



Research Article

# Learning to Care: Faculty Perspectives on Developing Empathy and Inclusive Mindsets in Biomedical Engineering

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**Abstract**—While we all have our own circumstances and experiences, being able to empathize is critical to recognizing injustice and considering the viewpoints of others in the community. In the human-centric field of biomedical engineering (BME), empathy is imperative to creating inclusive devices or equipment that are equally accessible to all who need them. To learn more about the importance of empathy in the discipline and the learning activities that can be used to promote it, we leveraged qualitative methods and interviewed six BME instructors and course coordinators. We applied Zaki’s framework of empathy as the theoretical foundation for our investigation and analysis, which considers cognitive, emotional, and motivational factors. In this study, we sought to address: (1) The need of empathy for BME students; (2) The need of empathy for BME educators; and (3) How specific learning activities can be used to appreciate and imbue empathy. The analysis resulted in six themes, and the findings illustrated that empathy was considered important for students’ personal and professional development. It can promote intercultural awareness, leadership, and may drive students to think and care about others and take action. Faculty perceived empathy as necessary for themselves as well and they described developing it over the course of their careers as they interacted with students and learned about the issues they faced. In turn, they mentioned how their own empathy served to strengthen their approach as educators, their interpersonal relationships, and their awareness of students in distress. We identified multiple learning activities which can foster empathy in students. Examples include writing personas to enhance perspective-taking or allowing students to share their own narrative to strengthen communication for the speaker and active listening and compassion from those hearing the stories. Requiring students to shadow physicians or conduct interviews with those that will use their products can serve to build compassion and help students to

think about others. However, to impact values and mindsets such activities should not just be inserted at a single time point, but instead, should be considered throughout the BME curriculum. The findings from this work not only encourage professional development of BME students and their ability to solve problems addressing the needs of real people, but they also speak to the value of empathy for individual growth and considering diverse perspectives.

**Keywords**—Empathy development, Faculty interviews, Engineering education.

## INTRODUCTION

Effective education involves not just designing curricula and instruction but also establishing supportive environments that can encourage students’ engagement, persistence, and self-efficacy, and which strengthen their disciplinary identity.<sup>16,27,46,47,62</sup> While institutions are often focused on developing knowledge related to conceptual understanding and theoretical foundations, also imbuing students with emotional intelligence can serve to benefit their personal and professional growth.<sup>32</sup> **Emotional intelligence** is a concept that includes the “perception, expression and control of emotions, self-control and empathy, communication, conflict resolution process, conscience, and perhaps many more”.<sup>32</sup> Although possessing this type of intelligence can be beneficial for many areas, such as self-awareness, motivation, and resilience, it can also abet in controlling emotions to deliver them appropriately and in handling relationships with others.<sup>24</sup> A key aspect of emotional intelligence is empathy.

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**Empathy** refers to the ability or attribute of being able to consider and understand the perspective, feelings, and needs of another individual or group.<sup>20</sup> It plays a critical role in social connections, in recognizing the feelings of a person with a different perspective, and in trying to understand the diverse assumptions, values, and beliefs they may hold.<sup>28</sup> Similar to this notion, **intercultural awareness** describes the duality of understanding one's own culture as well as acknowledging and seeking understanding of others', and recognizing where similarities and differences may exist. As such, empathy is also valuable for intercultural awareness and communication, both of which are vital considerations with the rise of globalization.<sup>17</sup> To work towards creating more equitable and inclusive environments and worldviews, individuals must move past indifference to listen and care about the needs of others.

Empathy can be a useful trait to develop in higher education, both for students and faculty.<sup>48</sup> It is a core competency that can aid in innovative thinking as students seek sensitivity to the needs of others.<sup>37</sup> Demonstrating empathy has also been shown to be valuable to teaching practice and can support students' development and aid in rapport formation.<sup>45</sup> It can enhance collaborations, promote positive environments, reduce conflict, and bolster creativity in teams.<sup>48,58</sup>

Professional skills enhanced by empathy, such as communication, are also highly important to engineering fields,<sup>64</sup> and are often considered critical to addressing socio-technical challenges. Yet despite the value, scholars have previously described the cognitive dissonance that results from engineering students' struggle to reconcile the analytical and objective nature of the discipline with empathy.<sup>63</sup> Internalization of empathy is also reliant on affective components. Furthermore, students' "values and individual aspirations"<sup>63</sup> influence how they extrapolate meaning from learning experiences and establish their understanding of empathy. Given these perceptions, and that empathy is often described as a teachable skill<sup>65</sup> or a construct that should be integrated into lessons, the question then becomes how can it be taught? Moreover, what approaches should educators employ for diverse sets of engineers?

While empathy may be advantageous for all interactions and across fields, it is especially critical in the human-centered discipline of biomedical engineering (BME), where engineers working in this area may not have the same lived experiences as the users for whom they design solutions. Inclusivity in designs is important to ensure devices or equipment are not just effective for one particular sub-group or population. Consideration of the perspectives of disparate stake-

holders, can lead to a more holistic analysis that can strengthen designs. However, most articles on empathy in engineering education or in BME education, focus almost exclusively on the human- or user-centered design aspect of empathy, which can take on an objective nature and operationalization.<sup>42</sup> To better understand the role of empathy across the BME curriculum and students' professional development, we sought to address the following research questions (RQs):

- **RQ1:** Why is empathy critical to BME students?
- **RQ2:** Why is empathy critical to BME educators?
- **RQ3:** How can specific learning activities promote empathy development in students?

Engineering faculty not only possess technical expertise but are also instrumental to students' professional formation in the discipline. Accordingly, to answer these research questions, we conducted semi-structured interviews with six BME faculty members, coupled with thematic analysis. While other researchers may have previously studied empathy broadly in engineering,<sup>23,25,29</sup> or in other engineering disciplines (e.g., aerospace and mechanical engineering),<sup>67</sup> typically they do so through examination of the student perspective.<sup>30,31</sup> Our work serves to fill the gap in our understanding of empathy development in BME, and specifically from the vantage point of faculty. Furthermore, this investigation is unique in that we provide insight not just based on a single course, but instead, from course coordinators and instructors that foster empathy throughout the curriculum for students at different stages in their academic career.

## RELATED RESEARCH

### *Embedding Empathy in STEM Curricula*

Empathy can be integrated into science, technology, engineering, and mathematics (STEM) education either through standalone projects or by interweaving the concept into existing activities.<sup>60</sup> Prior literature in STEM has described pedagogical approaches such as using role playing to enhance communication skills, employing case studies to develop problem based learning, utilizing interviews to enhance stakeholder engagement in projects, and providing hands on opportunities for students' experiential immersion.<sup>42</sup> To assess the efficacy of different approaches and for specific learning activities, researchers use either quantitative measures (e.g., a pre/post survey of empathy), qualitative exploration (e.g., semi-structured interviews), or some combination of both. Yet, while scholars have described how power dynamics can im-

pact responses and perspectives towards empathy,<sup>5</sup> typically research in STEM on empathy development focuses on the student.<sup>15,28,34,53,68</sup> As such, insight on the faculty perspective remains more limited.

Previously, Strobel *et al.* examined empathy using small group interviews with engineering faculty members from civil, environmental and ecological, aeronautical/astronautical, electrical, and industrial engineering.<sup>59</sup> Their findings highlighted that although faculty believed empathy could be valuable, they did not see it as necessary for success in engineering. The faculty also expressed that although empathy may be indirectly touched on in the curricula, it should remain as such, rather than being included in a separate course. Additionally, they did distinguish between empathy and care—while also noting the concepts are similar. According to their conclusions, the key difference was that “care involves action while empathy does not”.<sup>59</sup>

As a later part of this research, Strobel *et al.* also analyzed open-ended responses from practicing engineers, alumnae with at least one year of work experience.<sup>59</sup> The participants considered empathy with a utilitarian approach, most beneficial to making money and less important to interactions or conflict-resolution with others. Yet, responses indicated that the company or supervisor values often played a critical role in the engineers’ conceptions of the necessity of empathy and care. This finding demonstrates the value of empathy and the importance of embedding it into the culture to further its development. Despite reluctance from faculty, such lessons could be encouraging in shifting the perspectives of future generations in the field.

