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Review on empathy in engineering education: Conceptions, interventions, and challenges

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Abstract

Context

Despite an innate need for empathetic engineering, the dialogue on what constitutes empathy in engineering, its conceptualization, and the curriculum development to ingrain empathy as a transversal skill is still in its infancy.

Purpose or Goal

This study develops a broad conceptualization of empathy for engineering education and aggregate interventions to develop and measure it in engineering education. It specifically focuses on exploring the conceptions/frameworks/elements of empathy in engineering, curricular interventions for its development, and approaches and instruments used to measure it.

Methods

This study is a scoping review of Scopus and Web of Science databases for articles on empathy in engineering education published between 2013 and 2023.

Outcomes

This research illustrates that while the concept of empathy is not new, its inclusion, conceptualization, and measurements for engineering education are emerging. The conceptualization of empathy in engineering has taken various forms, with emerging frameworks highlighting its multi-dimensional nature. Eleven challenges come to light when examining the interventions for developing empathy at the module, course, and program levels.

Conclusion

Despite all that we know about the need for empathy in the engineering profession, its foray into engineering education is still in its infancy. The proposed scoping review has implications for both research and practice. It provides a synergistic view of literature on empathy development in engineering with critical findings for conceptions of empathy, recommendations for operationalizing the elements of empathy across progressive years of engineering study and disciplines leading to an array of curricular interventions with appropriate approaches for measuring it. Further research opens opportunities to develop instruments for measuring empathy from discipline-dependent and independent perspectives.

Keywords— challenges; engineering education; empathy; interventions

I. INTRODUCTION

Empathy has been a cornerstone on which social understanding, progress and sustenance have rested, as summarised by (Battarbee et al., 2014) in their insightful reflection, "We must intentionally seek opportunities to connect with people in meaningful ways …". In this regard, the Organization for Economic Co-operation and Development research includes empathy as one of the critical elements for social progress (Marta, 2015). This need for meaningful engagement with people applies to general humanity and is also an innate need among professions that seek to build socio-technical artefacts for human consumption based on society's needs, experiences, and aspirations.

While the roots of empathy are often seen entrenched in professions like Law (Hoffman, 2011), Social work (Eriksson & Englander, 2017), Health care (Decety, 2020) and allied professions (Alzayed, 2019), its need in engineering are evidenced when we view engineering as not just restricted to "an application of Math and Science" but a vehicle for engaging with and eliciting perspectives of stakeholders , which are influenced by their culture, race, religion, location, economic and social status (Mohedas, Sienko, Daly & Cravens, 2020), among other dependent factors; and shape the objectives, constraints and functions (Dym et al., 2005) of the technical artefacts designed for societal consumption: eventually guiding the principles of "human-centred design"(Oehlberg et al., 2012), and "empathetic design" practices (Tang, 2018). Academies of engineering, accreditation bodies and professional ethics for engineers all mandate the development of solutions, processes, devices and components that cater to public health, welfare and safety (Shuman et al., 2005). This focus on "public" requires engineers to act empathetically (Battarbee et al., 2014), i.e., understand users' needs, develop user-centric solutions, and act altruistically throughout the design process.

Historically, mature disciplines like social welfare, medicine, nursing, and law have a well-articulated conceptualisation of empathy. However, a definitive description of what it means to be an empathetic engineer is evolving, as seen in an emerging

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landscape of interpretive frameworks that identify elements of empathy (Hess et al., 2017; Sanz et al., 2023; Walther et al., 2020). While empathy is often seen as a trait, something an individual is born with (Kunyk & Olson, 2001), several studies have projected empathy as a teachable skill (Sanz et al., 2023; Walther et al., 2016), subsequently leading to several initiatives in engineering education, which have developed engaging curriculum, programs and courses designed to develop empathy (Bairaktarova, 2022; Yeaman et al., 2020). Despite the need and initiatives for fostering empathy in engineering education (Wilson & Mukhopadhyaya, 2022) have revealed that engineering students often face "cognitive dissonance" when their myopic perception of the engineering profession is juxtaposed with society, policy and education's thrust towards empathetic design. This is further compounded by the inhibitory relationship between students' degree of responsibility towards the public vis a vis their technical and analytical thought that engineering education develops (Levy, 2018; Hess et al., 2015; Shannon, Jones & Mina, 2019)

Despite all that we know about empathy, its need and initiatives to promote its development, scholars have revealed the need for a coherent framework (Guanes et al., 2022; Strobel et al., 2013; Surma-aho & Hölttä-Otto, 2022), a set of directed guidelines for its development (Alzayed et al., 2021) and a description of "direct, measurable impact of interventions on the empathy of engineers" (Wilson & Mukhopadhyaya, 2022, p.03). Considering the length and breadth of these needs, this study undertakes a scoping review of the literature to develop a broad conceptualisation of empathy for the engineering profession and aggregate interventions to develop and measure it in engineering education. It specifically focuses on exploring the conceptions/frameworks/elements of empathy in engineering, curricular interventions for its development, and approaches and instruments used to measure it through the following research questions:

1. How is empathy conceptualized in engineering?
2. What are the interventions for developing and measuring empathy in engineering education?
3. What kinds of challenges are experienced in designing learning contexts for developing empathy?

II. METHODS

This study follows the scoping review methodological framework proposed by (Arksey & O'Malley, 2005), which outlines the following steps in conducting the scoping review: 1) identifying the research question, 2) identifying relevant studies, 3) study selection, 4) charting the data, 5) collating, summarising and reporting the results. With the identified research problem and questions, the following sections detail how the protocol was adopted.

A. Identifying relevant studies

Inclusion criteria

1. The article is written in English and is peer-reviewed
2. The article focuses on the engineering/technology education
3. The article focuses on the development of empathy among engineering students.
4. The article identifies elements of empathy/conceptualisation of empathy in engineering education and practice OR It applies an existing empathy framework for its course/interventions.

