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Cultivating Inclusivity: A Systematic Literature Review on Developing Empathy for Students in STEM Fields

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Abstract
As demand for qualified workers in science, technology, engineering, and mathematics (STEM) fields continues to rise, there is a need to not only consider how to improve engagement and retention, but also an opportunity to strive towards broadening participation. To create a more equitable workforce, and in particular, one that encourages the enrollment and persistence of underrepresented minorities, pedagogy centered around cultivating inclusivity is key. Along these lines, empathy as a construct can play a crucial role in aiding students to consider the impact of their own decisions and behaviors on others and society. Given the necessity of embedding the concept of empathy within post-secondary education, we sought to understand how others have approached empathy in curricula, projects, and practice. We applied Zaki's model of empathy — which triangulates "sharing," "thinking about" and "caring about," as the theoretical framework guiding the inquiry — and performed a systematic literature review. We sought answers to the following research questions: 1) *How have educators integrated empathy development into learning activities in STEM?*; 2) *What pedagogical approaches have been shown to promote empathy of students in STEM?*; and 3) *How have scholars approached the development of different kinds of empathy in classrooms?* After querying Google Scholar, analyzing more than 10,000 publications, and applying the inclusion/exclusion criteria, we identified 63 articles that centered on empathy development in STEM education, and specific learning activities or courses working to achieve this goal. The results were defined in terms of the patterns observed, topics assessed, and contributions made to the existing body of knowledge. Although there may be a range of approaches employed, such as through storytelling or role play, embedding empathy can not only shape students' internalization of the concept, and the resultant shift of mindset, but it can also be critical to formulating their connection to the discipline and their exchanges with others. The publications obtained, and subsequent analysis, can be of tremendous value towards understanding how departments can create more inclusive curricula and environments. The conclusions from this analysis highlight the relevance of empathy and offers educators and academia ideas about how to foster compassion in students, as well as potential implementations which could enhance teaching in STEM fields.

1 Introduction

Initiatives promoting science, technology, engineering, and mathematics (STEM) education and training have become more prevalent in recent years, seeking to educate students in these fields and to build the workforce to remain globally competitive [1, 2]. Yet, as these disciplines continue to grow, disparities in the representation of women and racial/ethnic minorities remains an issue

[3]. Based on employed adults over age 25, Hispanic workers comprise 17% of the general workforce, however in STEM positions this declines to 8%. Similarly, Blacks compromise 11% of workers, but for STEM jobs this percentage drops to 9%. While women may be involved in STEM jobs at higher rates overall, this varies by field. Women are a majority in health-related professions but they remain under-represented in physical sciences, computing, and engineering.

To create a more equitable workforce, and in particular, one that encourages the enrollment and persistence of underrepresented minorities, pedagogy centered around cultivating inclusivity is key. Along these lines, empathy as a construct can play a crucial role in aiding students to consider the impact of their own decisions and behaviors on others and society. To promote students seeing themselves as members of the STEM community, and to help them approach interactions, tasks, and product design while considering the perspectives and needs of others, educators should think about how to embed empathy into the curriculum. Employing appropriate learning activities can be beneficial for developing empathy in students. Prior research on K-12 students has shown that infusing empathy into STEM lessons can advance interest in pursuing a career in STEM, and it can also foster a sense of belonging [4, 5].

While such practices may be efficacious in higher education as well, more understanding is needed. It is important to foster empathy in undergraduate/graduate students and faculty to work towards more inclusive mindsets and environments. Previously Hess and Fila [6] demonstrated that literature on developing empathy is often more focused on how it can be established during childhood, rather than considering adults. Given the necessity of also embedding the concept of empathy within post-secondary education, we sought to understand how others have approached empathy in curricula, projects, and practice. To examine what work presently exists, and uncover patterns in pedagogical approaches and learning activities in STEM fields, we performed a systematic literature review (SLR). In our research, we explored the following research questions (RQs):

- **RQ1:** *How have educators integrated empathy development into learning activities in STEM?*
- **RQ2:** *What pedagogical approaches have been shown to promote empathy of students in STEM?*
- **RQ3:** *How have scholars approached the development of different kinds of empathy in classrooms?*

In this document, we provide background information pertaining to the complex phenomena of empathy in Section 2. Then, we discuss the theoretical framework that was applied in this research in Section 3. In Section 4, we detail the methods utilized in the literature review, including the search terms applied and inclusion/exclusion criteria. We provide an overview of the publications identified in Section 5, and a discussion of how these relate to the RQs in Section 6. In Section 7, we describe the limitations of this investigation, and we conclude in Section 8 with a summary and suggestions for future work in the field.

2 Background on Empathy

Empathy is described as the cognitive and affective ability to ascertain and share another's emotion, state, reactions, or perspective [7, 8]. It has also been linked to behavior [9], and is delineated as a construct that may have self-centered, other-centered, or pluralistic orientations [10]. The "affective response more appropriate to another's situation than one's own" [11, p. 4], has also been characterized as central to moral and ethical decisions and interpretations of social justice.

Some scholars have labeled empathy as a teachable skill, virtue, and/or ability, and others highlight the role personal choice plays in its development [12–15]. As Wiggins and McTighe (2005) expressed, "It is not simply an affective response or sympathy over which we have little control, but the disciplined attempt to feel as others feel, to see as others see" [7, p. 98]. Rather than treating empathy as merely a trait to develop, it has also been described as a professional state [16].

Educators have increasingly considered the value of developing empathy in students' education. In 2018, Tang observed that in the realm of engineering, 439 papers published at the ASEE annual conference proceedings included the word "empathy" [17]. Also, Sochacka et al. mentioned that empathic communication is not just "a simple matter of adding an objective set of skills to students' tool kits. Rather...a range of potential tensions and synergies...may influence how students incorporate such training into their developing understandings of what constitutes engineering knowledge and practice" [18, p. 122]. While this definition is engineering specific, the principle is true in other STEM disciplines as well.

It should be cautioned that although empathy is related to, and often conflated with, the notions of care, emotional intelligence (EI), emotional contagion, and/or sympathy, empathy is distinct [19, 20]. For the purposes of highlighting the factors that make empathy unique, we describe each of these further below:

- **Care:** A behavioral response derived from empathy, that requires taking action [16, 20]. It not only involves feelings and actions, but also describes the intent to take action and to promote well-being of other people and broader systems (e.g., the environment) [16, 20]. As such, it is linked with an understanding of others, and potentially altruism [20]. However, scholars have described how the conceptualization of care may vary by discipline, such as engineering versus counseling [20].
- **Emotional intelligence:** Comprised of five elements: self-awareness, self-regulation, motivation, empathy, and adeptness in relationships [21]. Although empathy is described as a foundational aspect of EI [22], it more broadly helps one to anticipate and manage their emotions and those of others.
- **Emotional contagion:** "With empathy, the observer is aware that this feeling is a result of perceiving emotion in the other. With emotional contagion, the emotion is captured, but the observer lacks this awareness, and the observer believes this feeling to be his/her own" [23, p. 149].
- **Sympathy:** More often described as concern or as reaction to others' unfortunate circumstances, although like empathy, it may also involve perspective taking and

understanding another's emotions [24, 25]. As such, empathy is considered a deeper connection about sharing feelings together rather than solely feeling for another.