In addition, Leydens and Lucena spoke with engineering education faculty in the United States and Canada about potential avenues for incorporating social justice.<sup>41</sup> They emphasized that to be effective, engineers must not just serve as problem solvers but also be able to define problems. Doing so requires empathetic consideration of others as well as knowledge about factors such as resources, equality, and risks. To train engineers to be successful in this area, they offered recommendations on criteria to hone social justice considerations, such as listening contextually and identifying structural conditions. To promote these skills, they described different learning activities, such as using case studies to illustrate what does and does not work and interacting with individuals in the community. To engage with the perspectives of others, they described how students could interact with local partners and then could use reflection (e.g., through written assignments) to incorporate their understanding. They suggested instructors use questions that are structured but that also allow for adaption to maxi-

mize the benefits of reflection. Taking what they learned, the students could then work to establish designs with greater consideration of different stakeholders. Service learning/learning-through-service could also improve students awareness and abilities. However, the authors cautioned that while intentions towards service learning/learning-through-service practices in engineering can be grounded in a genuine desire to help and act, they may also “reinforce social injustices”.<sup>41</sup>

Given the dearth of faculty perspectives on empathy, in this research, we focused on individual interviews with biomedical engineering faculty. We sought to understand faculty perspectives on the students’ development of empathy as well as their own. In addition, we wanted to learn more about learning activities to foster empathy throughout the BME curriculum. Our goal was to explore empathy not only as a construct and as part of practice, but to assess the value it offers and its potential role in strengthening diversity, equity, and inclusion (DEI) in the field.

#### *Intercultural Awareness and Social Justice*

While there may be many approaches to improving DEI in engineering, intercultural awareness and social justice are vital foundations. Intercultural or intergroup training can also serve to enhance perspective-taking and to mitigate discrimination.<sup>67</sup> Furthermore, while verbal content is necessary in communication, non-verbal signals (e.g., posture and expression) can also have an impact on meaning and are often highly dependent on culture.<sup>52</sup> In engineering, having self-awareness and emotional intelligence can aid in communication and cross-cultural sensitivity. Allowing students to disclose personal information and creating spaces where students feel comfortable sharing can be important for raising awareness, developing intercultural communication competence, and establishing welcoming environments.<sup>52,67</sup>

In 2017, Leydens and Deters analyzed student papers and evaluations of student discourse from a senior-level engineering and applied science course, Intercultural Communication, to describe the need to transcend “individual-only explanations” and identify “how broader social structural forces also shape social problems”.<sup>39</sup> They suggested that to combat discrimination and stereotypes in engineering, it is critical to impart the social construction of race rather than to treat it as a scientifically defined phenomenon. Likewise, emphasizing the role of perspective in what is considered “normal” can help to reinterpret dominant ideologies, such as capitalism. They suggested that within institutions, to ensure all students feel welcome and connected to the discipline, it is important to

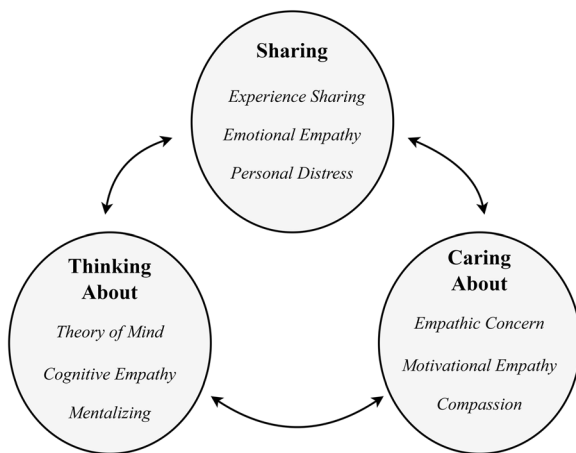


FIGURE 1. Zaki's empathy model, adapted from Ref.<sup>69</sup>

create a positive environment. To encourage collaboration and global competence, they suggested curricula focus on design and project-based learning projects that touch upon intercultural issues and that typically necessitate engaging with the community.

Moreover, prior research has described how **social empathy**, a concept rooted in consideration and understanding of cultural differences and perspectives, can add value and appreciation for social justice.<sup>55</sup> This stems, in part, from its foundation in **interpersonal empathy**, which is the ability to understand and interpret others' behavior.<sup>56</sup> It also considers structural inequities and macro perspective taking, which expands focus from individuals and their interactions (the micro) to systemic issues and collective needs (the macro).<sup>6,26,40</sup> To promote social empathy and help students refine their interpersonal empathy, it is critical for them to contextualize their position in the larger society, in alignment with the tenets of intercultural awareness.<sup>56</sup> In the research that follows, we describe the approaches taken by BME faculty to embed empathy in their teaching and curricula, and how it may impact components of intercultural awareness, interpersonal empathy, and social empathy.

## THEORETICAL FRAMEWORK

Previously, Zaki has described a theoretical framework for empathy that considers its cognitive, emotional, and motivational facets.<sup>69</sup> Specifically, it defines empathy as "Sharing," "Thinking About," and "Caring About" others. While each is described as distinct, they are also considered related processes, as illustrated in Fig. 1. Researchers have previously suggested that to establish community awareness, ideologies, and actions aimed at social justice, all three components of empathy are needed.<sup>2</sup> In this research,

Zaki's framework served as the lens that informed our research questions, protocol development, analysis, and the interpretation of the results. Below, we describe each component separately as well as the role they play in cultural development, understanding, and communication.

### *Sharing*

**Sharing** refers to recognizing, apprehending and comprehending, and reacting to another's emotions.<sup>69</sup> It includes the affective components of experience sharing, emotional empathy, and personal distress. In the broader context of society, shared or collective experiences can also lead to identification with others, which is considered the foundation of culture formation.<sup>8,13</sup> Insiders to a culture can find a community that provides meaning, engagement, and which may bolster resilience in the face of marginalization.<sup>14</sup> Through sharing, outsiders can gain intercultural awareness as they seek to obtain insight into the worldviews and perspectives of others, however, this can also result in discomfort.

### *Thinking About*

The **thinking about** component of Zaki's framework considers the cognitive aspect of empathy. It includes theory of mind, cognitive empathy, and mentalizing. As it pertains to trying to understand others' lived experiences, it is especially valuable to communication for intergroup relationships, innovative thinking, and intercultural awareness that can lead to reconciling cultural differences in engineering.<sup>52,67</sup> While it is impossible to entirely understand what another has been through, trying to interpret, process, and appreciate others' responses and perspectives is considered vital to sensitivity to injustice.<sup>22</sup>

### *Caring About*

**Caring about** describes behaviors or taking action as a result of the consideration of others. It includes concepts such as empathic concern, motivational empathy, and compassion. Another name for this is conative empathy, a term which denotes the "practical application of taking supportive actions in response to other people's feelings and problems".<sup>2</sup> Behaviors described by caring about are posited to arise from the cognitive (thinking about) and emotional (sharing) forms of empathy. Through the connection of shared experiences, literature has described how compassion and consideration of ethics can empower individual actions towards social justice.<sup>4,22</sup> Scholars have suggested that to do so in the domain of engineering

education, service learning activities and initiatives are especially valuable for students.<sup>41</sup>

## METHODS

In this study, we used semi-structured interviews coupled with thematic analysis. Previously, researchers have argued that rather than using thematic analysis as a process to supplement other methods, it is itself a distinct method which can be used to answer research questions and translate findings.<sup>49</sup> We describe the data collection further in Sect. 4.1 and the analysis in Sect. 4.2. Then, we describe the validation in Sect. 4.3, and authors backgrounds as they pertain to positionality in the data collection and analysis in Sect. 4.4.

### Data Collection

In alignment with the research questions, we established a protocol using several established items derived from others' prior research,<sup>59,70</sup> as well as introducing newly developed prompts driven by Zaki's components of empathy. An overview of the protocol is described further in Table 1. After receiving Institutional Review Board approval, semi-structured interviews were conducted using Microsoft Teams with a total of six biomedical engineering faculty in the summer of 2021.

The faculty were purposefully selected based on their role as course coordinators, instructors, or both in classes which enhanced lectures with learning activities that are thought to cultivate empathy.<sup>25,44,51,54</sup> Subjects included both traditional (e.g.,

design) and non-traditional (e.g., storytelling) content offered at different stages of the BME curriculum, as depicted in Table 2. All the faculty were affiliated with the BME department at a large, R1-designated university in the Southeastern region of the United States. In total, there were five participants interviewed that self-identify as male and one that self-identifies as female. The faculty varied in professional level and years of experience teaching, from a Lecturer who worked at the institution for 3 years to a Professor who worked at the institution for 35 years.

### Data Analysis

To analyze the interview transcripts, we applied thematic analysis to identify and report patterns, using the procedure described by Nowell *et al.*<sup>49</sup> The process broadly consists of: (1) Gaining familiarity with the data; (2) Creating initial codes; (3) Searching for themes; (4) Reviewing themes (5) Defining and naming themes; and (6) Report generation, including documentation of rationales for theoretical, methodological, and analytical decisions.

