an intentional practice of recognizing and working to mitigate biases that lead to marginalization or exclusion of some people [19]." As such the theme of diversity was used to code for participant responses relating to the inclusion and cultural awareness of different groups within the discipline. We identified inclusion codes as the affective and behavioral aspect of empathy used for diversity, and cultural awareness as the cognitive aspect of empathy for diversity.

1. Inclusion

The subtheme of inclusion was used to code discussion that addressed providing equal opportunity and resources to all students. Participant EE3 discussed how increased empathy in engineering could attract more women into the discipline. Participants also seemed focused on discovering if there could be a better way to provide students with the support they needed to succeed. EE5 discussed the struggles neurodivergent students face. Participant EE8 claimed educators could implement empathy by "creating an environment where those students with different backgrounds know they have the potential to succeed." The same participant mentioned, “if there's any way someone's not prepared for something… whether it's they just didn't have exposure” or are “from different areas versus from socio economic or ethnic” groups, the educators need to make allowances that support student success. Our participants espoused beliefs that engineering educators could boost student performance and morale by promoting inclusive behavioral empathy. Participant EE9 reasoned, “we're not going to make those advances in, in those marginalized student populations until we have a better understanding of what they need and what they're going through.”

2. Cultural Awareness

The cultural awareness subtheme was used to code moments in which the participants would try to cognitively understand the environment and culture that their students come from; with the hope of being able to better connect with the students and allow them to merge their own heritage and personality with the overarching culture of engineering. Participant EE3 recalled his experience teaching indigenous students by stating, “they also didn't have the same support structures of the family... when they had struggles, they couldn't go to mom and dad... in some cases they were going against their family's wishes by… going to college.” Having a cultural understanding of the students allows educators to better support their pupils through their collegiate and early careers. One educator, EE9, discussed the rural populations some universities serve stating, “They ain't going to have calculus people and… so really understanding those things in, in an empathetic way.” In a similar sentiment, EE3 suggested those coming from smaller communities may have the same ambition but lack the math preparedness of their urban counterparts.

C. Individualized Learning

All learners have unique experiences and education backgrounds which impact how they process and learn in the colligate classroom. We posit that to maximize student performance, engineering educators should meet the students where they are, and this sentiment was expressed by many of the participating educators. Reflective of the idea that engineers provide care for society, engineers, like social workers, should “’start where the client is’ and approach from a place of empathy, warmth, and genuineness in all interchanges [10].” Over half the participants discussed trying to meet the needs of their students. The theme of individualized learning was used to code these discussions and was broken into personalized and programmatic modifications.

1. Personalized Modifications

The personalized modifications refer to when the educators would make individualized changes to the course load of specific students. This subtheme related the idea of meeting an individual student’s needs and providing them individually with the tools they will need to succeed. Participant EE3 expressed this sentiment when he stated, “we really need to, to look at ways to help the students where they are and what they need at that time.” Understanding the needs of the students allows educators to identify the best ways to support their students as individuals. EE8 addressed the gradient of student experience and suggested, “maybe it means that your “on ramp” is a little longer, but you could be just as successful, if not more.” Other participants discussed the benefit of connecting the material to the individual students’ interests. EE1 discussed assigning his student a “useless machine” project where they are “coming up with a silly solution to no problem. But they learned throughout that experience in engineering design and many of them… relate to engineering in a better way and… continue successfully.” EE1 also discussed relating complex mathematic topics to students’ interests, by providing an analogy between the tools used to work on cars and the mathematical tools educators employ.

Table 2: The Code Book including themes, subthemes, descriptors, and example quotes