Other concepts often attributed to empathy, particularly in the realm of engineering, are user- and human-centered design practices. Among these, Zoltowski, Oakes, and Cardella comment that they are similar but also emphasize that "user-centered design focuses on the end-user of the product, whereas human-centered design considers the stakeholders more broadly than the stereotypical user" [26, p.31]. Scholars have also mentioned the closely-related conceptualizations of sustainable design [27] and, more explicitly, empathic design [28].

In this review, we sought to explore what empirical evidence exists for cultivating empathy, and which learning activities or pedagogical approaches can be used for its development in STEM students. While we do examine how some of these other concepts related to empathy were integrated into educational contexts, empathy remained at the forefront of our inquiry.

3 Theoretical Framework

In 2019, Stanford psychologist Jamil Zaki published *The War For Kindness: Building Empathy In A Fractured World* [29]. This book presented a call to action to develop empathy and "broaden kindness" to combat increasing divides in society. In this work, **empathy** is described as an "umbrella term" for reactions to interpersonal dynamics, and considers the specific components of sharing, thinking about, and caring about others' feelings (see Figure 1). Although these components may vary by context and activate unique neurological structures, they also overlap. Zaki mentions that "Sharing someone else's emotion draws our attention to what they feel, and thinking about them reliably increases our concern for their well-being."

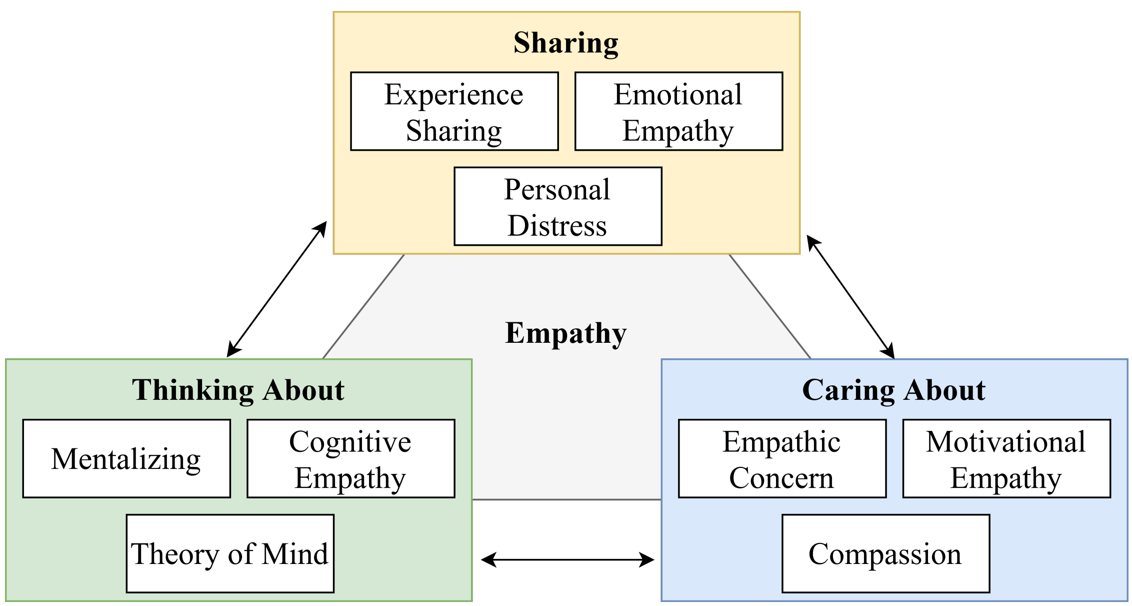

Figure 1: Zaki's model of empathy, adapted from [29, p. 178]

In Zaki's model, **"sharing"** pertains to "vicariously taking on the emotions we observe in others." It refers to the emotional comprehension of and reaction to others' positive and negative emotions. Such responses arise from sharing in the experience, and the conscious and unconscious feelings which arise from the perceived needs of those in distress. Experience sharing is neurologically rooted in mirror neurons, which are triggered in response to the mental and emotional state of others [30].

Meanwhile, **"thinking about"** refers to the cognitive component of empathy. Zaki describes it as "explicitly considering someone else's perspective." However, Wong et al. (2021) have expanded this definition to describe it as "the ability to identify and understand details about another's experience so that one can understand why people may think and feel the way that they do" [31, p. 1]. It should be noted that although "Theory of Mind" (ToM) and "mentalization" are often used interchangeably in the literature [32], many scholars differentiate between them conceptually, developmentally, and anatomically [33–37]. However, there is disagreement throughout the literature about which is the broader definition. Allen and Fonagy comment that "mentalizing is more than just theory of mind. It is more than just the understanding that others hold beliefs and that those beliefs can motivate their behavior" [37, p. 103]. They continue to describe that ToM is cognitively based but that mentalizing is affective as well and also includes the empathic component of recognizing others' states. Comparatively, Dvash and Shamay-Tsoory described Theory of Mind as a "a more advanced emotional form of mentalizing, rather than what has been called 'emotional contagion"' [35, p. 286].

Scholars have also described the importance of cognitive empathy in intercultural communication and how it can serve for "bridging cultural differences" [31, p. 2]. Among culturally divergent individuals and groups, it can create a a pluralistic and pro-social mindset [38–40]. Additionally, relational empathy reifies awareness of their own inability to posses first-hand knowledge of others' emotions or thoughts [41]. In turn, "Individuals instead jointly create interdependent understanding of experiences and empathy that are reflective of and shaping of their intercultural relationship dynamic" [31, p. 2]. Previously Wong et al. explicitly distinguished between each as [31, p. 7]:

- **Relational empathy** for specific individuals
- **Intergroup group empathy** for specific group
- **Critical dialogic empathy** for others that recognizes the structural positions of that individual and group in relation to power, privilege, and inequality in society

"Caring about" in Zaki's model considers the others-focused drive to take action. This component aligns closely with compassion, and Zaki describes it as the "motivation to improve someone else's well-being" [29]. Alternatively, **compassion** has also been previously defined by Catalanto as "the emotion that one feels in response to the suffering of others that motivates a desire to help" [42, p. 4]. In our research, we apply Zaki's interpretation that empathy can be enhanced or taught through learning activities. We also use this model to guide the inquiry in terms of the keywords searched and the analysis of the publications identified.