We utilized Dedoose qualitative software to organize and analyze the interview transcripts. The first and second authors independently engaged with the data, to familiarize themselves with the content, and to deductively devise a coding scheme. The researchers started with a provisional list of descriptive codes based on the theoretical framework and research questions in the initial phase. New codes were iteratively added as needed, refining and clarifying definitions, until each reached theoretical saturation. Then,

**TABLE 1. Questions included in the semi-structured interview protocol.**

Section	Sample questions
Opening Statements	Structure and purpose of the interview Interview logistics
Background	How long have you worked in academia? What field or fields have you taught or conducted research in?
Overview of Perspectives on Empathy	How do you define empathy? How much importance is placed on empathy...in your field? In your research? In your profession? In your teaching? How do you think empathy aids in the formation of connections with others?
Students' Empathy	What learning activities do you use to foster empathy in your class specifically? How do you typically see empathy develop over the course of the semester? How do you feel empathy could be better taught to engineers?
Educators' Empathy	How do you see empathy in the context of faculty/student interactions or relationships? What are some challenges of being empathetic as an educator? How might empathy training help you in the classroom?
Closing	Is there any other information you would like us to know about empathy development for students or faculty? Thanks and concluding statements

**TABLE 2. Overview of the courses that the BME faculty interviewed teach.**

Course	Description	Year typically Taken
Intro to Biomedical Engineering	Introduces students to the field and department. Foundational topics such as design thinking, reflection, and entrepreneurial mindset are introduced. Team-based design activities are included.	1st year
Problems in Biomedical Engineering	BME problems in industrial and clinical applications are addressed and solved in teams using problem-based learning methodologies.	2nd year
Introduction to BME Design	Students are introduced to the elements of process of good medical device design. Involves a semester long, team-based design project.	3rd year
The Art of Telling Your Story	This course uses a story-driven learning approach. Students learn to integrate, reframe, and make meaning of their diverse experiences in order to tell their unique stories in a variety of ways for different audiences.	3rd/4th year
Capstone Design	Team-oriented design project in BME, incorporating engineering standards and realistic design constraints. Includes introduction to relevant regulatory, intellectual property, and business management topics.	4th year

they met to negotiate, consolidate, and finalize the codebook before labeling the statements.

The first author coded the entire set of transcripts using the codes defined, but modifying the description, when appropriate. Upon completion, the second author then separately coded the transcripts using the same labels and definitions. Together, they obtained a pooled Cohen's Kappa of 0.76, which Landis and Koch describe as a "substantial" agreement.<sup>38</sup> After coding was complete, the authors then met to discuss and negotiate on the final definitions, labels, and to discuss the emergent themes.

Although faculty interviewed may have taught multiple courses throughout their careers, each primarily had their own focus. This ranged from introductory courses to capstone, as well as design classes, and even faculty for non-traditional story driven learning. All of the interviews were audio-recorded and then transcribed verbatim by a third party.

#### *Validation*

To ensure pragmatic validation, we considered the theoretical constructs that contributed to students' development empathy and its alignment with the empirical reality of the classrooms. This also lent itself to our use of Zaki's framework and its application to the topic of investigation to provide theoretical validation. We also sought to obtain ethical validation through the social realities of the faculty investigated and their experiences in the classroom. All of the methods were well-documented to promote process reliability, chronicling thinking and each decision

made with a reflexive log trail.<sup>66</sup> We also tried to mitigate subjectivity which could affect the interpretation using independent code and theme development and negotiation.

#### *Positionality of the Authors*

Previously scholars have described the importance of examining one own's beliefs, judgements, position, and experiences when conducting qualitative studies, since it can influence the research process and conclusions drawn.<sup>18,57</sup> Accordingly, we want to acknowledge the backgrounds of the authors involved in the experimental design and participant selection, data collection, and data analysis. The first and second authors were responsible for planning the overall investigation, and for establishing the interview protocol.

The first author conducted the semi-structured interviews and led the analysis efforts. She is a post-doctoral fellow who has not previously taught courses at the institution. As such, she was unfamiliar with the content and learning activities employed prior to the interviews.

The second author was not involved in the data collection but was involved in the data analysis. She is an actively teaching faculty member who has previously taught sections of some of the courses under investigation. As a result, her familiarity with the subjects brought another perspective to the interpretation as an inside member of the BME teaching community. It also led to knowledge that informed participant selection.

The third author is a faculty member who also taught courses at the institution. He was involved in the conception of the project. However, he was not involved in the data collection or analysis described. He was invited as an author to transparently provide critical questioning to these efforts.

## RESULTS

Upon triangulation and negotiation, we obtained a total of 12 codes, which fell under the umbrella of six themes, as described in Table 3. The major themes that emerged from the interviews were defining empathy, identifying empathy, creating value, encountering barriers, learning activities, and undergoing transformation. The subsequent sections describe each theme in further detail, highlighting contributing aspects of the underlying codes and providing examples of each.

### *Defining Empathy*

The theme of defining empathy refers to the way that faculty members described and conceptualized the construct. Although scholars may consider empathy in terms of its cognitive, emotional, and action-oriented components, many faculty defined empathy more broadly and typically just considered it in alignment with Zaki's definition of thinking about others. As one participant articulated, "*I would define empathy as your ability to understand what other people's feelings [are] or what they're thinking, putting yourself in their shoes.*"

Another faculty member stated:

*I would define it as how you can realistically put yourself into somebody else's situation or their head in an effort to try to understand where they are so that you're a little bit better prepared to meet them where they are.*

### *Identifying Empathy*

Identifying empathy describes how faculty viewed empathy in practice, through interactions, or observed its development. Unlike the theme of defining empathy, all three components of Zaki's framework were present in the responses. This often included providing examples that demonstrated specific components of empathy along with anecdotes and instances that illustrated compounded aspects of empathy.

Faculty frequently took on others' emotions or felt their distress, in regard to both students and other instructors. One participant described how they felt

when considering a students' reaction to a bad grade they received:

*I was like, 'Okay, they're in a spiral. They are in a stress spiral here.' I acknowledged this. I've experienced this. I can share that experience. I can find common ground. I was like, 'You do not want to take an incomplete in this class.'*

They also mentioned how their own empathy and opening themselves up to their students helped to make them stronger educators, and to form connections. As one participant commented:

*And so, I think showing vulnerability and trying to communicate with them that 'I remember what it was like to be a student and I made mistakes too,' and be patient with them and those kinds of things, and give them as much flexibility as possible, I think works well.*

Others described how empathy was valuable in their interactions with students, and how support and encouragement could strengthen morale and disciplinary ties. One faculty member shared a story about a student who was struggling and the positive effect of engendering empathy:

*One of the things I say is, 'Don't ever let anyone tell you you're not cut out to be an engineer.' [...] There's a student who the message is clearly resonating [with] [...] She started coming to all my office hours. She was really struggling. And so, I tried to understand what her situation was, but mainly I was just working with her [...] and just helping her understand the material and giving her a lot of support and say[ing], 'Of course you can do this.' [...] Then towards the end of the class, she was still struggling, but she was going to pass. And she said, 'Well, [Faculty Name], I'm going to crush the final and I'm going to get an A in your class.' [...] Turns out she had. [...] I opened the door by positing a situation that I know some of them are going through and making sure they know that I'm supportive of them and that I don't want them to transfer. I'll work with them to the greatest extent possible to help them achieve whatever they want to.*

In addition, the participants gave examples of the cognitive aspect of thinking about others, particularly in the context of engineering. As one individual remarked, "*The idea is, if you're going to design something for somebody, you really need to understand their*

**TABLE 3. Codes applied and themes which emerged.**

Theme	Codes	Description
Defining Empathy	EmpathyDefinition	Recognition or definition of how the participant defined the construct of empathy
Identifying Empathy	EmpathySharing	Vicariously taking on the emotions we observe in others, personal distress; Emotional comprehension of and reaction to others' positive and negative emotions
	EmpathyThinkingAbout	The cognitive component of empathy, considers explicitly considering someone else's perspective or needing to think about others' need and perspectives
	EmpathyCaringAbout	The others-focused drive to take action, which aligns closely with compassion
	EmpathyOverlap	Describes two or more components of Zaki's empathy model, specifically sharing, thinking about, or caring about others
Creating Value	EmpathyValue	Refers to empathy as a general construct and why it is valuable in the practice of engineering and for individual/group dynamics, communication, and relationships
Encountering Barriers	BarriersFaculty	Refers to the challenges, obstacles, and barriers faced by faculty, including their experiences faced with others, knowledge deficiencies, skill gaps mentioned, and a lack of empathy and/or understanding of its value
	BarriersStudent	Refers to the challenges, obstacles, and barriers faced by students, including their experiences faced with others, knowledge deficiencies, skill gaps mentioned, and a lack of empathy and/or understanding of its value
Learning Activities	LAMethods	Description of the learning activities or pedagogical tools and their implementation to foster empathy in students
	LAPurpose	Intended outcomes of the learning activities or pedagogical tools
Undergoing Transformation	TransformationFaculty	Refers to the changes that occur in an individual faculty member over time, their development and/or personal growth
	TransformationStudent	Refers to the changes that occur in an individual student or group of students over time, their development and/or personal growth