Theme	Subtheme	Descriptors	Example
Diversity	Inclusion	Different Socioeconomic Status, Different Academic Preparation, Different Gender Identity, Different Ethnicities, Neurodiversity,	"it's more targeted towards students who are lower income and… it helps provide them with resources. But just cause someone's low income doesn't necessarily mean they didn't excel at their school…"
	Cultural Awareness	Marginalized Student Populations, Rural Student Populations, Indigenous Student Populations, Privileged Student Populations, Popular Culture, Gaming Culture	"I had a lot of students coming off of the tribal communities… they wanted to do positive things that they could bring back to their community."
Individualized Learning	Personalized Modifications	Preparing Students, Helping Students, Meeting Students Where They Are, Improving Comprehension	"...identifying the best way to help students that kind of need more of that on ramp…"
	Programmatic Modifications	Curriculum Changes, Groups of Students, Department Level Changes, 3-year Plan, 5-year Plan	"we have things so lock step… you've gotta fit the mold at the input. And really, you ought to be fitting the mold on the output and the input should be much more flexible."
Understanding Students	Professor to Student	Different backgrounds, experiences, Identifying How to Help Students, Stating Student Feelings, Identifying Student Interests, Understanding COVID's Impact	"Do we actually think maybe if we could understand what these people are going through... they could start identifying as an engineer."
	Peer-to-Peer	Connecting Students, Teammates, Social Skills	"your teammates not doing as much work as you think they should and you say something and you don't understand how your words impact them."
Professional Practice	End User Considerations	Solutions for Clients, Positive Impact, Connecting Designs to Consumers	"they've chosen that because they want to go build devices to help people who can't walk"
	Serving Society	Helping humanity, Positive Things For Community, Pro-bono Engineering, Produce Good People	"I think a key part of it is, is demonstrating to future engineers how the profession can help humanity."
Collaboration	Teamwork	Group Projects, Working With Other Students, Working With Other Engineers, Communicating	"There are very few engineers out there that work individually every single day… so being sure that students can work in teams well and being be able to practice empathy in teams and get through challenges together"
	External Partnerships	Community Partners, Solutions for Clients	"when you're doing solutions for clients… that might relate to empathy and engineering formation"

2. Programmatic Modifications

Instances of programmatic modifications revolved around the idea of changing the structure or sequence of the curriculum to be more accessible for the different needs of students. These discussions often developed around the concept of extending or shortening the length of the curriculum. On the discussion of meeting students "where they are," participant EE3 also questioned, "what about the student that comes in with 20 AP credits? How do, how do we help them make a three-year plan?" In the same conversation, participant EE9 suggested, "all we have to do is do a five-year plan and you're going to feel better about yourself." By extending or shortening the curriculum plan, engineering educators can better meet the needs of their students. EE3 expressed his view by stating, "you ought to be fitting the mold on the output and the input should be much more flexible." While the majority of educators focused on undergraduate education in our discussion, one participant, EE8, discussed graduate program admittance. He stated some of his peers "only want people in [their] group who have chemical engineering background." Instead, he proposes that a variety of undergraduate backgrounds should be considered.

D. Professional Practice

Professional practice refers to the responsibilities and commitments of engineers to holistic service to society as designed by the model of empathy in engineering [14]. Based on the National Society of Professional Engineers' Code of Ethics [3], empathy is a vital aspect of the professional practice of engineering, and as such, is a necessary skill for engineering educators to model for and develop in their students. Literature defines empathetic design as the process in which, "engineers have to not only care about the humanistic consideration of technical dimensions in the pre-planning and design phases but also about the others' feelings and thoughts during the preliminary phases [7]." Considering the impact of designs on others takes a step past simply understanding others and moves towards more affective and behavioral forms of empathy. In the focus groups, participants discussed both end user consideration and serving society when considering how professional practice related to empathy.

1. End User Consideration

The end user consideration subtheme coded for instances when participants would discuss the importance of teaching students how to empathize with the needs of the person who uses a product or service. Participant EE2 recalled asking students to explain how their designs would affect end users and claimed they were "struggling to connect what they're excited about [in] their design to somebody who… is going to use this." By reinforcing empathetic design with students, engineering educators can better prepare them for industry positions where they would need to understand the needs of the client or end user.

2. Serving Society

The serving society subtheme denoted any moment when the participants emphasized the role of engineers as societal caregivers. They discussed how educators should focus on teaching students the benefits of helping others. Participant EE10 suggested engineering formation could benefit from "mandatory community service for a year where… they are working alongside a nonprofit, a community-based organization, and providing… pro bono engineering related services." By allowing students to practice behavioral empathy in the community so early in their career, they can be better prepared to help society after they finish schooling.