4 Methods

To learn about how educators promote empathy for students in STEM disciplines we performed a systematic literature review. This research was conducted in alignment with the steps for SLRs described by Petticrew and Roberts [43], and the STEM-specific principles of Verdin et al. [44] and Borrego et al. [45]. We used a methodical approach to examine the present state of the art.

We sought to identify the literature that presently exists, explore the content, and then to synthesize findings and identify gaps in our understanding [44, 46].

4.1 Source Selection and Search

Initially, a pilot search was conducted to identify the best search strings (in terms of relevance to the RQs) and databases [45]. This step occurred over 4 phases of iteration and refinement. Since we wanted to focus on undergraduate and graduate students, we did end up explicitly including the word "student" after the STEM-base to scope to more pertinent literature.

After refining the list, the final search was conducted in Google Scholar during June-August 2021. The following contained the relevant terms in alignment with Zaki's framework and our RQ goals:

((Experience sharing **OR** Emotional empathy **OR** Personal distress **OR** Empathic concern **OR** Motivational empathy **OR** Compassion **OR** Mentalizing or Mentaliz* **OR** Cognitive empathy **OR** Theory of mind)
AND
(Learn* **OR** Pedagog* **OR** Educat* **OR** Develop*)
AND
(STEM Student* **OR** Science Student* **OR** Tech* Student* **OR** Comput* Student* **OR** Engineer* Student* **OR** Math* Student*)

One issue encountered was the stopping conditions in our databases. For example, Google Scholar often lists hundreds of thousands of results. As such, we only included the first 50 hits from each combination. Although not all of the combinations delivered a full 50, the majority did extend well beyond this but the content became decreasingly relevant with additional pages. All publications were examined manually to guarantee adherence to the inclusion/exclusion criteria.

4.2 Study Execution

An overview of the SLR publication identification process is shown in Figure 2. The initial search identified 10,730 articles pertaining to the given topics. After removing the duplicates, 5,743 publications remained, and these were further screened for applicability by title. The abstracts were read of the pertinent articles collected, for which there was 423 in total. However, often a full review of the text was necessary to determine if the article met the inclusion criteria. In total, 133 full texts were assessed for their eligibility. The inclusion and exclusion criteria is described further below.

Snowballing was also performed to maximize relevant sources [47]. In this context, backward snowballing refers to searching a paper's reference list. Comparatively, forward snowballing refers to the use of the citations which reference a publication. Throughout the snowballing phase, the process was similar to that undertaken with publications selected in the database search. It also involved the same inclusion and exclusion criteria. One round forward and backward snowballing identified 200 potential candidates, based on their titles. After duplicates were removed, 147 publications remained, and the abstracts were read from each of these. After considering the relevance of the abstracts, 43 publications were read in their entirety. This led to the addition of 15 applicable papers which were added to the original candidates. In total, 63

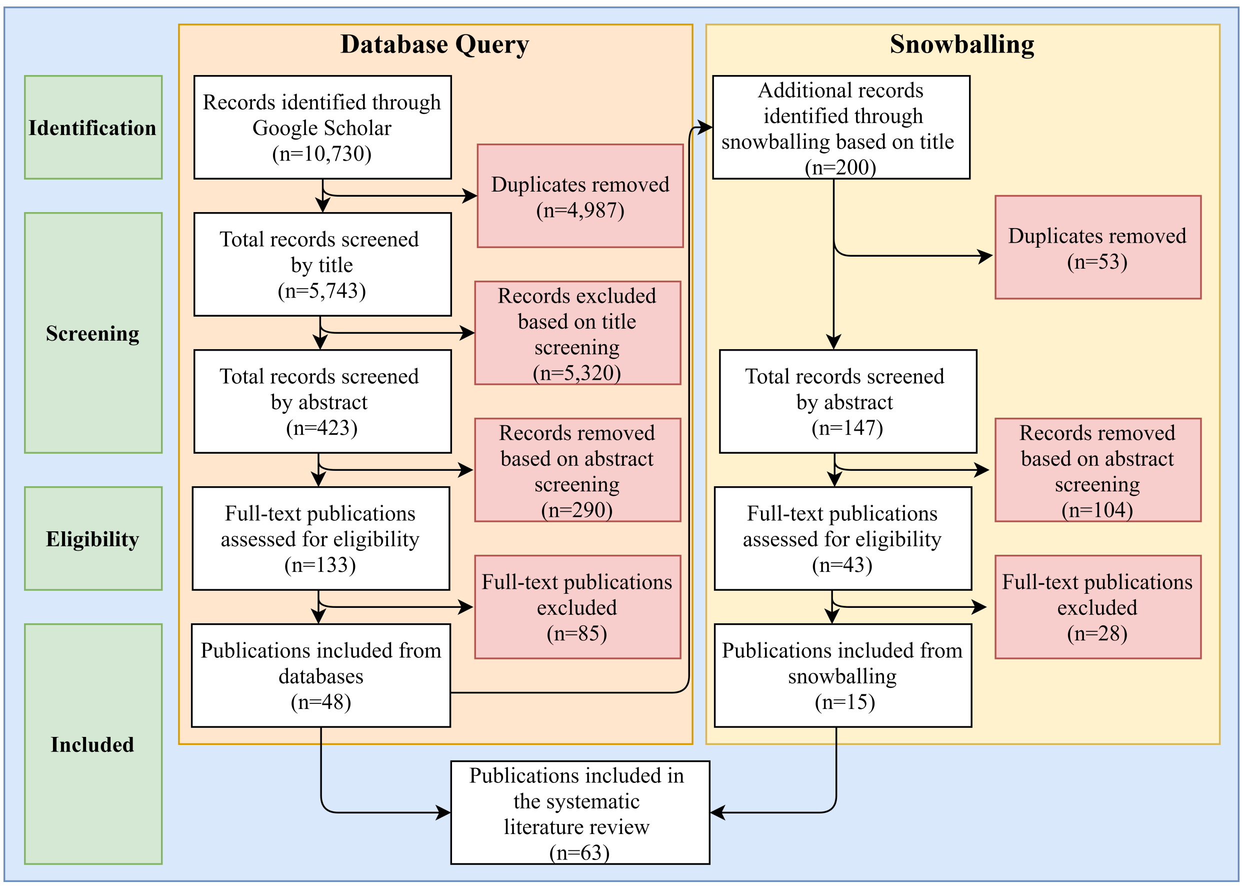

Figure 2: SLR paper selection process

publications were included in the systematic literature review.

4.3 *Study Inclusion and Exclusion Criteria*

The search strings generated a lengthy list of sources, that often were not related to the research questions. To filter databases and publications from their title to abstract to content, we applied a list of additional criteria, illustrated in Table 1. We excluded articles if they did not meet these criteria or if the full text was unavailable.