*point of view and try to understand what they're struggling with."*

Thinking about the students' perspectives, emotions, and needs also lead to instances where the faculty took supportive actions (conative empathy). As one participant shared:

*My office has a glass door, and it's in a main hallway [...] And so there've been probably a dozen times when I've seen students literally run out crying when I know that they're supposed to be in class. And so in those cases, I've either, stuck my head out the door and asked if they're okay, or I've sent them a follow-up email. [...] Also just everyday interactions and how I improvise pedagogy is, 'Hey, I can see, I can read on your face that you're having a bad day. You having a bad day is negatively impacting your learning. Let's just make this deadline flexible because my goal is your learning.' To me, I really try and focus on the students'*

*learning as my goal, and that necessitates me continuing to improve my empathic sense of my students and continuing to bring that into the classroom, both at a big picture design, but as well as at a micro interaction level.*

### *Creating Value*

Creating value considers the utility and importance of empathy for educators, their students, the BME profession, and/or society. Instructors spoke of how it could motivate students to act and to give and receive support in the community. As an example, one student was driven to establish an organization to provide housing after a close friend struggled with homelessness during the COVID pandemic. Participants also touched on how empathy could help individuals holistically lead "better lives" through having empathy for themselves and others. As one participant stated:



*I think if they are working with clients, I think being able to really fully understand someone else's experience will allow them to be more successful creators. I believe if they are leaders and they want to support the development of a team, empathy is crucial. I think if they want to have a meaningful life where they have rich relationships among friends, and family, being able to understand and to extend a sense of generosity that is so inherent in empathy is so important to having a full life. So I think it matters professionally, personally, emotionally.*

Faculty also discussed how empathy could be beneficial to resolving conflicts and to consideration of others' perspectives, needs, and values. In the case of neurodivergent students, faculty described how personal experiences with friends or family members, either their own or as mentioned by their students, evoked empathy and compassion for others. They emphasized that empathy could improve teamwork and could lead to support when facing challenges or coping with issues, such as imposter phenomena or discrimination. As another participant detailed:

*They're very hard on themselves, and it's an extremely stressful environment. So they can start suffering from things like imposter syndrome and stereotype threat. That could probably lead to mental health challenges. I think if they have empathy for each other, that can improve. They can support each other through these challenging times. They will probably be better teammates. So much of what they do in engineering education and in the real world is centered on teamwork.*

While most faculty members gave examples of empathy across a range of situations and contexts, they also depicted specific instances of empathy in the context of engineering. As one faculty member pointed out:

*As engineers, we're problem solvers. We're supposed to be creating solutions to society's problems, technical problems, stuff like that. And the only way to know how to solve a problem properly is you've got to talk to the people with the problem and figure out what it is that they actually do need.*

They also mentioned how empathy informed their role as educators, allowing them to understand their students needs, and strengthening their personal and professional growth. As one participant expressed:

*It's very important because, as I mentioned before, without it, as I was lacking earlier in my career, we*

*tend to make assumptions about them that their...The whole point of being an educator is to help people flourish and learn something that they didn't know before. So, of course, if you're doing it right and to do that well, you want to challenge people, right?*

Others considered empathy as critical to making connections with the students, as useful for understanding them to help them achieve success, and described how empathy shapes engagement with the discipline. As one participant shared:

*I think when people are empathetic with their students, they can know them as real people, beyond their GPA and beyond how they show as a student. And I believe that is what makes all of this meaningful, is it's not only the exchange of information in the classroom, but it's the relationships that you build, it's watching them feel cared by you, believe in themselves because you believe in them. And to watch them stand up straighter and be able to go into an interview with a greater sense of self. And I just think that is the best part of all of this.*

Empathy also served the faculty members as role models, who sought to encourage positive environments and ideals. One interviewee articulated the challenges of BME and how opening up to the students could help to cultivate relationships with them and to inspire their perseverance:

*This is a really hard program. These students work so hard, they care so deeply, they want to succeed, they want to see themselves in their professors and in their role models. [...] If a professor [...] or a faculty member could make the choice to share a story where they were less than perfect, that's such a gift to a student. Then, they can recognize themselves in their professor as opposed to, 'Oh, they're perfect. They never struggle. This is all business. They don't see me as a person.' And I also think you work hard for people who you believe care about you. So I think that could also impact the level of commitment and the level of support. I mean, it's who you do things with as well as what you do. So I think it's critically important.*

### *Encountering Barriers*

Obstacles occurred in many forms for both faculty and students in terms of knowledge deficiencies, skill gaps, and issues with displaying or cultivating empathy. Given that empathy relies on a particular world

view and epistemic beliefs, it could be hard to articulate or internalize. It was mentioned that as a result of the emphasis on logic and analytical thinking in engineering, other faculty and/or students may not always see the value of empathy. As explained by a faculty member:

*I don't really see a lot of emphasis on it in terms of the faculty who teach engineering thinking that that is something that they're responsible for or to think about. There's a lot of pieces and facts and figures and skills and technical skillsets.*

Faculty interviewed described that to incorporate empathy or adapt it into teaching and learning required viewing it as more than a box to check. Instead, it entailed a process of working together to change foundational views and appreciate its necessity. For those faculty who felt like they already had empathy and demonstrated it to students, they provided descriptions of unanticipated side effects empathy could cause, from being taken advantage of to the toll it took on them. They detailed how, as a result of the connections formed, they may receive multiple requests from students to write recommendations or requests for flexibility with assignments and grades. To mitigate such experiences, they mentioned needing to distinguish between empathy and sympathy for the sake of student growth. Alternatively, others spoke about just having a lack of bandwidth, as one faculty member mentioned:

*I think being empathetic means slowing down a little bit and taking the time to ask questions, to try to get to know your students and to give them opportunities to share stuff with you and share. You should be vulnerable with them and share stuff with them as well. That takes time and energy. And a lot of times we're just trying to get through the day, and we end up going through the motions.*

The participants also spoke about it being especially difficult to get to know students in larger courses, where there were fewer opportunities for more personal interactions. As one participant described:

*I think some of the major challenges are the numbers of students that one has, or could have potentially....More often than not, in this class I'm teaching there's well over a hundred students. And I don't get to know, or don't have the opportunity to get to know, many of the students in the class and I think that's one of the more frustrating parts is that their names on a spreadsheet, more often than I could put a face to that name. And that's the*

*frustrating, and challenging part, just a numbers game. And lack of ability to devote more individual attention to students.*

Likewise, even in courses where empathy was covered, there was often a range of experiences. While some students internalized the material and value, others took it too literally, resulting in displays that suggested they may have listened without truly getting the point. One faculty member shared how learning activities shaped empathy but it might not have gone as anticipated:

*It increases in volume. It's like a vector. Everybody's vector gets longer. The magnitude of empathy increases. [...] It doesn't always go into the direction that I would expect. The example I give with that, we did this project last year [...] where they were designing something [...] for the people of Chad. And one group really did a good job of empathizing, understanding the lived experience, that religion and belief are really important to people there and that [...] Unless it respected all those religious beliefs, people weren't going to do it. I'm like, 'This is fantastic. This is fantastic. This is fantastic.' Then, what comes out on the other end [...] Their solution was, 'We are going to tell people. We're going to give people this device to filter water.' I'm like, 'Good. How are you going to get them to use it?' They're like, 'We've solved this. We thought about that.' I'm like, 'This is empathy in practice. You're considering not just give this to somebody and let them use it. You're considering how to engage with people.' They say, 'We're going to tell them that we were sent by God, and this device was sent by God.' I'm just like, 'Oh, no. Oh, no.' It was this clear, deep empathy. But that first level of empathy, of understanding the experience. There was not that next level of, 'Okay, how do I engage with this other person's lived experience in a way that is respectful and appropriate and doesn't make assumptions?'*

Another faculty member mentioned how instances of a lack of empathy further reinforced the need for including empathy in the curriculum:

*[...] in the last two offerings of this course, there has been some displays of lack of empathy in group presentations. They certainly weren't intentional, but really point out the need for doing these type of exercises. Where you get individuals that clearly are having more difficulty than others, recognizing what the needs of the users are. Again, a level of arrogance and not understanding, a lack of*