E. Collaboration

Engineers collaborate often with people of varying technical and nontechnical experience on projects. Collaboration is thus both a behavioral and an affective facet of empathy in engineering formation. Tang et al. claims "the commitment to empathetic communication is particularly important when engineers work to meet the needs of underserved communities [20]." Focus group participants voiced similar sentiments and discussed how their students worked together on group projects. We coded for the theme of collaboration when participants discussed students working in teams or when they discussed sending students to external partners in the community. As such, the theme of collaboration was divided into the teamwork and external partnerships subthemes.

1. Teamwork

The teamwork subtheme was used to code discussions around the internal collaboration within a group of engineers. Some discussions revolved around the importance of communication and empathy within cross-functional teams. Participant EE6 felt his students "struggle a lot in teamwork and… communicating with their teammates…" This aligns with the idea that there is a "culture of disengagement [2]" at some universities, which could be resolved by teaching students affective and behavioral empathy. Teaching students empathy will boost their communication skills and make them better collaborators [11]. Many engineering programs are accredited by ABET, and thus have the specific student learning outcome of "an ability to *function effectively on a team* whose members together provide leadership, *create a collaborative and inclusive environment*, establish goals, plan tasks, and meet objectives." [21] Embedded within this outcome is the need for empathy. Statements made by participants recognized this need, especially in teamwork. For example, EE2 expressed that "few engineers…work individually… so being sure that students can work in teams well and being able to practice empathy in teams" is an important aspect of engineering formation.

2. External Partnerships

The code external partnerships was used to denote when participants discussed how empathy would affect themselves or their students' interactions and relationships with others in the community, beyond the engineering discipline. Participant EE7 felt engineering educators should teach students empathy when they are "doing solutions for clients." By emphasizing the importance of empathy with external collaborations students can learn how to better understand the needs of their partners. Understanding partners' and clients' needs involves empathic skills, such as perspective taking and affective sharing, as well as empathic orientations such as epistemological openness and reflective value awareness. One participant discussed a concern that some students struggle with these skills and orientations due to a lack of social intelligence and being oblivious to their own privilege. Requiring community serving engineering activities as part of the curricula was suggested to help students increase their social awareness and align themselves with the goals of the engineering discipline

F. Summative View

Every theme each participant discussed is shown in Table 3. In this table each row pertains to a single participant denoted by their identification code in the leftmost column. An "X" in any other column was used to identify if the corresponding participant said something which was coded using that column's subtheme. We identified that 8 out of 10 of the participants discussed professor to student understanding, making it the most discussed theme. Programmatic changes, inclusion, and cultural awareness were discussed by 6 out of the 10 participants. Personalized modification, serving society and teamwork were each mentioned by 5 of the 10 participants. Only 3 participants discussed end user consideration. The least discussed subthemes were peer-to-peer and external partnerships, each only being mentioned by 2 participants. Many statements made by participants related to multiple subthemes or participants would begin discussing one subtheme then connect the discussion to another subtheme. Figure 2 acts as a visual representation of the occurrence and overlap of each theme. In this figure the size of the circle and the number in the parenthesis represent the occurrence of each theme, with the total number of coded statements in parenthesis. Similarly, the thickness of the lines connecting the codes and the numbers in the square brackets represent the quantity of overlap between the connected codes. The most cooccurrences happened between the understanding students, individualized learning, and diversity themes. The responses of participating educators suggested empathetic enhancements in engineering formation began with understanding students, which is cognitive empathy. From cognitive empathy, we observed educators move into the behavioral and affective aspects of empathy through individualized learning and diversity. This process was seen in one of EE8's responses when he stated,

> "Something that's super critical is… if someone has come from one area into a new area or has less experience having that empathy to understand… they might not have as much of a background on that area. But if they're willing to put in the time and effort, they could be just as capable. And I think having that perspective, that different backgrounds, you know, even if you haven't had the courses, maybe it means that your 'on ramp' is a little longer, but you could be just as successful, if not more."