Inclusion	Exclusion
Publications that address the RQs	Publications not in English
Publications where the primary focus of the research was undergraduate or graduate students	Publications where the primary focus of the research was K-12 students, faculty, practicing clinicians or non-college or university students
Research was conducted in the United States or in Canada	Research specific to a university outside of the United States or Canada
Focus of publication is empathy, component of empathy described by the framework, or which mention how to develop/foster/imbue empathy	Focus of publication is not empathy, and if it includes empathy is more about measuring empathy than its development or learning
Include medical and nursing publications	Full text of publication not available
Publications include clear research question or hypothesis driven inquiry, where a study was conducted, or a description of a course. This may include literature reviews so long as methods are explicit.	Publication describes an idea or presents an argument without background or research, and no study is conducted, such as powerpoint slides and posters

Table 1: SLR Inclusion and Exclusion Criteria

As indicated, publications were excluded if there was no empirical study conducted, and/or if they merely discussed options that could be implemented, or which should be implemented to enhance empathy. This included many book chapters as they often were more general overviews on the topic. For example, Becker [48] described the principles pertaining to human-centered design and described models applied to education. While it did provide a comparison to encourage application to pedagogy, it did not describe an experiment conducted to determine their efficacy nor an overview of the implementation of a specific course. Although there may be an overlap between empathy and other topics such as ethics, emotional intelligence, and humanitarianism, articles which touched on these other topics were only included if empathy development was a major component examined or considered in the research. Many that integrated empathy did not directly explore its growth or development, it was more of a component considered or as part of the curriculum rather than the goal of the research. For example, McDonald and Pan (2020) presented feedback from graduate students on ethical considerations for artificial intelligence [49]. While this work elicited insight into prompting consideration of bias and fairness, fostering empathy was more of an indirect outcome than the phenomena of focus. Alternatively studies conducted in other countries were excluded since the interpretation and assessment of empathy may vary by culture depending on the societal norms and preferences.

4.4 *Interrater Reliability*

Initial article collection was performed by the first author. However, full texts were reviewed by the first and third authors independently using the full articles and assessing them based on the inclusion and exclusion criteria described. The authors then met to determine their alignment. Articles were only included which both authors agreed upon, with any uncertainties reconciled by negotiation.

5 Results

5.1 *Publications*

In total, the SLR identified 63 applicable STEM-related publications related to empathy pedagogy and learning activities. The complete list of publications, and the topics they covered, is provided in Appendix A. In total, the majority of publications pertained to the field of engineering (56 of the 63 total). In addition, 6 publications focused on the discipline of medicine and 2 considered science-centric populations, and there were no publications identified from mathematics, computing, and/or technology.

The role of empathy and its importance varied as it was contextualized for different disciplines. In engineering, developing empathy was described as considering the needs of others, a user or human centered focus, and defined in terms of the emotions involved with design, innovation, and evaluation [6, 50–52]. Scholars also mentioned its role in emotional intelligence, care, service-learning, communication, collaboration, ethics education, and considering the viewpoint of others (also referred to as perspective taking) [6, 22, 50, 51, 53, 54].

5.2 *Empathy Instruments*

While the focus of this review was more about the development or growth of empathy, pre-post testing to measure empathy was frequently included to determine the effectiveness of lessons and interventions. The complete list applied in publications, and the topic they are intended to assess is described further in Appendix B. Among the measures employed, Davis' Interpersonal Reactivity Index (IRI) was the most common, which is used to evaluate individual differences in empathy [55].

6 Discussion

The majority of the publications identified focused on students and education in the field of engineering. Although there were more papers observed in the initial search from the medical domain, they often were more concerned with measuring empathy levels in students than with educational tools to foster its development, and thus did not satisfy the inclusion criteria for the SLR. Given that cultivating empathy can be beneficial for all students in STEM, the results suggest more disciplines should consider pedagogical approaches to support its growth and establish inclusive mindsets. In the sections that follow, we discuss the findings for each RQ separately.

6.1 ***RQ1:*** *How have educators integrated empathy development into learning activities in STEM?*

Educators have integrated empathy development into learning activities as modules or interventions within existing courses [10, 14, 20, 50, 51, 56, 57], as stand-alone courses or workshops [27, 31, 58–61], or even as part of extra-curricular activities, particularly in the case of service learning. Often empathy integration was followed by reflective activities for students

[12, 62]. Some researchers also tested potential pedagogical tools outside the traditional curricula using STEM students to implement the new approaches [63, 64].

Empathy is pivotal to effective communication, to the application of ethical reasoning, and for human-centered design [26, 65]. Being able to understand the needs of users, and taking their perspectives into account can be crucial for STEM students to contribute globally. Along these lines we recommend several activities which can aid in empathy development. The first serves to develop active listening. Alternatively, role-playing can serve to give consideration to alternative perspectives.

Human-Centered design was described as vital for ethics and considering the value of designs in relation to engineering [26, 65]. Contextualizing problems was important for thinking about the broader impact of designs on others and for finding more inclusive solutions [65, 66]. One particularly creative approach to developing such skills, and thinking about the needs of others, was curricula established around “alien-centered design” [67]. Students were tasked with thinking about “a new, inter-galactic student exchange program planned with students from the planet Xenos” in two courses. As part of the process, students in one of the courses applied more traditional design methodogolgies to learn more about their stakeholders: 1. Needfinding: Day-in-the-life of an alien story, photos of possible needs 2. Problem Scoping: the team’s focus, goals, constraints and criteria 3. Concept generation 4. Concept reduction and selection 5. Concept detailing and prototype. In the other course, students considered these exchange students and suggested ideas for and created prototypes for adaptive devices to meet the aliens unique needs while on campus. Using traditional engineering principles while engaging students’ creativity allowed them to build their own empathy while solving problems from users unlike themselves.

Another course that proved beneficial to helping students develop competencies pertaining to emotional intelligence, with a large focus on empathy, was a class titled “Engineering Emotional Intelligence” [22]). The course began with encouraging personal development and internal reflections of students own values and beliefs. Later modules included empathic communication and service, specifically focused on service learning. The course also promoted communication, teamwork and collaboration, and discussed conflict negotiation and diplomacy. Among the exercises, empathic listening was determined to be particularly beneficial, an activity in which one student listened to another for 30 minutes, and then recorded the conversation. This was followed by written reflections on the experience, to promote cognitive empathy.

As an alternative to, or supplement to lecture-based lessons, readings followed up with group discussions and reflections have been suggested to facilitate learning in relation to emotional intelligence [68]. Shannon et al. also described how replacing traditional quizzes with games where students work together to find solutions to problems or to explore concepts well-received, and served to develop a community amongst the students. In addition, homework assignments were structured to move away from “traditional, lengthy, formulaic problem sets and instead focus on approaching problems from a different perspective, giving students the opportunity to connect the ideas that were discussed in class” [68, p. 7]. Students viewed these shifts in implementation positively, and these learning activities were reported to improve their self-awareness and empathy.