*appreciation. It kind of shows that this is a needed exercise. And that it's more than...This isn't the last time they're going to have to see or experience this. Cause it's something that takes time to develop.*

Several instructors described how engineering students might be prone to focusing on accomplishing their goals at the expense of considering what could be the most valuable for others. As a participant detailed:

*There's definitely some students who are so focused on getting through the project and making their vision a reality. We almost can't help but brainstorm, when we think we understand a problem, it's so easy, especially for [Institution Name] students that are incredibly smart and talented and creative, we almost immediately, so often, the students haven't even selected a final device yet to study, much less any kind of understanding of the people who use it and are affected by it. They already are asking me, well, could I do this? What if I put a laser on it? You're like 'You don't even know anything yet. Just calm down'*

### *Learning Activities*

The theme of learning activities involved the gamut of learning activities that faculty employed in the curriculum and the rationale for their inclusion. Although empathy was considered central to design, learning activities were deployed throughout the BME curricula in additional places, from introductory classes through senior capstone courses. As one faculty member described:

*In our intro class, we do a lot of empathy. You have to interview an undergraduate senior or junior, somebody who is you in the future. That's an empathic exercise. You have to go do all these activities around campus, where you meet different people. Go to our chairs' office hours. That's an empathic exercise because it's very easy for you to think, 'This is the person who is in charge of the program. That's all they do.' But the humanizing aspect of actually interacting with them and empathize and seeing and understanding why they scheduled their office hours for students in the way that they do, because they are that busy. It's not a lack of care. It's a lack of time in the day and that type thing.*

Others mentioned different kinds of activities such as storytelling, role playing, team activities, developing

personas, creating user stories, observation, case studies, and interviewing different stakeholders. Storytelling was seen as valuable not only for the more overt benefits of aiding in enhancing communication skills but also in terms of empathy, as one faculty member mentioned that “*Storytelling is the medium by which we grow empathy. It is the offering of a shared experience that allows people to walk in another shoes, to understand another person's perspective.*”

The participant further elaborated on the power of sharing and its ability to strengthen bonds and find points of connection with others:

*What I'm doing is like, 'Oh, now I feel like I know something about you. There's a different level of connection.' And that's the basis of empathy. So we're listening to stories with that opportunity to say, 'Me too. I've had an experience, and it doesn't have to be exactly that experience, but it's a place where I can now see myself in you.' And that is the basis of an empathetic relationship.*

Faculty spoke to how specific examples could serve to further enhance understanding and encourage students to consider the impact of their work. One instructor illustrated how a humanizing example could strengthen the lesson:

*One of the ones that they do, comes up quite often, is the pulse oximeter. It's just, it doesn't really do well when people have dark skin. And so, it can have huge consequences for somebody that, say they have COVID. One of the key indicators that you're in trouble is that your oxygen levels have dropped and if its not working for folks who have darker skin, and in general have less likely good outcomes. [...] If you tell a story of an individual who's actually died or hospitalized because of this, then actually it tends to generate a much more emotional response and a stronger connection with these ideas.*

Participants also mentioned the benefits of observation, such as shadowing physicians or perhaps using videos to supplement instruction. An as example, one instructor spoke to how employing videos to prepare students' on how to approach interactions, could demonstrate the value of conscientious planning and communication before they were sent out to interview technical experts:

*I think you just need to give them examples of how to connect with people, specific examples. Almost like, we show them YouTube videos of good examples of how to ask questions and bad exam-*

*ples of how to ask questions so that they can see that there are better ways to do it. There's ways that you can eliminate bias, and there's ways that you can avoid asking simple questions that elicit a yes or no answer. Instead, you go after a question where they have to tell you a story to answer it, and stuff like that.*

The rationale for these learning activities was often rooted in a desire to promote empathy, compassion, and listening. As one faculty stated, “Discomfort, excitement, radical changes in perspective and belief...that we can reflect on to appreciate the why empathy has a role in what we are doing and why empathy has a role in their learning.” Another faculty member commented, “I expect them to have a greater sense of compassion and generosity and the ability to listen and the invitation to know themselves.”

### *Undergoing Transformation*

Transformation was a theme that emerged throughout the interviews as the participants shared instances where both students and faculty developed additional skills, insight, or empathy over time. Faculty frequently spoke about their personal growth, as articulated by one instructor:

*Just all of these things I think increased my empathy a whole heck of a lot, where now I understand, I feel like I understand a lot better what they're going through, but I also am humble in the sense that I know that I don't know 99% of it. So I need to ask questions and be open and try to make them feel comfortable in sharing with me and just asking questions that can open a line of communication. So I try that. From where I started to where I am now...huge differences.*

Increases in the faculty members' empathy also informed their pedagogical approach, learning activities, and viewpoints considered. As one participant mentioned:

*Now that I see so many students, I have such a rich chance to practice this and be exposed to so many different perspectives that there's actually a lot more tools in the arsenal now that I can go, 'Oh, that didn't work. I remember a student that this worked on.' And I can try to maybe come around and approach them from a different direction.*

While sometimes this growth came directly from student interactions, experiences, or departmental efforts towards faculty development, other times it came

from their teaching assistants (TAs) or even encounters with family members. One participant described that:

*The best empathy training I get isn't from faculty development. It's from my TAs, because they're so much closer to that. My empathy trainers are my TAs. I would value that because the lived experience of a human being changes constantly. Society changes constantly. Our students, every year they come in and they have a different set of lived experiences. I need to continue to learn.*

Students' transformation was often described broadly as being successful, as observed by faculty. Specific examples helped to elaborate further, as one participant detailed:

*We had a student who wanted to develop something. [...] And she started asking people that she knew who were clinicians and nurses and doctors what [...] would actually make people's lives better. [...] And one need that came up was that basically there are quite a few types of paraplegia in which basically having a bowel movement is very difficult. And she was like, 'Well, I didn't think I was going to be making a device that helps paralyzed people poop,' but she did. And so it's an automated, perfectly safe, self-administered enema device that has all the safety features and convenience features built in. And even though the initial cost of it is higher than just a normal enema device, it could potentially save people a lot of money by not having to necessarily hire a caretaker as many hours a week and things like that. So it's a device that, no one would ever have come up with that just by thinking of the cool biomedical devices that people want to talk about, but it comes from a real need, and she won awards for her innovative design and it helped her get her job that she wanted.*

## DISCUSSION

This study answers three research questions focused on how our participants perceive empathy, its role in undergraduate BME education, and its impact on professional growth and interpersonal relationships. We want to call attention to the disconnect between what educators perceived as empathy in the theme of defining empathy and the examples they gave and the themes that emerged. Although the definitions only considered Zaki's component of thinking about others, the faculty members spoke about empathy observations and encounters using language that encompassed

affective and action-oriented components of sharing and caring about others as well. In the sections that follow, we answer each RQ through the themes that emerged in the context of Zaki's framework.

*RQ1: Why is empathy critical to BME students?*

Empathy is rarely defined explicitly within the BME curriculum. Notwithstanding, several of the student outcomes for engineers defined by ABET do correspond to fostering empathy. For example, the "ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts"<sup>1</sup> can follow from thinking about others. Likewise, students' "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"<sup>1</sup> may entail all three components of empathy from Zaki's model. The responses from the faculty interviewed highlight aspects of ABET's key measures and further argues for the need for empathy as part of pedagogy and practice.

Faculty depicted BME students as highly intelligent, competitive, and driven, typically prone to taking an analytical approach that would incline them to detach from their work. Yet, as encompassed by the theme of creating value, an empathic mindset was seen as critical for engineers not only in terms of thinking about disparate stakeholders and design solutions but also for personal and professional development. Contrary to the prior findings from interviews with a range of engineering faculty where empathy was seen as "valuable, but not absolutely necessary" to being a "good engineer",<sup>59</sup> BME faculty in this investigation did see empathy as vital to success in the field. They described how it should not only inform practice but that it could allow students to develop "rich relationships" and interactions beyond the discipline.

The BME faculty articulated the role of empathy in enhancing communication and intercultural awareness, as others have described for aerospace and mechanical engineering students.<sup>67</sup> They mentioned that consideration of systemic inequities and income disparities could benefit discussions on design in BME, especially since projects often included the creation of devices for remote or rural areas or low-income patients. The theme of undergoing transformation encapsulated how empathy also helped students to reframe their cognitive processes to not just think about others, but to emotionally connect with the struggles others face, and to take action (as described by caring about in Zaki's framework).