Exclusion criteria

1. The article focuses on non-engineering streams like arts, medicine, sports, nursing, early childhood and economy
2. Empathy in engineering practice towards customers
3. Empathy as a perspective while identifying problems in engineering

The search was conducted for the Scopus and Web of Science (WoS) databases by using the search strings: "Empath*" AND "Engineer*" OR "Technology*" published between the years 2013 and 2023. Both conference and journal articles were included. Of the 148 and 276 records from the Scopus and WoS databases, 95 and 132 were selected by screening the title, keywords and abstracts. After screening the full papers, 61 records were included for review. Of which 52 belonged to Scopus and 09 to WoS databases. The remaining records were excluded from the study due to the following reasons: duplicity; empathy between team members; teacher empathy; empathy for inclusion and diversity; entrepreneurial mindset learning spaces, promoting engagement of female students; historical and intercultural empathy, empathetic Technology, digital empathy, non-engineering education context, and detection of empathetic dialogue in digital conversations.

B. Tracking and Analysis

Based on the study's objective, initial themes were identified based on the research questions: conceptualization of empathy, interventions, engineering discipline, course name, research design, data collection instruments, participants, recommendations, challenges, and scope for the future. In order to validate the paper screening and data analysis, the first three authors independently screened the abstracts and the title for the first 10 records, followed by a discussion for convergence between them. The 4th author then screened 10% of the records. At the second level, the first three authors independently appraised the full papers based on the themes mentioned earlier. With an initial agreement of around 60%, the researchers converged through a discussion to reach a consensus of 89%. The 4th research then assessed the final coding of all records, leading to 61 records being included in this scoping review.

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III. FINDINGS

A. Demographics of selected records

In order to explore publications on empathy development in engineering education, demographic information was classified into the following aspects: country, publication source, engineering discipline, research design and article type.

In terms of the 24 publication sources, the distribution of articles is as follows: Journal of Engineering Education(3), Engineering Studies(3), European Journal of Engineering Education(2), International Journal of Engineering Education(2), Journal of Mechanical Design(2), IEEE Transactions on Education(1), Journal of creative behaviour (1), Knowledge Management and E-Learning(1), Pedagogies(1), Social Sciences(1), Sustainability(1), TechTrends(1), Australasian Journal of Engineering Education(1), Design Journal(1), Design Studies(1), Education for Chemical Engineers(1) and Education Sciences(1). The 37 papers were presented at the following conferences: ASEE Annual Conference and Exposition, Conference Proceedings (21), IEEE International Professional Communication Conference(3), Proceedings - Frontiers in Education Conference, FIE (4), IEEE International Professional Communication Conference(2), among other conferences related to engineering education.

Among the 11 countries, 46 papers were from the USA, followed by the UK, Japan and Canada at two each. There was only 1 record from India.

For many records, the engineering discipline was not mentioned, as the intent of the records was to conceptualise empathy in engineering and not specific to a discipline. Further, the records revealed specific articles from biomedical engineering (2) and chemical engineering (2), each from Computer science and electrical engineering. Two studies also focused on developing empathy in the context of entrepreneurial mindset and design thinking. Six articles focused on developing empathy in the first year of engineering education.

Based on the scope of the records, three categories of papers were identified: conceptualisation of empathy (15), design of a course for the development of empathy and subsequent effect on it (35) and literature review (11). The records can be grouped into qualitative studies-36% (22), quantitative studies-23% (14), literature review-20% (12), mixed methods- 15% (9) and multi-methods-6.6% (4).

B. Conceptualization of empathy in engineering

From the earliest conceptualisations of empathy describing empathy as an ability to "think and feel oneself into the inner life of another person" (Kohut, 1959, p.82), several dimensions of empathy have been identified to reveal the complex and multi-dimensional facets of empathy in engineering education. While it appears that the cornerstone perspectives of empathy come from its cognitive, affective and behavioural aspects, which are widely cited in the literature, its interpretation for engineering education is still evolving. The literature review presents 08 conceptualisations of empathy, as indicated in Table I. A closer look at the conceptualisations reveals the means (communication, relationship, listening, resonance, connection, expansive empathy) vs ends (orientation, skills, professional way of being) dichotomy between the elements. Thus, this indicates that empathy is both a process and an outcome.

C. Interventions for developing and measuring empathy in engineering education

Table II showcases different courses and their interventions that promote the development of empathy among students. It captures the approach, empathy frameworks applied and measurement instruments.

1) Course Levels and Duration

The development of empathy as a skill is implemented at different levels of education, from course-level interventions to broader program-level experiences varying from a single university to multiple universities, which span weeks to longer, semester-length engagements. For example, the "Design for Sustainable Development" course extends over 20 weeks, allowing students to engage deeply with real-world case studies and iterative design processes (SCO09). In contrast, the "global innovation program" extends for a year, bridging academia and industry (SCO36).

2) Intervention: Real-World Problems and Community Engagement

The interventions involve students in real-world projects or challenges, such as waste management (SCO18), bridge design (SCO50), accessibility to older adults (SCO59), assistive technology for old age (SCO45, SCO06), drones for social good (SCO30) and sustainable development (SCO45, SCO42), which are designed in collaboration with nonprofit clients or industry. Notably, service learning and community engagement courses like "Technical Communication" (SCO41, SCO60), Design for Sustainable Development (SCO09), Introduction to Engineering Design (SCO58), Introduction to Engineering (SCO48) highlight the positive impact on local communities and society. Interventions in SCO58, SCO48, and SCO51 emphasise problem-based learning (Chen, Kolmos & Du (2021). Empathy often involves effective written communication and collaboration, evident in (SCO47, SCO49, SCO17). Interventions in (SCO26, SCO18) explicitly connect empathy with ethical behaviour. Empathy develops via reflective assignments, as in (SCO22, SCO16).