6.2 ***RQ2:*** *What pedagogical approaches have been shown to promote empathy of students in STEM?*

Educators used a variety of pedagogical tools to facilitate empathy in STEM fields. Among the approaches that were shown effective [9, 20, 31, 59, 66, 69–72], we consider the following categorizations: 1) Narrative and creative arts techniques (e.g., creative writing, readings, drama, poetry, comics, and film); 2) Communication skills training or interventions (e.g., interpersonal development, active listening, or intercultural small group discussions); 3) Problem-based learning; 4) Stakeholder engagement or interactions; and 5) Experiential immersion (e.g., service learning).

6.2.1 Narrative and Creative Arts Techniques

Alternative approaches to teaching that applied narrative and creative arts techniques (e.g., storytelling, poetry, etc.) were often well-received by students. Narratives have been used to consider alternative perspectives and to develop empathy [73]. Prompting medical students to write about their personal experiences with illness was shown to elicit introspection that informed their professional caregiving. It also served to raise awareness of vulnerabilities and biases. Reflections on this writing experience illustrated that students felt it would positively impact their understanding of others and their caregiving.

Likewise, in the domain of engineering, a course established around the pedagogy of storytelling, in which students constructed and shared personal narratives, was also shown effective at developing empathy in students [59]. This course was established with the goal of fostering entrepreneurially minded learning into the curriculum, by encouraging students to create value, expand their curiosity, and to form connections amongst information that may seem unrelated. In particular, this work sought to not only establish disciplinary identity but also to “habitualize the use of that skill set to create value for themselves, others, and society as a whole” [59, p. 4].

Alternatively, rather than students’ sharing their own stories, readings of poetry, skits and short stories on topics such as pain and cross-cultural issues have helped to ameliorate understanding and consideration of others’ perspectives [74]. These activities touch upon the “thinking about” component of Zaki’s framework, and potentially also “caring about” in the form of compassion. Likewise, an “empathic walkthrough” or personas can be used to tell stories from the vantage point of users’ to understand their position and encourage consideration of challenges or concerns they may have [64]. This method, externalizing decisions that may have otherwise been implied, can aid in the establishment of plausible user stories and can drive innovation.

Lectures, small group discussions, and audio and video tapes —or a combination of these activities — were also used to enhance communication [70]. Alternatively, drama interventions, such as those acting out the challenges associated with aging, were especially effective when followed up with small-group discussions. The study labeled as an “empathy intervention” (conducted by Bayne [75]) was considered effective and described “a program consisting of didactic and experiential content, including communication skills training and role-play, in an attempt to address both domains of empathy. Facilitators acknowledged the external characteristics of the decline of empathy, working with students to develop strategies to overcome perceived barriers to empathy in practice” [69, p. 1174]. Moreover, Tsao and Yu (2016) found through focus groups that “animated online comic strips on diabetes management” were effective at helping students recognize a lack of empathy not only in the animated doctors, but also in themselves [72]. Follow up investigations yielded insight that the comics served to improve the students' attitudes as they recognized the value of empathy in considering the patients' perspective.

Additionally, empathy maps served as useful tools both for students enrolled in courses, and as artifacts to organize thoughts around stakeholders when designing [57]. Empathy maps involve the creation and implementation of the strategic canvas of a landscape, a means for collaborative teams to gain a deeper insight into the goals and initiatives. They are often used in business and design to organize objectives and plan strategy.

6.2.2 Communication Skills Training or Interventions

Communication skills training was often achieved using role-playing, and mentioned the value of "coaching on formulating empathic phrases, and conveying empathy verbally and nonverbally" [69, p. 1173]. Role playing was also shown to be effective, as students considered the links between themselves and stakeholders and built emotional connections aligned with the "sharing" component of Zaki's framework [56, 62, 76, 77].

Previously Wong et al. described how social identity sharing and active listening experiences can be used to foster cognitive empathy and to facilitate learning on how culture can impact communication [31]. In a two day workshop they used several exercises, such as case studies, small group activities to practice active listening, and lectures about stereotype threats, aversive racism and sexism, and the benefits of cognitive empathy. Similarly, engaging listening to others speaking during ethical reasoning case studies has been shown to facilitate awareness and integration of others' viewpoints [20]. By introducing complex topics that may otherwise be considered "uncomfortable," and helping students to recognize the challenges others may face, students can be encouraged to confront injustice and prioritize empathy. Such actions are imperative long term to developing more inclusive mindsets, and to beginning to recognize and dismantle unconscious bias.

6.2.3 Problem-based Learning

Defining problems and encouraging students to research the parties involved in potential scenarios can foster consideration of the needs of diverse stakeholders [53, 58]. In particular, role playing can encourage the expression of emotions as students take up different viewpoints of stakeholders in various situation. It can also promote empathy and thinking about the perspectives of others and how they can impact design tasks. James et al. have also directly encouraged assets-based pedagogy [53], which considered the community and cultural needs of others to form connections in their discipline.

Developing the perspective taking component of empathy is considered especially effective when developed with consideration to ethics [58, 78]. It can encourage familiarization with professional codes of ethics as well as giving consideration to larger issues of social justice [58]. Previously Hess et al. (2020) used a mixed methods approach to study the interplay between empathy and ethics in an animal tissue harvesting lab [79]. As part of this work, students completed written reflections which allowed them to consider the ethical implications of animal research and to consider treatment of animals, benefits to humans, worth of life, and emotion. Showing videos coupled with observations and focus groups of the students yielded insight into recognition of the distress of the animals and greater moral questions such as “whether the taking of a life does moral damage to the person taking the life” [79, p. 20].

In addition, discussions on case studies supplemented with small groups working together to create reports can serve to encourage perspective taking and consideration of implicit biases [78]. Educational interventions could also serve to develop emotional regulation which mitigated personal distress. Furthermore, incorporating case studies based on ethical reasoning have been shown to be especially beneficial when involving situations where the answer may be ambiguous, since this forced students to reconcile their uncertainty when finding a solution, raising awareness of the perspectives of divergent stakeholders and collaborators [51, 77]. Encouraging dialogue between students and faculty can also foster internal reflection and integration of alternative viewpoints into students’ own decision-making. Alternatively, using recorded stakeholder interviews (e.g., between individuals with spinal cord injury and a practitioner specialized in caring for mobility challenged adults) coupled with the creation of personas can help students to reflect on the needs of those they are designing for, and also the societal impact of their designs [51]. In addition, it has been suggested that for the use of case studies to develop to be most effective “information has to go beyond stating the medical need and include details on the circumstances where the solution will be applied” [10, p. 8].

Scholars have commented it can also be valuable for educators to shift focus from the micro level of considering individual stakeholders to the macro level considering the impact on society [66]. They suggest that beyond the presentation of ethical dilemmas or projects meeting the needs of individual users, faculty could present larger issues pertaining to social justice and global implications to imbue broader considerations of empathy. Example scenarios derived from real-life experiences were also better received by students [76].