Personal engagement encouraged students to identify problems they were unaware of, and it informed solutions with more impact that were better aligned with human needs. This aided in innovation, as demonstrated by the example about the development of the enema device — although this was not the only example faculty provided along these lines. Such descriptions spoke to discovery, students' recognition of opportunities, problem solving, and consideration of the value they could contribute to others and society.

The stories shared and comments made align with prior literature that describes how empathy may bolster perspective-taking<sup>50</sup> and that it can serve as a mediator for social justice<sup>2</sup> and for reducing prejudice in intergroup contact experiences. Contrarily, individuals with low empathy levels and color-blindness, a lack of awareness of race or the systemic implications, can negatively impact cultural sensitivity, resulting in an ingroup bias and affecting relationships with others.<sup>10,12</sup> Accordingly, higher levels of empathy may serve biomedical engineers to better understand the impact of decisions, to consider how choices may impact others and society, and to enhance their social interactions.

*RQ2: Why is empathy critical to BME educators?*

Power relations play a role in interpersonal dynamics and interactions and have been shown to influence students' views towards themselves in the discipline.<sup>63</sup> BME educators are uniquely positioned to influence not only the content students are taught, but also to serve in a leadership role. As described by the theme of creating value, faculty members considered empathy beneficial to themselves and their relationships. They touched on how expertise on a subject is an important prerequisite to teaching, but that it alone is insufficient to ensure students' performance and engagement.

The importance of empathy in teacher-student interactions and multicultural classrooms has been discussed previously.<sup>5</sup> In this study, empathy served the BME educators to better understand students' needs and perspectives and helped to prevent them from making assumptions. Throughout the interviews, the faculty provided examples in which they observed or understood empathy to play a role, as described by the theme of identifying empathy. While several faculty were more focused on the applications to engineering and how empathy could inform problem solving, even the faculty who took a more pragmatic approach provided personal examples where it informed their actions towards students. They described instances where empathy informed how they reacted, highlight-

ing examples of offering leniency and flexibility when needed and refining lessons to ensure students' comprehension. Such narratives demonstrated extending perspective-taking (and thinking about) into other forms of empathy (e.g., caring about).

Additionally, empathy was considered useful in the context of building a rapport and serving as a role model. This aligns with literature describing empathy's utility in mentoring relationships and the value of mentors sharing experiences and understanding how they are interpreted to provide targeted advice.<sup>19</sup> The notion of circle practice describes how dialogue can structure communication to elicit connections between context and content.<sup>61</sup> Circle practice has been shown to be valuable in academic settings and can induce "development, community organizing, emotional healing, conflict resolution, political dialogue, team building, collaboration, and organizational planning".<sup>11</sup> Instances where faculty engaged in circle practice or offered guidance to students, particularly to students in distress, were enhanced by making themselves vulnerable to share their own experiences, and were met with positive outcomes. Exposing uncertainties and sharing emotional difficulties is often considered useful for engendering empathy and establishing supportive environments.<sup>7</sup> Through recognition of students' concerns and the barriers they encountered, the faculty opened up about their own insecurities and failures, resulting in meaningful moments not just for the students but also for the educators. Going forward, we suggest BME faculty consider the value of doing so and employ it in their own interactions.

The theme of undergoing transformation described the changes that occurred in faculty over the course of their careers, as they shared experiences that altered their thinking, affected them emotionally, and which shaped their pedagogy and exchanges. Exposure to different perspectives and students gave them additional "tools in the arsenal." In turn, this informed how they proceeded to try to allow students to maximize the value of the material and to improve engagement.

However, as depicted by obstacles for faculty (which fell under the umbrella of the theme of encountering barriers), empathy can yield both positive and negative outcomes depending on the context. While there were multiple positive instances where empathy enhanced communications, relationships, and meaningful connections with students, it could also bias decisions, and result in feeling taken advantage of, stressed, and burnt-out. They noted a lack of time in the day and an inability to give students individual attention, particularly in larger classes. Instructors spoke about the struggle of balancing expectations and academic rigor

with flexibility. They divulged that showing too much understanding and empathy could prevent them from covering everything that they intended. These potential drawbacks are something that should be considered to encourage instructors to set boundaries and manage expectations to allow them to maintain balance as well.<sup>33,36</sup>

It can be important to promote emotional, psychological, and social well-being for both educators and students. Personal support from faculty, staff, and peers may play a role, but awareness and destigmatization of mental health issues and encouragement of a supportive culture are critical too.<sup>21</sup> At the institutional level, well articulated policies and systems to identify and treat depression, anxiety, and stress in addition to an increased awareness of risks, can establish more positive learning and workplace environments.<sup>21,43</sup> When doing so, it is recommended that such lessons begin early on in the career and focus on "personal interaction and discussion, not online modules".<sup>21</sup>

In the future, faculty mentioned that they would also appreciate it if their departments and institutions offered empathy training and development for them. Several faculty touched on the value of offering strategies for them to cope with students facing larger issues, to recognize their own blind spots, or to deal with different personality types. Alternatively, sharing suggestions on assignments or ways to cultivate empathy could serve to enhance their instruction. Other scholars have also described the value of departments coaching faculty and providing support for them to incorporate inclusive practices into their pedagogy.<sup>9</sup> Learning about what others have implemented or how they tried to approach empathy and interactions in their classrooms could make educators more mindful of methods they could employ.

*RQ3: How can specific learning activities promote empathy development in students?*

All of the faculty interviewed thought empathy could be cultivated, or that it was at least partially a skill which could be taught and understood through intentional effort. Lessons and learning activities could raise students' awareness of the concept and could enhance its development. The practice of empathy could also alter students' perceptions and allow them to give it greater consideration in their interactions and approach towards others. However, they also touched upon worldview and environment and how they could inform an individual's stance towards empathy, their basal levels of it, and their internalization of the concept. This finding from faculty in BME extends what was observed previously in students from mechanical

engineering, in which the authors highlighted the role of epistemic assumptions (e.g., core beliefs) and suggested empathy required affective development processes as well.<sup>63</sup> Additionally, this expanded understanding of empathy aligns with literature that describes empathy as a state or “way of being”.<sup>59</sup>

Among the components of empathy described by Zaki’s framework, only caring about others can be observed, since it is demonstrated through visible behaviors and actions.<sup>2</sup> Nonetheless, in our study, faculty were able to describe the other components of empathy as interpreted through interactions where students described or produced artifacts which demonstrated sharing or thinking about others. The theme of learning activities covered a lot of specific implementations of different approaches to develop empathy throughout the curriculum. Faculty noted that certain activities seemed to be better suited to strengthening different components of empathy. However, learning was contingent upon reconciling the disconnect between the self and pluralistic consideration of others.

Including interviews with stakeholders, observations, or case studies into the curricula helped students to think and care about others and to share their emotions, developing compassion and intercultural awareness. Yet, for students to make sense of what they learned, reflecting on their individual values and knowledge relative to what they gathered from others, required critical analysis. As scholars describe, “critical analysis of assumptions, perspectives, values, and frames operating within the context of the engineering work at hand—particularly those which result in marginalization, oppression, or other forms of often invisible suffering”<sup>2</sup> is necessary for “meaningful engineering work.” Accordingly, when seeking to develop broader values from empathy pertaining to social justice, others suggest that it is important to consider students’ orientation and to employ a micro to macro focus,<sup>25</sup> raising potential risks and issues surrounding power dynamics and structural inequities.<sup>65</sup>

While we will not go into detail on each learning activity, since the benefits of many of these have been well described in the literature already,<sup>42</sup> we will focus on story-driven learning since it may be less familiar in the context of BME. In the institution examined, storytelling was used to engender empathy, as the focus of one the more non-traditional courses. The faculty member who led the course mentioned how storytelling helps individuals to articulate their own narratives and to recognize defining moments by reframing and integrating prior experiences, empowering them to see their own capability even through challenges. It also allowed students to practice active listening and to

make connections with each other, providing support and encouragement. Going forward, it would be valuable to delve further into this course in particular to explore students’ development and growth through these kinds of learning activities.

Social interactions, lessons, and direct instructor advising can also enhance concepts like compassion and care. Previously, others have described that trust, communication, and collective empathy can moderate relationships and improve product development.<sup>3</sup> Similarly, faculty in BME gave accounts of teamwork and how empathy enhanced consideration of others. Students’ appreciation of others’ unique approaches to problem solving helped them when working in pairs and groups. Faculty also observed peer mentoring, which later students mentioned was valuable to assimilating and accommodating knowledge. When instructors encouraged students to disclose personal situations which may affect their productivity to teammates (e.g., the loss of a family member), it enhanced communication within the group. Observable behaviors surrounding empathy came out of these interactions with others and illustrated the use of empathy, even when it was not directly covered within the learning activity.