These interventions demonstrate several opportunities to develop empathy through hands-on experiences, problem-solving, collaboration, ethical considerations, and self-reflection. Ultimately, these efforts aim to produce engineers and professionals who excel in their technical abilities and understand and address the human aspects of their work, contributing to positive social impact.

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TABLE I
CONCEPTUALISATIONS OF EMPATHY

ID	Conceptualisation of empathy
[SCO40]	Empathy in Design for Engineers exists at two levels: Self-Centered and user-Centered State 1 Self-Centred: Self-Awareness - understanding of the self and Other awareness - differentiating the self from others State 2: User-Centered: 1). Listening - the engineer is pulled into the client's world, exploring, absorbing, and experiencing without judgement. 2). Resonance - engineer shares emotional state with client related to client's needs 3) Connection - The engineer uses shared resonance to form a bond with the client, understanding emotions and needs 5) Detachment - The engineer steps back from interaction with the client ;switches modes from empathy to analytic to design for client's needs
[SCO47]	Conceptualizes empathy as a skill, a practice orientation, and a professional way of being
[SCO57]	Empathic engineering education framework that includes a set of four categories of learning theory and three categories of analytical skills
[SCO81]	Expansive empathy has been defined as the capacity to comprehend and provide inclusive design solutions that consider the intricate relationships between the engineering system and the requirements of various stakeholders, including those who are vulnerable, marginalized, and mainstreamed.
[SCO95]	A Skills, Professional, and Citizenship Model for Developing Empathy From Situational, Systemic, and Global Perspective/Framework for developing empathy in Computer science
[WEB010]	A framework to teach higher-order skills which includes empathy in the context of engineering and entrepreneurial skills: Knowledge, Persuasiveness, and Empathy (KPE)
[SCO02]	Empathy is a human trait, professional state, communication process, caring and a special relationship.
[WEB24]	Five core concepts that form the overall concept of empathy in design: understanding, action, research, orientation and mental processes

3) Pedagogy

The table II reveals a spectrum of pedagogical approaches, from active learning (SCO40, SCO50), training (SCO22), workshops (SCO59), collaborative teamwork (SCO47, SCO30), design thinking (SCO17) and project-based learning (SCO58, SCO36) to service learning (SCO41, SCO60, SCO49) and laboratory experiences (SCO18). For instance, the "Engineering Ethics" course employs a Sequential Interactivity, Reflection, and Application (SIRA) framework to facilitate ethical discussions through case studies (SCO26). Further, the "Exploring LegaCs" program (SCO85) incorporates narrative and storytelling as tools to develop empathy. Researchers and educators must consider these pedagogies to design interventions to foster empathy among students.

4) Data Collection Approaches

The most widely used data collection approaches for measuring empathy include reflections, interviews, classroom observations, and self-report surveys. This diversity highlights the complexity of measuring empathy, which requires quantitative and qualitative data following the mixed or multi-method approach for data analysis, especially within curricular constraints.

5) Frameworks for Empathy Measurement

Table II highlights several frameworks and scales used to measure empathy. These tools allow researchers to assess different dimensions of empathy, such as perspective-taking, fantasy, and empathetic distress among participants. The Davis's Interpersonal Reactivity Index (IRI) is a widely used psychological assessment tool designed to measure an individual's dispositional empathy (SCO58, SCO95, SCO85, SCO48, SCO36, SCO42). The IRI consists of four subscales or dimensions, each of which assesses a different aspect of empathy: Perspective-taking (PT), Fantasy (FS), Empathic Concern (EC) and Personal Distress (PD). Toronto Empathy Questionnaire is used to measure an individual's empathic tendencies (SCO41, SCO60). It is also measured as a state of empathy, i.e., State 1, Self-centred; this state involves self-awareness, where one understands oneself and develops awareness of others. State 2 is User-centred: this state shifts the focus to the user or client (SCO40). In (SCO18) the authors use the framework of Empathy, Care, and Ethics to understand and practise empathy. Goleman's Three Types of Empathy (SCO09) refers to three main types: cognitive empathy (understanding another person's perspective), emotional empathy (feeling the emotions of others), and empathic concern (caring about the well-being of others). (SCO22) measures empathy through Cognitive Empathy or Perspective-Taking using a prominent aspect of empathy studied in social psychology. The Engineering Professional Responsibility Assessment Tool (SCO30) assesses personal and social awareness, professional development, and professional connectedness. Zaki's Framework of Empathy (SCO85) considers aspects such as sharing, thinking about, and caring about others when understanding and measuring empathy. Baron-Cohen's Model outlines a skills, professional, and citizenship approach to developing empathy from situational, systemic, and global perspectives (SCO95). The Empathy Assessment Index (EAI) (SCO45) assesses empathy and comprises five affective and cognitive constructs: affective response, mentalising, self-other awareness, emotion regulation, and perspective-taking. Another views empathy as a multifaceted concept encompassing skill practice, orientation and a professional way of being (SCO47, SCO32, SCO49, SCO51). Measuring empathy is challenging due to its multifaceted and context-dependent nature. The non-linear progression of empathy development and its context specificity makes it difficult to assess straightforwardly.