Similarly, EE3 expressed an understanding of students which led him to suggest individualized learning changes, as displayed in the following quote:

> "So not only did they not have good preparation in, in their math and problem-solving skills, but they also didn't have the same support structures of the family… you know, to go back home to say, yeah, I, I failed. That's a, that's a huge demoralizing thing for… an individual… I think we really need to, to look at ways to help the students where they are and what they need at that time… I think we need to do everything we can to help them to get there and to not stigmatize the fact that, OK, so you need a year of pre-calc before you're ready… that's OK… there's not a, a negative connotation to that."

In these example quotes engineering educators took on the perspectives of their students and this led them to think about what curricular modifications could be made to best support the students. The understanding of students allowed them to suggest personal and programmatic changes to the curriculum.

While the connection between understanding students, individualized learning, and diversity created the most prevalent triangle for discussion, participants also discussed other subthemes in connection with one another. For example, EE2 expressed understanding of her students in connection with their need to practice teamwork and understand the end-user in the following quote:

> "I think even my students that are about to graduate… they feel like they can't identify themselves as an engineer… so I like to connect them with our graduates who are either right out of college or even 5-10 years out of college… also just think in engineering design and… teamwork, as I frequently will get freshman students in the design course that I teach and they have these grand ideas of products that they want to design or they have these things that are interesting to them. And, and so they'll explain this idea and I'll say, OK, who's buying this or what purpose does this serve?"

The idea that empathy was integral to collaboration and to students' future careers was echoed by many participants, suggesting empathy should be practiced through collaborative group projects. Additionally, educators can provide students with insight into empathy's role in collaboration and professional practice within the field of engineering.

Table 3: Table of themes indicating which participant responses contained segments coded for each subtheme

	Diversity		Individualized Learning		Understanding Students		Professional Practice		Collaboration	
Participant Codes	Inclusion	Cultural Awareness	Personalized Modification	Programmatic Modifications	Professor To Student	Peer to Peer	End User Consideration	Serving Society	Teamwork	External Partnerships
EE1			X		X					
EE2					X	X	X		X	
EE3	X	X	X	X	X		X	X		
EE4	X	X		X	X			X		
EE5	X			X					X	
EE6			X		X			X	X	
EE7	X	X			X	X	X	X	X	X
EE8	X	X	X	X	X					
EE9	X	X	X	X	X					
EE10		X		X				X	X	X

G. Implications for Engineering Administrators and Educators

Nearly all participant responses were suggestions for engineering administrators and educators to enhance engineering formation through empathetic thoughts, feelings, or actions. We suggest that engineering educators begin with the cognitive process of empathy to understand their students. Considering the Model of Empathy in Engineering [14], development of cognitive skills such as perspective taking and self and other awareness can enable engineering educators and administrators to understand the unique students at their institution. As discussed in the summative view section, many participants demonstrated how understanding student needs (cognitive empathy) led them to suggest ways empathy could tangibly be employed to serve students (affective and behavioral empathy). Many of the participants displayed empathetic orientations and ways of being as well, serving as an example of how other educators and administrators can model empathy more fully to their students. For example, participants demonstrated reflective value awareness when discussing expectations for incoming students and students' outside commitments. Additionally, many participants expressed sentiments related to how the engineering profession should holistically serve society and uphold the dignity and worth of people and the natural environment. While the skills, orientations, and ways of being from the Model of Empathy in Engineering could be individually explored, developed, and employed, our participants provided some concrete examples. Suggestions for individual educators to employ empathy to enhance engineering formation include allowing students to turn assignments in late if they have reached out to request an extension, finding out what your students are interested in so that you can relate content to it, and emphasizing the impact engineering has on humanity. Our participants also made concrete suggestions for administrators and chairs, such as the creation of 3- and 5-year plans that are respected alternatives to the 4-year plan.

Not only do engineering educators need to employ cognitive, affective, and behavioral empathy, but also engineering students need practice with each construct of empathy in preparation for their careers. A career in engineering involves teamwork, cross-functional collaboration, and stakeholder understanding; to be adept in these aspects, empathy is needed. Engineering educators should not expect that their students are receiving training in empathy from other sources. As one participant said, “It has to start at the department level.” One participant suggested pro-bono engineering as a way to develop empathy within students. Engineering educators should consider low-consequence methods for students to explore and develop empathic skills and orientations. For example, if students will be designing a product or device, have them write a narrative where they consider how someone will use it or consider the perspective of someone performing maintenance on the device. In a statics class, when structural elements are discussed, have students interview stakeholders of a current construction site in their area. In a thermodynamics class, have students advocate for different energy transformation methods, considering efficiency, availability, and social impacts. In addition to showcasing the socio-technical nature of engineering to students, these suggestions also align with ABET student learning outcomes [21].