Overall, we want to emphasize that empathy is a complex construct. While faculty could point to examples of its value and application, there was also the caveat that it is not necessarily something that can just be inserted into a course and then understood and applied. We suggest educators intentionally integrate it throughout the undergraduate curriculum, to promote its value through a combination of accumulated experiences and activities.

## LIMITATIONS AND FUTURE WORK

The present study had several limitations which should be mentioned. The participants were purposefully selected faculty known to lead instruction using a range of learning activities, rather than to seek out those offering more traditional lecture-based courses. In the future, it might be beneficial to also include faculty who may not utilize empathy to provide a contrasting or complementary view and to yield additional insight into the perspectives of these faculty. Selection of the participants based on those leading specific courses with the inclusion of such learning activities also limited the diversity of the faculty interviewed. In addition, all of the BME faculty interviewed were from a single institution, and the local and departmental culture and experiences could result in different interactions. Going forward, including BME faculty from additional backgrounds

and sources may yield further knowledge about the potential of various learning activities, the different lived experiences of those interviewed, and the value of empathy. As mentioned, one of our team's future research goals also includes extending these findings to further explore the role of story-driven learning and student constructed narratives in cultivating empathy.

## CONCLUSION

Often, diversity is considered only in terms of “what we can see and count” (representational diversity<sup>35</sup>), but it is important to think more holistically about practices and to build inclusive cultures into the BME mindset. The capacity to engage diversity effectively (interactional diversity) and how an organization or institution enacts this commitment (structural diversity) are also critical to effective learning and praxis.<sup>35</sup> Training, dialogue, and support can allow students to learn more about empathy, but modeling it as an educator and employing it in communication are equally vital.

These findings and discussion highlight the value of empathy for higher education students and faculty. The recognition and promotion of empathy within BME is important not just to establish more meaningful, relevant, and impactful designs, but also for professional development and connections with others. However, the results also point to there being a spectrum of understanding and internalization of empathy. Empathy is a complex skill that takes time to develop, and as such, is probably best fostered by infusing empathy building learning activities throughout the curriculum. By embedding learning activities into multiple BME courses, educators and administrators can help students' to develop their knowledge and refine their empathic abilities to result in engineers with greater intercultural awareness and sensitivity, and to create more inclusive mindsets. The application of this environment could lead to the attraction, retention, and empowerment of a more diverse group of students who are better able to connect with each other and broader society.

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## REFERENCES

- <sup>1</sup>ABET Engineering Accreditation Commission: ABET 2022-2023 Criteria for Accrediting Engineering Programs, Baltimore, MD 2021. <https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/>.
- <sup>2</sup>Afroogh S, Esmalian A, Donaldson J, Mostafavi A. Empathic design in engineering education and practice: an approach for achieving inclusive and effective community resilience. *Sustainability*. 2021;13(7):4060.
- <sup>3</sup>Akgün AE, Keskin H, Cebecioglu AY, Dogan D. Antecedents and consequences of collective empathy in software development project teams. *Inf Manag*. 2015;52(2):247–59.
- <sup>4</sup>Amari N. Social justice in counseling psychology practice: actualizing the ethics of compassion. *J Humanist Psychol* 2021;00221678211039968.
- <sup>5</sup>Anderson A. “I Was That Student”: exploring instructor experience of empathy amid identities in the classroom. Master's thesis, Oregon State University 2013.
- <sup>6</sup>Badescu V, Cathcart RB, Schuling RD, editors. *Macro-engineering: a challenge for the future*. Dordrecht: Springer; 2006.
- <sup>7</sup>Bartz DE, Bartz DT, Doctor J. Confidence, vulnerability, and empathy: friends to managers. *Int J Bus Soc Sci*. 2017;8(10):1–6.
- <sup>8</sup>Bergey BW, Kaplan A. What do social groups have to do with culture? the crucial role of shared experience. *Front Psychol*. 2010;1:199.
- <sup>9</sup>Billiar K, Gaver DP, Barbee K, Singh A, DesJardins JD, Pruitt B, Tranquillo J, Gaudette G, Winkelstein B, Makowski L, Amos, JR, Saterbak A, LeDoux J, Helmke B, Grimm M, Benkeser P, Segan LAD, Pfister B, Meaney D, Arinzeh T, Margulies S. Learning environments and evidence-based practices in bioengineering and biomedical engineering. *Biomed Eng Educ*. 2022;2(1):1–16. <https://doi.org/10.1007/s43683-021-00062-z>.
- <sup>10</sup>Bloom P. Empathy and its discontents. *Trends Cogn Sci*. 2017;21(1):24–31.
- <sup>11</sup>Boyes-Watson C. Seeds of change: using peacemaking circles to build a village for every child. *Child Welfare* 2005;84(2).
- <sup>12</sup>Burkard AW, Knox S. Effect of therapist color-blindness on empathy and attributions in cross-cultural counseling. *J Couns Psychol*. 2004;51(4):387.
- <sup>13</sup>Cassels TG, Chan S, Chung W, Birch SA. The role of culture in affective empathy: cultural and bicultural differences. *J Cogn Cult*. 2010;10(3–4):309–26.
- <sup>14</sup>Causadias JM. What is culture? Systems of people, places, and practices. *Appl Dev Sci*. 2020;24(4):310–22.
- <sup>15</sup>Cavanagh DP, Tranquillo J. Diseases, devices, and patients: exposing BME students to the patient experience. In: 2017 American Society for Engineering Education (ASEE) Annual Conference & Exposition.