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TABLE II
INTERVENTIONS AND FRAMEWORK FOR EMPATHY MEASUREMENT

ID	Learning Context /Level/Approach	Data Collection	Framework for empathy measurement	Duration	Pedagogy	Intervention/Activity
SCO60 /41	Technical Comm [C][Mixed]	Surveys & Reflections	Toronto Empathy Questionnaire (Spreng et al., 2009)	6 weeks,	Service Learning	Students partnered with a nonprofit client
SCO18	Design Lab Course [C][Qual]	field notes, observations, interviews	Empathy, care and ethics. (Campbell, Yasuhara, & Wilson, 2015), (Campbell, Yasuhara, & Wilson, 2012)	six hours each week	Laboratory	waste management challenges in developing country
SCO22	Principles of Design[C][Quan]	Survey	NA	2-day training	Design-based	complex, open-ended problems affecting a fictitious world called "Planet Vayu,"
SCO58	introduction to engineering design [C][Mixed]	Survey, essay Reflection Interview	IRI scale. (Davis, 1983)	8 weeks	Project Based	Project to identify affected stakeholders and their needs
SCO47	Engineering and Society course [C][Qual]	Reflections	(Walther et al., 2017)	NA	Design-based	Team-based design challenges, readings/ discussions
SCO32	Engineering and Society course [C] [Qual]	Reflections	(Walther et al., 2017)	1 hour 15 mins per module	Service Learning	
SCO49	NA [C] [Qual]	semi-structured interviews	NA	10 hours	Community service project	Field visits, simulations of disability experiences
SCO51	Engineering and Society Course [C] [Qual]	Reflection prompt	(Walther et al., 2017)	NA	Project Based	Real-world problem
SCO42	Introductory Engineering Design [C][Quan]	NA	IRI scale. (Davis, 1983)	8 weeks	Active-learning reflections, role plays	project on United Nation's Sustainable Development Goal 3,
SCO09	Design for Sustainable Development [C] [Qual]	Observations, Reviews and Interviews	cognitive empathy, emotional empathy, and empathic concern. (Goleman & Senge, 2014)	20 weeks	Design-based	Design problems
SCO17	product design course [C][Multi]	Testimonies, Observation, Interviews or Focus Groups	NA	NA	group-based, open-ended design challenges	human-powered Washing machine to be used in developing countries.
SCO26	Engineering Ethics [C] [Qual]	semi-structured interviews	NA	NA	Case-based	Ex-Development and distribution of tissue-engineered heart valves
SCO16	Engineering and Society course [C] [Qual]	Skill Activity, Applied Activity, Reflective Homework Prompts	Walther et al., 2017)	1 hour 15 mins per module	Project Based	Real-world problem
SCO95	Programming and Programming Fundamentals [Multi]	Survey, Teacher observations and student perceptions	(Baron-Cohen, 2012)	NA	practical sessions, problem-solving, and lab practice.	Sudoku Programming
SCO45	Rehabilitation engineering course [Multi] [Mixed]	Survey, interviews	(Segal et al., 2017)	10 weeks	Design-based societal challenge	Projects on disabilities or recreation with local nonprofit organizations
SCO30	NA [Multi] [Mixed]	Survey and Open-ended design challenge	(Canney & Bielefeldt, 2016) (Davis, 1983)	One Sem	Design-based societal challenge	Teamwork, collaboration, conversations, workshops, group discussions

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TABLE III(CONTD)
INTERVENTIONS AND FRAMEWORK FOR EMPATHY MEASUREMENT

ID	**Learning Context /Level/Approach**	**Data Collection**	**Framework for empathy measurement**	**Duration**	**Pedagogy**	**Intervention/Activity**
SCO36	Global Innovation Program [Multi] [Quan]	Survey	(Davis, 1983)	1 year		open-ended industry projects
SCO40	Electromagnetic Fields and Waves [Course] [Qual]	Reflections	Goleman's 5 key elements of EQ (Goleman, 2020)	One sem	Active Learning	NA
SCO85	Exploring Life Stories of Engineers [Multi] [Mixed]	Survey, Open-ended responses, Semi-structured Interviews	(Davis, 1983) (Zaki, 2019)	8 weeks	Story focused learning	Prompts and group discussions culminating in a "Story Slam."
SCO48	Introduction to Engineering [course] [Qual]	observation, interviews and peer feedback	(Davis, 1983)	One semester	Cooperative PBL	sustainable development-
SCO50	NA [Multi][Mixed]	daily observations, Interviews and surveys	NA	NA	think pair share, teamwork	electrical circuits, water access issues, bridge design, and biomedical engineering, boat-float challenge

TABLE III
CHALLENGES IN DESIGNING LEARNING CONTEXTS FOR DEVELOPING EMPATHY

Sl. No	**Category of challenge**	**Challenges of developing empathy in engineering education**
1.	Non-separation with technical content	Empathy is not a standalone concept [SCO02], pedagogical[SCO26], Integration of Empathy and Care into Engineering Education[SCO27], danger of disciplinary separation of content[SCO38]
2.	Development of real-world context	To be developed in the context of Societal and ethical responsibilities [SCO02], classroom interventions[SCO26], proximity, similarity, and familiarity biases, temporal, spatial[SCO32], micro-to-macro contexts of problems[SCO49]
3.	Empathy needs Multicultural perspectives.	Empathy in a multicultural setting and international setting [SCO06], Cultural Analysis[SCO18], international students[SCO26], contextualize empathy training within broader cultural norms[SCO31]
4.	Academic/curriculum-related	Optimal engagement via a standalone module, course or program [SCO09], against established learning practices and instructional norms[SCO16], Instructional Discomfort[SCO18], Time Constraints, Instructional Consistency[SCO30], Balancing Curriculum and Participation[SCO30], Short duration of courses[SCO45], Time in high-enrollment courses[SCO72], Single extra-curricular experience[SCO81], Balancing Curriculum and Participation[WEB103], Instructional Consistency[WEB103],
5.	Threats to measuring/assessment empathy/reliable measures	Prolonged nature of courses affected by real-time, non-academic events [SCO09]. It is challenging to measure the delta change in empathy [SCO09], Assessment of Empathy Progress[SCO30], data collection is primarily self-report questionnaires[SCO33], requires emotional understanding and reflecting[SCO36], Lack of sufficient Time to show a marked difference[SCO81], Assessment of Empathy Progress[WEB103],
6.	Multi-dimensionality of construct	Intricate and multifaceted relationships between empathy measures and innovative behaviours [SCO12], unintended Outcomes[SCO23]
7.	Discipline-independent measures of empathy	It is challenging to create a survey instrument that reliably assesses the influence on participation and gauges views of empathy across a range of engineering specialities [SCO14]
8.	Discipline-specific empathy interpretation and interpretation	Absence of training to nurture empathy in an engineering context[SCO21] Limited Focus on Empathy and Care Training in Engineering Education, Need for Engineering-Specific Training Methods[SCO27], the challenges of students' gradual transition to accepting a concept such as empathy as relevant to engineering[SCO38]
9.	Cognitive dissonance	Tension and reluctance among students caused by the difference between their expectations from engineering[SCO16], lack of alignment, technical overemphasis [SCO18], the disparity between the technical and empathic mindsets[SCO21], the need to overcome the perception of empathy as external to technical work[SCO21], attracting empathetic individuals to engineering, changing perceptions of engineering, developing empathy and care in engineers [SCO27], the role of epistemological differences for both students and instructors [SCO38], connection between empathy and engineering [WEB103]
10.	Dependent on prior conditioning	Inspired by prior experiences[SCO16], prior engagement with the community[SCO89]
11.	Psychological biases	Comfort Zone Bias, Narrow Empathic Horizon, Emotional Complexity [SCO18], Empathic Biases, Experience, Internalization, Emotional Regulation[SCO23]