6.2.4 Stakeholder Engagement or Interactions

Stakeholders are described as “all the people who have an interest or are affected by a project” [80, p. 7], and may include patients, doctors, experts, regulatory bodies, manufacturers, potential users, etc. Engaging with stakeholders has been demonstrated to help students to gain insight into alternatives perspectives, and to establish effective solutions to meet the stakeholders’ needs [10, 24, 28, 50, 57, 66, 81, 82]. In the context of design, it can be critical to not only apply domain-specific understanding, but also to utilize situationally-relevant strategies. In an effort to learn more about the needs of others, and to create more “meaningful and feasible designs,” students often used interviews or focus groups [57].

Kim et al. described how interviews with stakeholders served to guide students’ process of reframing decisions into more user-centered, empathic designs [50]. Similarly, Mitchell and Light mentioned how involving stakeholders can add depth to the quality of projects produced and to consider the needs of others [24]. Yet, in lieu of more formal interviews, they suggested including “non-threatening interviews conducted by phone or in-person to break down resistance to verbally asking questions to less familiar people” [24, p. 10]. Zoltowski et al. also suggested that “interacting with users informally and in social situations” [26, p. 46] could help to establish connections and a deeper understanding of their needs.

Throughout the design process and interactions with stakeholders, Kong et al. recommended students use journals to document exchanges, and mentioned how encouraging these interview could help students to apply "empathic techniques more conscientiously and confidently" [10, p. 6]. Additionally, following up on lessons and encounters with reflection assignments was suggested to reconcile what students thought problems were against the actual problems identified through stakeholder engagement, and to interpret the role this could play in their problem-solving going forward.

6.2.5 Experiential immersion

Hands on experiences and immersion can help students to build empathy and improve their own work [82]. Previously, Bairaktarova et al. (2016) described one particular application, in which students were tasked with "an extreme affordability context for the design of alternatively powered washing machine" [57, p. 115]. Although many students were unfamiliar with the plight of those who had to wash clothing by hand with limited access to water, only a small subset attempted to understand their users' plight by physically doing so. Yet, the authors suggested this approach could help to inform empathic designs. In the context of a distance learning course, students submitted photos to demonstrate their experience.

Alternatively, a walking tour of a historic villages helped students think about how to formulate solutions about sewage management issues [58]. The authors described that "by physically experiencing their environs, students were able to locate themselves in the otherwise abstract temporal and geographical context. Extant structures and infrastructure enabled students to imagine the past and connect it to the present, giving them an appreciation of how the built landscape reflected, and continues to reflect, social, cultural and industrial priorities." [58, p. 12].

Experiential immersion and prioritizing community-engagement in Earth Science curricula have also been shown to promote ethical development, even in the absence of explicit discussions on ethics in courses [83]. In general, service learning (SL) experiences were demonstrated to be useful pedagogical tools in developing empathy as a type of understanding, helping students to establish emotional connections with others, compassion, [9, 42, 54, 71, 80, 84–86] and a type of "critical consciousness" [42]. Direct observation overtly lead to seeing their points view, as well as how designs could be applied in real world contexts [9, 80].

Service learning experiences can have several other benefits as well. They can provide opportunities for students to engage with those close to the user to establish a discourse and develop "empathy by proxy" [9]. Additionally, they can enhance projection onself, where the student imagines themself in the user's position and understanding their situations [9, 80]. Likewise, Wilson has previously described how students "began to establish relationships with the people being served and see commonalities between themselves and those they are serving" [84, p. 210]. This can also help them to adjust their goals and compromise[80]. Additionally, it can create a pluralistic mindset [87] and foster altruistic thinking as students seek to enhance others' well-being [88]. In particular, SL has been shown to promote perspective, empathy, and self-awareness and knowledge learning when coupled with reflection to internalize the experience

[54, 71, 84, 85].

The camaraderie aspect of participating in SL experiences, particularly when coping with challenges that may arise, can also serve to develop emotional connections [54]. Empathy was considered important in other teamwork contexts as well. Scholars described how it could encourage perspective taking that can benefit conflict resolution [89]. Furthermore, creating diverse groups of students from different cultural backgrounds can help to broaden their perspective [8].

*6.3 **RQ3:** How have scholars approached the development of different kinds of empathy in classrooms?*

Researchers have distinguished between being self-oriented and having an individualistic focus and being other-oriented or having a pluralistic focus [6, 90]. Promoting a collectivist or pluralist mentality can serve to shift "thinking about" (as described by Zaki) towards larger societal needs. However, debate exists surrounding the impact of implementation and social justice depending on the field and context. Previously, Walter et al. (2017) cautioned that, in the realm of engineering, given the range of contexts for problems, "actively and directly promoting social justice may not be a realistic or productive orientation and expectation" [13, p. 136]. Instead, they suggest "active, purposeful, transparent, and equitable discourse around the heterogeneous values-informed purposes driving different forms of engineering work" [13, p. 136].

Literature also described how individuals are less likely to empathize with those with backgrounds that are divergent from their own, and mentioned how this can be especially challenging for students [8, 51]. As such, they recommended an indirect approach, introducing it into teamwork along with communication. Even simple exercises in encouragement, reminding students about the stresses associated with online learning and teamwork, can serve to foster empathy between classmates [51]. This is not to say that educators cannot also be more direct. Faculty could consider celebrating and encouraging consideration of the assets different individuals can contribute to enrich a team, and can emphasize the value in diversity of individuals and in thinking in their lessons.

From the perspective of faculty, empathy has been suggested to be valuable and helps them to "understand their academically diverse student population" [16, p. 148]. It can also encourage more personalized approaches when assisting students and meeting their needs. Guanes et al. have previously described the role of faculty in students' empathy development, and expressed that merely including empathy in the curricula is insufficient [66]. Instead, it is critical for educators to learn the principles of empathy themselves, and to reflect on how it could be integrated into the curriculum. One means for doing so suggested was including stakeholders in grading of projects or rubric development, and/or establishing assessments along with students. Likewise, Mitchell and Light (2018) described how the requirements of deliverable rubrics could be continually assessed ensure alignment with stakeholders preferences and needs, as proof-of-concept models are refined [24].

Furthermore, scholars have cautioned that students' experiences and responses to empathy exercises and activities may vary widely. Although many students do engage, others will reject the process. They note that "Being aware of this range can put us in a position to facilitate a shared experience and discussion that does not invalidate students experience at either end of the range and perhaps opens opportunities for beneficial peer influences in a socio-cultural learning dynamic" [56, p. 7].