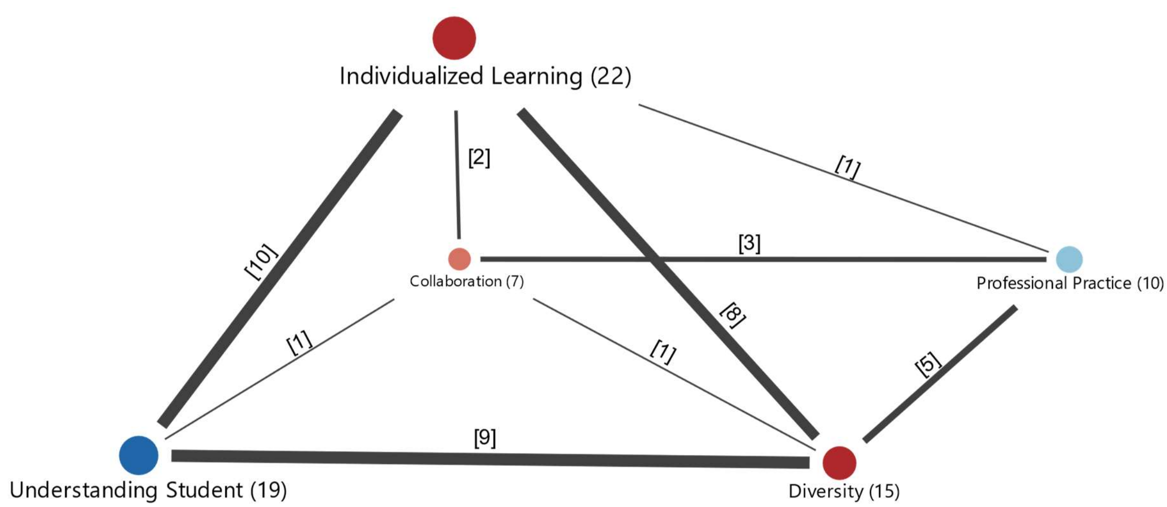

Figure 2: An illustration to visually represent the overlapping of themes within participant responses. Each theme is represented by a circle and the overlaps between them are shown as black lines. The size and thickness of the circles and lines are indicative of their quantity, the larger they are the more they occurred. We also provide the quantity of each occurrence in the parenthesis and square brackets associated with each element of the figure.

IV. Conclusion

In order to more effectively serve society, engineers should develop empathic skills, orientations, and ways of being [14]. Empathy allows engineers to more holistically understand the problems faced by society and will lead to better design solutions. Our research team conducted five focus groups with 10 engineering educators who were asked, "What areas of engineering formation could be enhanced by greater empathy?" Through thematic analysis we identified five main themes and 10 subthemes within the participants testimony. Within the theme of understanding students, educators expressed an awareness of their students' unique struggles, strengths, and identities. Within the theme individualized learning, the key sentiment expressed by educators was to meet students where they are. Discussion related to the theme of diversity emphasized the historical lack of diversity in engineering and efforts to broaden participation. Comments made that were coded as professional practice largely related to the societal impact of engineering. Discussion related to collaboration focused on teamwork and engineers' interactions with outside stakeholders. A reoccurring pattern in responses was a shift from using cognitive empathy to understand students, to suggestions of behavioral empathy, such as, changes to classes or curriculum. Implications for engineering administrators and educators highlight the need for program level changes, such as creation of 3- and 5- year plans. Engineering educators should implement opportunities for students to explore and develop empathic skills and orientations to reinforce the socio-technical nature of engineering. Using the unique themes and subthemes, this study was able to find similarities in participant answers that facilitate continued research in promoting the use of empathy in the higher education classroom to enhance engineering formation.

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