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D. *Challenges in designing learning contexts for developing empathy*

The challenges experienced in developing empathy in engineering education are listed in Table III. A nuanced and granular look at the challenges reveals that the challenges exist at different levels: Non-separation with technical content, development of real-world context, empathy needs multicultural perspectives, academic/curriculum-related, threats to measuring/assessment empathy/reliable measures, multi-dimensionality of construct, discipline-agnostic measures of empathy, cognitive dissonance, dependent on prior conditioning, psychological biases, discipline-specific empathy interpretation and interpretation. Among these challenges, those related to academics and curriculum form the most extensive set which focuses on how to design interventions and what level: module, course, or program level to ensure prolonged and effective engagement with the community. However, this prolonged engagement introduces threats on external validity of the measures and pose challenges for interpreting the success of the assessments. The second set of challenges comes from the epistemological assumptions of undergraduate engineering students, which portrays a conflict between what they believe about engineering, what they majorly learn in engineering and what they are expected to accomplish as professional engineers. This is further compounded by the analytical-heavy coursework, which eventually leads to a dip in their empathetic understanding.

IV. Discussion and Conclusion

This paper scrutinizes evidence regarding the conceptualization of empathy, interventions for developing it and challenges faced in engineering education based on a scoping review of literature from two databases (Web of Science and SCOPUS) published during 2013-2023. This research illustrates that while the concept of empathy is not new, its inclusions, conceptualization, and relevance for engineering education are emerging.. The conceptualization of empathy in engineering has taken various forms, with emerging frameworks highlighting its multi-dimensional nature. Empathy is viewed as a skill, a practice orientation, a professional way of being, (Walther et al., 2017) and a crucial component of engineering ethics. It involves cognitive, affective, and behavioural aspects (Goleman & Senge, 2014), each dimension playing a distinct role in engineering education and practice.

All the initiatives that seek to develop empathy portray that empathy cannot be developed by separating technical content from societal connections (Rivas & Husein, 2022). They seek to leverage technical knowledge for community engagement through service and community-based learning. These experiences expose students to the realities of the communities they serve, fostering empathy as they work to address real-world issues, which are commonly addressed using design-based pedagogy. Further, on examining the interventions, eleven challenges for developing empathy are seen at different levels: module, course, and program levels; faculty and student related; and discipline specific and discipline independent. These challenges present opportunities for further design of interventions.

While literature supports immersion in real-world problems for developing empathy, the openness and ill-structuredness of the problem pose a challenge in terms of time, effort and technical feasibility. This is interpreted by (Guanes et al., 2022) as the micro-meso-macro focus of problems that must be carefully arbitrated by the instructors much ahead of Time. In addition, instructors also need to develop learning contexts that are consonant with the students in terms of familiarity, similarity, proximity of the situation (Brewer et al., 2017.), and stakeholders, which, if avoided, may contribute to further cognitive dissonance.

Further, while this study sees empathy as a unitary entity, scholars often view it in conjunction with ethics, entrepreneurial thinking, design-based research, creative thinking, innovation, and care. Thus, this opens up avenues for instructional designers to design a holistic ramp of courses that focus on these transversal skills intertwined with technical competency.

Although engineering education can strive to develop effective and efficient interventions to develop empathy, empathy often depends on personal dispositions and characteristics, such as civic-mindedness (Lin et al., 2021), which refers to valuing community engagement and empathic interpersonal communication. Thus, this opens opportunities to explore how civic-mindedness can be developed even before students join engineering education. Specific studies also highlight the gender-dependent nature of empathy, with female students demonstrating higher levels of empathy than male counterparts (Christov-Moore et al., 2014).

Measuring empathy is challenging (Hall & Schwartz, 2022) due to its multifaceted and context-dependent nature. The non-linear progression of empathy development, context specificity, and its generic nature make it difficult to assess straightforwardly. The instruments and scales commonly used to measure empathy are dated and do not reflect engineering-specific and discipline-dependent nuances of engineering, which opens up thrust for further investigation.

Lastly, this study has several limitations: search is restricted to just the last decade, is confined to the in-person engagement and does not delve into the empathic responses in technology-enabled environments and does not focus on the assessment and evaluation structure of the courses.