Apart from seeking to enhance empathy, this work illustrates the need to also develop pluralistic mindsets, emotional intelligence, and the capability for ethical consideration in STEM students. Along these lines, service to the the community and society is suggestion to raise "value awareness" [13, p. 137]. Meanwhile, scholars caution that limiting class discussions on ethical questions, and leaving content to be implied without proper grounding or follow up, can hamper ethical reasoning development [52].

7 Limitations

The findings from this investigation are limited in several ways. Source selection was conducted from a single database, which could limit the publications identified. Although additional databases such as IEEE or PubMed may have identified additionally relevant content, given the range of databases which may be applicable in STEM fields, we intentionally chose to use a tool which offered broader coverage. In addition, while keywords queried seemed to cover the subject adequately based on a pilot search, expanding to include additional terms might have identified different material. As described, although we wanted to focus on empathy this topic often overlaps with research on other topics, such as emotional intelligence or ethics. As such, future research may want to explore these topics further.

8 Conclusions

Ultimately, this SLR provided insight not only into how other scholars have described empathy, but also into how educators have studied and taught the concept in STEM courses and applied it to their lessons. The results were defined in terms of the publications identified and the learning activities activities, programs, workshops, and opportunities established. Overall, we observed that STEM publications concerning empathy development are often limited to a focus in engineering or medicine. This lacuna in the literature demonstrates a need to extend these pedagogical approaches and research to other STEM disciplines such as computing and/or mathematics. In addition, given that the construct of empathy may vary so widely, and that it may overlap with several other concepts, it is frequently presented alongside or as part of other interventions. However, a concerted effort to put a spotlight on empathy can help to raise awareness of its importance, and to encourage students to internalize it, along with disciplinary knowledge, to establish more inclusive mindsets.

The publications obtained, and subsequent analysis, can be of tremendous value towards understanding how departments can improve curricula and environments. The conclusions from this analysis highlight the relevance of empathy, and offers educators and academia ideas about how to foster compassion in students, and potential implementations which could enhance teaching. To broaden participation in STEM fields, it is vital to do so, and to cultivate awareness of others, equitable thinking, and inclusive environments. Going forward, educators should think about their role in promoting empathy in their students, and also about how they can apply empathy in their own practices.

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A Publications Included in the SLR

We describe the publications identified in the SLR below.

Reference	Type of Publication	Field of Focus	Sharing: Experience sharing, Emotional empathy, Personal Distress	Caring About: Empathic concern, Motivational empathy, Compassion	Thinking About. Mentalizing, Cognitive empathy, Theory of mind	Codes of Ethics or Rules	Listening	Communication	Emotional Intelligence	Teamwork and/or Collaboration	Service Learning	Pluralism	Human Centered Design or User Centered Design or Empathic Design or Sustainable Design
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.	Journal	Engineering	✓	✓	✓			✓				✓	✓
Hess, J. L., & Fila, N. D. (2016). The development and growth of empathy among engineering students. American Society for Engineering Education.	Conference	Engineering				✓		✓		✓	✓		✓
Hess, J. L., Miller, S., Higbee, S., Fore, G. A., & Wallace, J. (2020). Empathy and ethical becoming in biomedical engineering education: a mixed methods study of an animal tissue harvesting laboratory. Australasian Journal of Engineering Education, 1-11.	Journal	Engineering	✓	✓	✓	✓			✓				
Lee, C., Bristow, M., & Wong, J. C. (2018). Emotional intelligence and teamwork skills among undergraduate engineering and nursing students: A pilot study. Journal of Research in Interprofessional Practice and Education, 8(1).	Journal	Engineering					✓		✓	✓			
Fila, N. D., & Hess, J. L. (2016). In their shoes: Student perspectives on the connection between empathy and engineering. American Society for Engineering Education.	Conference	Engineering	✓	✓	✓	✓				✓			✓
Wilson, J. C. (2011). Service-learning and the development of empathy in US college students. Education + Training.	Journal	Science	✓	✓	✓						✓		
Batt-Rawden, S. A., Chisolm, M. S., Anton, B., & Flickinger, T. E. (2013). Teaching empathy to medical students: an updated, systematic review. Academic Medicine, 88(8), 1171-1177.	Journal	Medicine	✓	✓	✓			✓					
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.	Conference	Engineering	✓	✓	✓					✓	✓	✓	
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.	Conference	Engineering			✓			✓				✓	
Walther, J., Brewer, M. A., Sochacka, N. W., & Miller, S. E. (2020). Empathy and engineering formation. Journal of Engineering Education, 109(1), 11-33.	Journal	Engineering	✓	✓	✓			✓					
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, 1-12.	Journal	Engineering	✓	✓	✓						✓		
Wang, L., Carroll, T. K., & Delaine, D. A. (2018, January). A Pilot Study of the Development of Empathy within a Service-learning Trip from a Qualitative Perspective. In ASEE Annual Conference proceedings.	Conference	Engineering	✓	✓	✓					✓	✓		
Walther, J., Miller, S. E., Sochacka, N. W., & Brewer, M. A. (2016). Fostering empathy in an undergraduate mechanical engineering course. In American Society for Engineering Education (ASEE) Annual Conference and Exposition, New Orleans, LA.	Conference	Engineering	✓	✓	✓			✓					
Tanu, E. D., Quan, G. M., Gupta, A., & Turpen, C. A. (2017). The role of empathy in supporting teaching moves of engineering design peer educators. In ASEE Annual Conference & Exposition, Columbus, Ohio. https://peer. asee.org/29004.	Conference	Engineering	✓	✓	✓					✓			
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.	Journal	Engineering	✓	✓	✓			✓		✓			✓
Sochacka, N. W., Delaine, D. A., Shepard, T. G., & Walther, J. (2021). Empathy Instruction through the Propagation Paradigm: A synthesis of developer and adopter accounts. Advances in Engineering Education, 9(1).	Journal	Engineering	✓	✓	✓			✓			✓		
James, J. O., Svihla, V., Qiu, C., & Riley, C. (2018). Using design challenges to develop empathy in first-year courses. In American Society for Engineering Education Annual Conference & Exposition, Salt Lake City, UT.	Conference	Engineering	✓	✓	✓	✓							✓
Alsager Alzayed, M., McComb, C., Menold, J., Huff, J., & Miller, S. R. (2020). Are you feeling me? An exploration of empathy development in engineering design education. Journal of Mechanical Design, 1-57.	Journal	Engineering	✓	✓	✓								✓
Hess, J. L., Beever, J., Zoltowski, C. B., Kisselburgh, L., & Brightman, A. O. (2019). Enhancing engineering students' ethical reasoning: Situating reflexive principlism within the SIRA framework. Journal of Engineering Education, 108(1), 82-102.	Journal	Engineering	✓	✓	✓	✓	✓						
Guanes, G., Wang, L., Delaine, D. A., & Dringenberg, E. (2021). Empathic approaches in engineering capstone design projects: student beliefs and reported behaviour. European Journal of Engineering Education, 1-17.	Journal	Engineering	✓	✓	✓								✓