- <sup>16</sup>Chen HL, Lattuca LR, Hamilton ER. Conceptualizing engagement: contributions of faculty to student engagement in engineering. *J Eng Educ*. 2008;97(3):339–53.
- <sup>17</sup>Chen G-M, Starosta WJ. A review of the concept of intercultural awareness. *Hum Commun*. 1998–1999;2:27–54.
- <sup>18</sup>Corlett S, Mavin S. Reflexivity and researcher positionality. *The SAGE handbook of qualitative business and management research methods*. 2018;377–399.
- <sup>19</sup>Cox E. For better, for worse: the matching process in formal mentoring schemes. *Mentor Tutoring: Partners Learn*. 2005;13(3):403–14.
- <sup>20</sup>Cuff BM, Brown SJ, Taylor L, Howat DJ. Empathy: a review of the concept. *Emot Rev*. 2016;8(2):144–53.
- <sup>21</sup>Daskivich TJ, Jardine DA, Tseng J, Correa R, Stagg BC, Jacob KM, Harwood JL. Promotion of wellness and mental health awareness among physicians in training: perspective of a national, multispecialty panel of residents and fellows. *J Grad Med Educ*. 2015;7(1):143–147.
- <sup>22</sup>Decety J, Yoder KJ. Empathy and motivation for justice: cognitive empathy and concern, but not emotional empathy, predict sensitivity to injustice for others. *Soc Neurosci*. 2016;11(1):1–14.
- <sup>23</sup>Fila ND, Hess JL. In their shoes: student perspectives on the connection between empathy and engineering. In: 2016 American Society for Engineering Education (ASEE) Annual Conference & Exposition.
- <sup>24</sup>Goleman D. Emotional intelligence, the 10th anniversary edn. New York: Bantam Books; 2005.
- <sup>25</sup>Guanes G, Wang L, Delaine DA, Dringenberg E. Empathic approaches in engineering capstone design projects: student beliefs and reported behaviour. *Eur J Eng Educ* 2021;1–17.
- <sup>26</sup>Herkert JR. Ways of thinking about and teaching ethical problem solving: microethics and macroethics in engineering. *Sci Eng Eth*. 2005;11(3):373–85.
- <sup>27</sup>Hernandez PR, Bloodhart B, Barnes RT, Adams AS, Clinton SM, Pollack I, Godfrey E, Burt M, Fischer EV. Promoting professional identity, motivation, and persistence: benefits of an informal mentoring program for female undergraduate students. *PLoS ONE*. 2017;12(11):0187531.
- <sup>28</sup>Hess JL, Carrillo-Fernandez A, Fila ND, Schimpf CT. Exploring how empathy manifests with/for teammates in a junior-level biomedical engineering course. In: 2021 American Society for Engineering Education (ASEE) Virtual Annual Conference & Exposition.
- <sup>29</sup>Hess JL, Fila ND, Purzer S, Strobel J. Exploring the relationship between empathy and innovation among engineering students. In: 2015 American Society for Engineering Education (ASEE) Annual Conference & Exposition; pp. 26–740.
- <sup>30</sup>Hess JL, Fore GA, Sorge BH, Coleman M, Price MF, Hahn TW. Exploring ethical development from standard instruction in the contexts of biomedical engineering and earth science. In: 2019 American Society for Engineering Education (ASEE) Annual Conference & Exposition.
- <sup>31</sup>Hess JL, Miller S, Higbee S, Fore GA, Wallace J. Empathy and ethical becoming in biomedical engineering education: a mixed methods study of an animal tissue harvesting laboratory. *Austral J Eng Educ*. 2021;26(1):127–37.
- <sup>32</sup>Ioannidou F, Konstantikaki V. Empathy and emotional intelligence: what is it really about? *Int J Caring Sci*. 2008;1(3):118.
- <sup>33</sup>Jennings PA, Greenberg MT. The prosocial classroom: teacher social and emotional competence in relation to student and classroom outcomes. *Rev Educ Res*. 2009;79(1):491–525.
- <sup>34</sup>Johnson DG, Genco N, Saunders MN, Williams P, Seepersad CC, Hölttä-Otto K. An experimental investigation of the effectiveness of empathic experience design for innovative concept generation. *J Mech Des*. 2014;136(5):051009.
- <sup>35</sup>Kardia D. Three approaches to diversity, equity, and inclusion. Kardia Group LLC. 2017. <https://kardiagroup.com/three-approaches-diversity-equity-inclusion/>.
- <sup>36</sup>Kennedy DR, Clapp P, DeLuca JL, Filtz TM, Kroon L, Lamberts JT, Oliphant CM, Prescott WA, Ray SD. Enhancing pharmacy faculty well-being and productivity while reducing burnout. *Am J Pharm Educ* 2021.
- <sup>37</sup>Korte R, Smith KA, Li CQ. The role of empathy in entrepreneurship: a core competency of the entrepreneurial mindset. *Adv Eng Educ*. 2018;7(1):1.
- <sup>38</sup>Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;159–174.
- <sup>39</sup>Leydens JA, Deters J. Confronting intercultural awareness issues and a culture of disengagement: An engineering for social justice framework. In: 2017 IEEE international professional communication conference (ProComm), 2017; pp. 1–7. IEEE.
- <sup>40</sup>Leydens JA, Lucena JC, Schneider J. Are engineering and social justice (in) commensurable? A theoretical exploration of macro-sociological frameworks. *Int J Eng Soc Justice Peace*. 2012;1(1):63–82.
- <sup>41</sup>Leydens JA, Lucena JC. Social justice: a missing, unelaborated dimension in humanitarian engineering and learning through service. *Int J Serv Learn Eng Humanit Eng Soc Entrep*. 2014;9(2):1–28.
- <sup>42</sup>Lunn SJ, Bell-Huff CL, Le Doux JM. Cultivating Inclusivity: a Systematic Literature Review on Developing Empathy for Students in STEM Fields. Paper presented at 2022 CoNECD (Collaborative Network for Engineering & Computing Diversity). New Orleans, Louisiana; 2022. <https://peer.asee.org/39112>.
- <sup>43</sup>Meeks K, Peak AS, Dreihaus Adam. Depression, anxiety, and stress among students, faculty, and staff. *J Am Coll Health* 2021;1–7.
- <sup>44</sup>Mehdiabadi AH, James JO, Svihla V. Ethical reasoning in first-year engineering design. In: 2019 American Society for Engineering Education (ASEE) Annual Conference & Exposition.
- <sup>45</sup>Meyers S, Rowell K, Wells M, Smith BC. Teacher empathy: a model of empathy for teaching for student success. *Coll Teach*. 2019;67(3):160–8.
- <sup>46</sup>Micari M, Pazos P. Connecting to the professor: impact of the student-faculty relationship in a highly challenging course. *Coll Teach*. 2012;60(2):41–7.
- <sup>47</sup>Micari M, Pazos P. Fitting in and feeling good: the relationships among peer alignment, instructor connectedness, and self-efficacy in undergraduate satisfaction with engineering. *Eur J Eng Educ*. 2016;41(4):380–92.
- <sup>48</sup>National Research Council. Education for life and work: developing transferable knowledge and skills in the 21st century. Washington, DC: National Academies Press; 2012.
- <sup>49</sup>Nowell LS, Norris JM, White DE, Moules NJ. Thematic analysis: striving to meet the trustworthiness criteria. *Int J Qual Methods*. 2017;16(1):1609406917733847.

- <sup>50</sup>Pettigrew TF, Tropp LR. How does intergroup contact reduce prejudice? Meta-analytic tests of three mediators. *Eur J Soc Psychol.* 2008;38(6):922–34.
- <sup>51</sup>Prabhu R, Starkey EM, Alzayed MA. Student reflections on sustainability and empathy: The outcomes of a sustainability workshop in first-year design courses. In: 2021 American Society for Engineering Education (ASEE) Virtual Annual Conference & Exposition.
- <sup>52</sup>Riemer MJ, Jansen DE. Non-verbal intercultural communication awareness for the modern engineer. *World Trans Eng Technol Educ.* 2003;2(3):373–8.
- <sup>53</sup>Sanders EA, Goldstein MH, Hess JL. Assessing ways of experiencing human-centered design via student reflections. In: 2021 American Society for Engineering Education (ASEE) Virtual Annual Conference & Exposition.
- <sup>54</sup>Schmitt E, Morkos B, Kames E, Conway TA. The importance of incorporating designer empathy in senior capstone design courses. In: 2016 American Society for Engineering Education (ASEE) Annual Conference & Exposition.
- <sup>55</sup>Segal EA. Welfare as we should know it: Social empathy and welfare reform. The promise of welfare reform: rhetoric or reality 2006;265–274.
- <sup>56</sup>Segal EA, Wagaman MA. Social empathy as a framework for teaching social justice. *J Soc Work Educ.* 2017;53(2):201–11.
- <sup>57</sup>Sochacka N, Walther J, Jolly L, Kavanagh L. Confronting the methodological challenges of engineering practice research: a three-tiered model of reflexivity. In: Research in engineering education symposium (REES), 2009; pp. 20–23.
- <sup>58</sup>Stahl GK, Maznevski ML, Voigt A, Jonsen K. Unraveling the effects of cultural diversity in teams: a meta-analysis of research on multicultural work groups. *J Int Bus Stud.* 2010;41(4):690–709.
- <sup>59</sup>Strobel J, Hess J, Pan R, Wachter Morris CA. Empathy and care within engineering: qualitative perspectives from engineering faculty and practicing engineers. *Eng Stud.* 2013;5(2):137–59.
- <sup>60</sup>Sun K. The importance of cultivating empathy in STEM education. *Sci Scope.* 2017;40(8):6–8.
- <sup>61</sup>Veloria C, Boyes-Watson C. Learning in circles: the power of a humanizing dialogic practice. *J Pedagog Plur Pract.* 2014;6(1):67.
- <sup>62</sup>Vogt CM. Faculty as a critical juncture in student retention and performance in engineering programs. *J Eng Educ.* 2008;97(1):27–36.
- <sup>63</sup>Walther J, Brewer MA, Sochacka NW, Miller SE. Empathy and engineering formation. *J Eng Educ.* 2020;109(1):11–33.
- <sup>64</sup>Walther J, Miller SE, Kellam NN. Exploring the role of empathy in engineering communication through a transdisciplinary dialogue. In: 2012 American Society for Engineering Education (ASEE) Annual Conference & Exposition, pp. 25–622.
- <sup>65</sup>Walther J, Miller SE, Sochacka NW. A model of empathy in engineering as a core skill, practice orientation, and professional way of being. *J Eng Educ.* 2017;106(1):123–48.
- <sup>66</sup>Walther J, Sochacka NW, Benson LC, Bumbaco AE, Kellam N, Pawley AL, Phillips CM. Qualitative research quality: A collaborative inquiry across multiple methodological perspectives. *J Eng Educ.* 2017;106(3):398–430.
- <sup>67</sup>Wong K, Norris RL, Siddique Z, Altan MC, Baldwin J, Merchan-Merchan W. Cognitive empathy in design course for a more inclusive mechanical engineering. In: International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, 2016;50138:003–04005. American Society of Mechanical Engineers.
- <sup>68</sup>Yeaman A, Bairaktarova D, Reid K. A qualitative study of empathy in the experiences of students in a first-year engineering service learning course. In: 2020 American Society for Engineering Education (ASEE) Virtual Annual Conference & Exposition.
- <sup>69</sup>Zaki J. *The war for kindness: building empathy in a fractured world.* New York: Crown Publishing Group; 2019.
- <sup>70</sup>Zhao Y, Fuller L, Daugherty KK. Evaluating pharmacy faculty perceptions of empathy in education: a qualitative study. *Curr Pharm Teach Learn* 2021.

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