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REFERENCES

Afroogh, S., Esmalian, A., Donaldson, J. P., & Mostafavi, A. (2021). Empathic design in engineering education and practice: an approach for achieving inclusive and effective community resilience. Sustainability, 13(7), 4060. **[SCO57]**

Alzayed, M. A. (2019, October). An exploration of the role of student empathy in engineering design education. In 2019 IEEE Frontiers in Education Conference (FIE) (pp. 1-2). IEEE. **[SCO42]**

Alzayed, M. A., McComb, C., Menold, J., Huff, J., & Miller, S. R. (2021). Are you feeling me? An exploration of empathy development in engineering design education. Journal of Mechanical Design, 143(11), 112301. **[SCO58]**

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. International Journal of Social Research Methodology, 8(1), 19–32. https://doi.org/10.1080/1364557032000119616

B. Bush, S., Edelen, D., Roberts, T., Maiorca, C., Ivy, J. T., Cook, K. L., ... & Cox Jr, R. (2022). Humanistic STE (A) M instruction through empathy: leveraging design thinking to improve society. Pedagogies: An International Journal, 1-20. **[WEB003]**

Bairaktarova, D. (2022). Caring for the future: Empathy in engineering education to empower learning. Journal of Engineering Education, 111(3), 502-507. **[SCO79]**

Battarbee, K., Suri, J. F., & Howard, S. G. (2014). Empathy on the edge: Scaling and sustaining a human-centered approach in the evolving practice of design. IDEO. Http://Www. Ideo. Com/Images/Uploads/News/Pdfs/Empathy_on_the_Edge. Pdf.

Besser, D., Brown, K., Nowariak, A. H., Brass, T., Leininger, R. A., & Thomas, A. (2020, June). Empathy, engineering, and girls. In 2020 ASEE Virtual Annual Conference Content Access. **[SCO50]**

Beyond Surface Knowledge: An Exploration of How Empathic Design Techniques Enhances Engineers Understanding of Users' Needs. (2016). International Journal of Engineering Education. **[SCO17]**

Brewer, M. A., Sochacka, N. W., Walther, J., & Miller, S. E. (2017, July). How do students meaningfully interpret the role of empathy in engineering? A social phenomenological study. In Proceedings of the 2017 Research in Engineering Education Symposium, Bogota, Colombia (pp. 6-8). **[SCO32]**

Burns, H. D., & Lesseig, K. (2017, June). Infusing empathy into engineering design: Supporting under-represented student interest and sense of belongingness. In 2017 ASEE Annual Conference & Exposition. **[SCO31]**

Busu, T. N. Z. T. M., Mohd-Yusof, K., & Rahman, N. F. A. (2020, December). Empathy enhancement among engineering students through cooperative problem-based learning. In 2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE) (pp. 889-894). IEEE. **[SCO48]**

Campbell, R. C., Yasuhara, K., & Wilson, D. (2012, October). Care ethics in engineering education: Undergraduate student perceptions of responsibility. In 2012 Frontiers in Education Conference Proceedings (pp. 1-6). IEEE.

Canney, N. E., & Bielefeldt, A. R. (2016). Validity and reliability evidence of the engineering professional responsibility assessment tool. Journal of engineering education, 105(3), 452-477.

Chen, J., Kolmos, A., & Du, X. (2021). Forms of implementation and challenges of PBL in engineering education: a review of literature. European Journal of Engineering Education, 46(1), 90-115.

Christov-Moore, L., Simpson, E. A., Coudé, G., Grigaityte, K., Iacoboni, M., & Ferrari, P. F. (2014). Empathy: Gender effects in brain and behavior. Neuroscience & Biobehavioral Reviews, 46, 604–627.

Cooper, L. A., Johnston, A., Hubbard, E. H., & Self, B. P. (2020, June). Development of Empathy in a Rehabilitation Engineering Course. In 2020 ASEE Virtual Annual Conference Content Access. **[SCO45]**

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multi-dimensional approach. Journal of personality and social psychology, 44(1), 113.

De Lira, C. (2017, August). Improving the Learning Experiences of First-Year Computer Science Students with Empathetic IDEs. In Proceedings of the 2017 ACM Conference on International Computing Education Research (pp. 293-294). **[WEB84]**

Decety, J. (2020). Empathy in medicine: What it is, and how much we really need it. The American Journal of Medicine, 133(5), 561–566.

Dostál, D., Plháková, A., & Záškodná, T. (2017). Domain-specific creativity in relation to the level of empathy and systemizing. The Journal of Creative Behavior, 51(3), 225-239. **[WEB82]**

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. Journal of Engineering Education, 94(1), 103–120.

Eriksson, K., & Englander, M. (2017). Empathy in social work. Journal of Social Work Education, 53(4), 607–621.

Fila, N. D., & Hess, J. L. (2016, June). In their shoes: Student perspectives on the connection between empathy and engineering. In 2016 ASEE Annual Conference & Exposition. **[SCO21]**

Goleman, D. (2020). Emotional intelligence. Bloomsbury Publishing. (Goleman, 2020)

Goleman, D., & Senge, P. M. (2014). The triple focus: A new approach to education.(Goleman & Senge, 2014)

Gray, C., De Cresce El Debs, L., Exter, M., & Krause, T. (2016). Instructional Strategies for Incorporating Empathy in Transdisciplinary Technology Education. 2016 ASEE Annual Conference & Exposition Proceedings, 25746. https://doi.org/10.18260/p.25746 **[SCO18]**

Guanes, G., Wang, L., Delaine, D. A., & Dringenberg, E. (2022). Empathic approaches in engineering capstone design projects: student beliefs and reported behaviour. European Journal of Engineering Education, 47(3), 429-445. **[SCO72]**

Hall, J. A., & Schwartz, R. (2022). Empathy, an important but problematic concept.The Journal of Social Psychology,162(1), 1–6.

Hauke, E., Cresswell-Maynard, K., & Craddock, D. (2015). An interdisciplinary approach to embedding the global dimension into engineering design: empathy, engagement and creativity. In DS 82: Proceedings of the 17th International Conference on Engineering and Product Design Education (E&PDE15), Great Expectations: Design Teaching, Research & Enterprise, Loughborough, UK, 03-04.09. 2015 (pp. 087-092). **[SCO09]**

Hess, J. L., Beever, J., Strobel, J., & Brightman, A. O. (2017). Empathic perspective-taking and ethical decision-making in engineering ethics education. Philosophy and engineering: Exploring boundaries, expanding connections, 163-179. **[SCO33]**

Hess, J. L., Carrillo-Fernandez, A., Fila, N. D., & Schimpf, C. T. (2021, July). Exploring how empathy manifests with/for teammates in a junior-level biomedical engineering course. In 2021 ASEE Virtual Annual Conference Content Access. **[SCO52]**

Hess, J. L., Sanders, E., & Fila, N. D. (2022, January). Measuring and promoting empathic formation in a multidisciplinary engineering design course. In ASEE annual conference exposition proceedings. **[SCO80]**

Hess, J. L., Sprowl, J. E., Pan, R., Dyehouse, M., Morris, C. A. W., & Strobel, J. (2012, June). Empathy and caring as conceptualized

https://doi.org/10.52202/073963-0012

inside and outside of engineering: Extensive literature review and faculty focus group analyses. In 2012 ASEE Annual Conference & Exposition (pp. 25-520). **[WEB111]**

Hess, J. L., Strobel, J., & Brightman, A. O. (2017). The development of empathic perspective-taking in an engineering ethics course. Journal of Engineering Education, 106(4), 534-563. **[SCO26]**

Hess, J. L., Strobel, J., & Pan, R. (2016). Voices from the workplace: Practitioners' perspectives on the role of empathy and care within engineering. Engineering Studies, 8(3), 212-242. **[SCO24]**

Hess, J. L., Strobel, J., Pan, R. (Celia), & Wachter Morris, C. A. (2017). Insights from industry: A quantitative analysis of engineers' perceptions of empathy and care within their practice. European Journal of Engineering Education, 42(6), 1128–1153. https://doi.org/10.1080/03043797.2016.1267717

Hess, J. L., Strobel, J., Pan, R., & Morris, C. A. W. (2014, June). Practicing engineers' perceptions of empathy and care: derived exploratory factor structure from a 37-item survey. In 2014 ASEE Annual Conference & Exposition (pp. 24-991). **[WEB103]**

Hess, J. L., Strobel, J., Pan, R., & Wachter Morris, C. A. (2017). Insights from industry: a quantitative analysis of engineers' perceptions of empathy and care within their practice. European Journal of Engineering Education, 42(6), 1128-1153. **[SCO27]**

Hess, J., Fila, N., Purzer, S., & Strobel, J. (2015). Exploring the Relationship between Empathy and Innovation among Engineering Students. 2015 ASEE Annual Conference and Exposition Proceedings, 26.740.1-26.740.12. https://doi.org/10.18260/p.24077 **[SCO12]**

Hoffman, M. L. (2011). Empathy, justice, and the law. Empathy: Philosophical and Psychological Perspectives, 230–254.

Hoople, G. D., & Choi-Fitzpatrick, A. (2017, June). Engineering empathy: a multidisciplinary approach combining engineering, peace studies, and drones. In 2017 ASEE Annual Conference & Exposition. **[SCO30]**

Jacobs, E., De Jongh Curry, A., Deaton, R., Astorne-Figari, C., & Strohmer, D. (2016). Empathy and Gender Inequity in Engineering Disciplines. 2016 ASEE Annual Conference & Exposition Proceedings, 26936. https://doi.org/10.18260/p.26936 **[SCO14]**

Jaycox, H., Hess, J. L., Zoltowski, C. B., & Brightman, A. O. (2014). Developing novel practices of somatic learning to enhance empathie perspective-taking for ethical reasoning and engineering design. 2014 IEEE Frontiers in Education Conference (FIE) Proceedings, 1–5. https://doi.org/10.1109/FIE.2014.7044278 **[SCO06]**

Johnson, N., Wang, L., Delaine, D., & Walther, J. (2022, August). Evidence-based Opportunities for the Development of Empathy in Engineering through Community-based Learning. In 2022 ASEE Annual Conference & Exposition. **[SCO73]**

Kohut, H. (1959). Introspection, empathy, and psychoanalysis an examination of the relationship between mode of observation and theory. Journal of the American Psychoanalytic Association, 7(3), 459–483.

Kunyk, D., & Olson, J. K. (2001). Clarification of conceptualizations of empathy. Journal of Advanced Nursing, 35(3), 317–325.

Levy, M. (2018, March). Educating for Empathy in Software Engineering Course. In REFSQ Workshops (pp. 1-9).

Levy, M. (2018, March). Educating for Empathy in Software Engineering Course. In REFSQ Workshops (pp. 1-9). [SCO38]

Lin, A., Hess, J. L., & Fernández, A. P. C. (2021, October). The Relationship Between Empathy and Civic-Mindedness in First-Year Engineering Students. In 2021 IEEE Frontiers in Education Conference (FIE) (pp. 1-9). IEEE. **[SCO63]**

Lingappa, A. K., Kamath, A., & Mathew, A. O. (2022). Engineers and Social Responsibility: Influence of Social Work Experience, Hope and Empathic Concern on Social Entrepreneurship Intentions among Graduate Students. Social Sciences, 11(10), 430. **[SCO86]**

Litvinov, A., Gardner, A., Pradhan, S., & Childers, J. (2022, October). The role of empathic experiences of entrepreneurial engineers within accelerators: a phenomenological study. In 2022 IEEE Frontiers in Education Conference (FIE) (pp. 1-7). IEEE. **[SCO76]**

Lunn, S., & Bell-Huff, C. (2022, August). What Story Do You Want to Tell? Developing Empathy in Engineering Students through an Extra-Curricular Narrative Sharing Experience. In 2022 ASEE Annual Conference & Exposition. **[SCO85]**

Marinelli, M., Male, S., Chapman, E., & Strobel, J. (2022). Engineers' perceptions of the importance of empathy and care: initial insights from engineers practicing in Australia. In Towards a new future in engineering education, new scenarios that european alliances of tech universities open up (pp. 2066-2071). Universitat Politècnica de Catalunya. **[SCO75]**

Marta, R. (2015). "Skills for Social Progress: The Power of Social and Emotional Skills.

Mashhadi, A. R., & Svihla, V. (2022, August). Expansive Empathy: Defining and Measuring a New Construct in Engineering Design. In 2022 ASEE Annual Conference & Exposition. **[SCO81]**

Mohedas, I., Sienko, K. H., Daly, S. R., & Cravens, G. L. (2020). Students' perceptions of the value of stakeholder engagement during engineering design. Journal of Engineering Education, 109(4), 760–779.

Neubauer, D., Paepcke-Hjeltness, V., Evans, P., Barnhart, B., & Finseth, T. (2017). Experiencing technology enabled empathy mapping. The Design Journal, 20(sup1), S4683-S4689. **[SCO25]**

Oehlberg, L., Leighton, I., Agogino, A., & Hartmann, B. (2012). Teaching human-centered design innovation across engineering, humanities and social sciences. International Journal of Engineering Education, 28(2), 484.

Pappa, C. I., Reinhold, S., Pittich, D., Vogel-Heuser, B., & Strobel, J. (2020, April). Engineers' job-related perceptions of empathy in Germany. In 2020 IEEE Global Engineering Education Conference (EDUCON) (pp. 741-745). IEEE. **[SCO43]**

Patterson, L. (2019, July). Engineering students' empathy development through service learning: Quantitative results from a technical communication course. In 2019 IEEE International Professional Communication Conference (ProComm) (pp. 194-200). IEEE. **[SCO41]**

Patterson, L. (2021, October). Engineering Students Empathy Development through Service Learning: Examining Individual Student Experiences in a Technical Communication Course. In 2021 IEEE International Professional Communication Conference (ProComm) (pp. 93-100). IEEE. **[SCO60]**

Rivas, D. F., & Husein, S. (2022). Empathy, persuasiveness and knowledge promote innovative engineering and entrepreneurial skills. Education for Chemical Engineers,40, 45-55. **[WEB010]**

Sanz, C., Coma-Roselló, T., Aguelo, A., Álvarez, P., & Baldassarri, S. (2023). Model and Methodology for Developing Empathy: An Experience in Computer Science Engineering. IEEE Transactions on Education. **[SCO95]**

Segal, E. A., Gerdes, K. E., Lietz, C. A., Wagaman, M. A., & Geiger, J. M. (2017). Assessing empathy. Columbia University Press.

Shannon, R. A., & Jones, S. K., & Mina, M. (2019, June), Designing a Multi-Cycle Approach to Empathetic Electrical Engineering

Courses Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida. 10.18260/1-2--32612 [SCO40]
Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET "professional skills"—Can they be taught? Can they be assessed? Journal of Engineering Education, 94(1), 41–55.
Sochacka, N. W., Youngblood, K. M., Walther, J., & Miller, S. E. (2020). A qualitative study of how mental models impact engineering students' engagement with empathic communication exercises. Australasian Journal of Engineering Education, 25(2), 121-132. **[SCO51]**
Spreng*, R. N., McKinnon*, M. C., Mar, R. A., & Levine, B. (2009). The Toronto Empathy Questionnaire: Scale development and initial validation of a factor-analytic solution to multiple empathy measures. Journal of personality assessment, 91(1), 62-71.:Toronto Empathy Questionnaire
Strobel, J., Hess, J., Pan, R., & Wachter Morris, C. A. (2013). Empathy and care within engineering: Qualitative perspectives from engineering faculty and practicing engineers. Engineering Studies, 5(2), 137–159. https://doi.org/10.1080/19378629.2013.814136
Surma-aho, A. O., Björklund, T. A., & Holtta-Otto, K. (2018, June). Assessing the development of empathy and innovation attitudes in a project-based engineering design course. In 2018 ASEE annual conference & exposition. [SCO36]
Surma-Aho, A., & Hölttä-Otto, K. (2022). Conceptualization and operationalization of empathy in design research. Design Studies, 78, 101075. **[WEB24]**
Tang, X. (2018, June). From'Empathic Design'to'Empathic Engineering': Toward a Genealogy of Empathy in Engineering Education. In 2018 ASEE Annual Conference & Exposition. [SCO37]
Wallisch, A., Briede-Westermeyer, J. C., & Luzardo-Briceno, M. (2021). Fostering user-empathy skills of engineering students by collaborative teaching. International Journal of Engineering Education, 37(1), 223-243. **[SCO59]**
Walther, J., Brewer, M. A., Sochacka, N. W., & Miller, S. E. (2020). Empathy and engineering formation. Journal of Engineering Education, 109(1), 11–33. https://doi.org/10.1002/jee.20301 **[SCO47]**
Walther, J., Miller, S. E., & Sochacka, N. W. (2017). A model of empathy in engineering as a core skill, practice orientation, and professional way of being. Journal of Engineering Education, 106(1), 123-148. **[SCO34]**
Walther, J., Miller, S., Sochacka, N., & Brewer, M. (2016). Fostering Empathy in an Undergraduate Mechanical Engineering Course. 2016 ASEE Annual Conference & Exposition Proceedings, 26944. https://doi.org/10.18260/p.26944 **[SCO16]**
Wilson, E., & Mukhopadhyaya, P. (2022). Role of empathy in engineering education and practice in North America. Education Sciences, 12(6), 420. **[SCO89]**
Wong, K., Norris, R. L., Siddique, Z., Altan, M. C., Baldwin, J., & Merchan-Merchan, W. (2016, August). Cognitive empathy in design course for a more inclusive mechanical engineering. In International Design Engineering Technical Conferences and Computers and Information in Engineering Conference (Vol.50138, p. V003T04A005). American Society of Mechanical Engineers. **[SCO22]**
Yeaman, A., Bairaktarova, D., & Reid, K. (2020). A Qualitative Study of Empathy in the Experiences of Students in a First-Year Engineering Service Learning Course. 2020 ASEE Virtual Annual Conference Content Access Proceedings, 34040. https://doi.org/10.18260/1-2--34040 **[SCO49]**
Zaki, J. (2019). The war for kindness: Building empathy in a fractured world. Crown