Table 2: Publications and Topic

Reference	Type of Publication	Field of Focus	Sharing: Experience sharing, Emotional empathy, Personal Distress	Caring About: Empathic concern, Motivational empathy, Compassion	Thinking About. Mentalizing, Cognitive empathy, Theory of mind	Codes of Ethics or Rules	Listening	Communication	Emotional Intelligence	Teamwork and/or Collaboration	Service Learning	Pluralism	Human Centered Design or User Centered Design or Empathic Design or Sustainable Design
Hess, J. L. (2015). A multi-phase exploration of conceptualizations, perceived importance, and the development of empathy within engineering (Doctoral dissertation, Purdue University).	Thesis	Engineering	✓	✓	✓	✓	✓			✓			
DasGupta, S., & Charon, R. (2004). Personal illness narratives: using reflective writing to teach empathy. Academic Medicine, 79(4), 351-356.	Journal	Medicine	✓	✓	✓								
Shapiro, J., Morrison, E. H., & Boker, J. R. (2004). Teaching empathy to first year medical students: evaluation of an elective literature and medicine course. Education for Health: Change in Learning & Practice, 17(1).	Journal	Medicine	✓	✓	✓								
Stepien, K. A., & Baernstein, A. (2006). Educating for empathy. Journal of general internal medicine, 21(5), 524-530.	Journal	Medicine	✓	✓	✓			✓					
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.	Journal	Engineering	✓	✓	✓	✓	✓	✓					
Crowley, L., Dolle, J. R., Litchfield, B., & Price, R. (2001, June). Engineering emotional intelligence: Course development and implementation. In 2001 Annual Conference (pp. 6-431).	Conference	Engineering	✓	✓	✓		✓	✓	✓	✓	✓		
Youngblood, K. M., Sochacka, N. W., Walther, J., & Miller, S. E. (2019). How mental models impact students' engagement with empathic communication exercises. In 30th Annual Conference for the Australasian Association for Engineering Education (AAEE 2019): Educators Becoming Agents of Change: Innovate, Integrate, Motivate (p. 85). Engineers Australia.	Conference	Engineering	✓	✓	✓		✓	✓					
Howcroft, J., Mercer, K., & Boger, J. (2021). Developing Ethical Engineering with Empathy. Proceedings of the Canadian Engineering Education Association (CEEA).	Conference	Engineering	✓	✓	✓	✓	✓	✓		✓		✓	✓
Kim, E., Purzer, S., Vivas-Valencia, C., Payne, L., & Kong, N. (2020, June). Problem Reframing and Empathy Manifestation in the Innovation Process. In 2020 ASEE Annual Conference & Exposition, Montréal, Quebec, Canada.	Conference	Engineering	✓	✓	✓			✓					✓
Hess, J. L., Fila, N. D., Purzer, S., & Strobel, J. (2015, June). Exploring the relationship between empathy and innovation among engineering students. In 2015 ASEE Annual Conference & Exposition (pp. 26-740).	Conference	Engineering	✓	✓	✓								
Carroll, T. K., Wang, L., & Delaine, D. A. (2018, November). A Quantitative, Pilot Investigation of a Service-Learning Trip as a Platform for Growth of Empathy. In 2018 World Engineering Education Forum-Global Engineering Deans Council (WEEF-GEDC) (pp. 1-5). IEEE.	Conference	Engineering	✓	✓	✓						✓		
Hess, J. L., & Fila, N. D. (2016). The manifestation of empathy within design: findings from a service-learning course. CoDesign, 12(1-2), 93-111.	Journal	Engineering	✓	✓	✓						✓	✓	
Hess, J. L., Fore, G. A., Sorge, B. H., Coleman, M. A., Price, M. F., & Hahn, T. W. (2019). Exploring Ethical Development from Standard Instruction in the Contexts of Biomedical Engineering and Earth Science. ASEE.	Conference	Engineering and Science	✓		✓	✓						✓	
Kong, N., Purzer, S., Payne, L., Kim, E., & Vivas-Valencia, C. (2020, June). Research Initiation: Enhancing the Learning Outcomes of Empathic Innovation in Biomedical Engineering Senior Design Projects. In 2020 ASEE Annual Conference & Exposition, Montréal, Quebec, Canada.	Conference	Engineering	✓	✓	✓								✓
Brewer, M. A., Sochacka, N. W., Walther, J., & Miller, S. E. (2017). How do students meaningfully interpret the role of empathy in engineering? A social phenomenological study. In Research in Engineering Education symposium, Bogota, Colombia.	Conference	Engineering	✓	✓	✓								
Patterson, L. (2020, July). Engineering Students' Empathy Development Through Service Learning: Qualitative Results in a Technical Communication Course. In 2020 IEEE International Professional Communication Conference (ProComm) (pp. 68-75). IEEE.	Conference	Engineering	✓	✓	✓	✓				✓	✓		✓
Shannon, R. (2020). Designing a multi-cycle approach to empathetic electrical engineering courses.	Conference	Engineering	✓	✓	✓				✓				✓
Jordan, S., Lande, M., Cardella, M., & Ali, H. (2013, October). Out of their world: Using alien-centered design for teaching empathy in undergraduate design courses. In 2013 IEEE Frontiers in Education Conference (FIE) (pp. 907-913). IEEE.	Conference	Engineering	✓	✓	✓								✓
Koehler, J., Pierrakos, O., Lamb, M., Demaske, A., Santos, C., Gross, M. D., & Brown, D. F. (2020, June). What Can We Learn from Character Education? A Literature Review of Four Prominent Virtues in Engineering Education. In 2020 ASEE Virtual Annual Conference Content Access.	Conference	Engineering	✓	✓	✓					✓	✓		
Hess, J. L., & Fore, G. (2018). A systematic literature review of US engineering ethics interventions. Science and engineering ethics, 24(2), 551-583.	Journal	Engineering	✓	✓	✓	✓							

Table 3: Publications and Topic

Reference	Type of Publication	Field of Focus	Sharing: Experience sharing, Emotional empathy, Personal Distress	Caring About: Empathic concern, Motivational empathy, Compassion	Thinking About. Mentalizing, Cognitive empathy, Theory of mind	Codes of Ethics or Rules	Listening	Communication	Emotional Intelligence	Teamwork and/or Collaboration	Service Learning	Pluralism	Human Centered Design or User Centered Design or Empathic Design or Sustainable Design
Bairaktarova, D., Bernstein, W. Z., Reid, T., & Ramani, K. (2016). Beyond surface knowledge: An exploration of how empathic design techniques enhances engineers understanding of users' needs. International Journal of Engineering Education, 32(1), 111-122.	Journal	Engineering	✓	✓	✓								✓
Schmitt, E., Morkos, B., Kames, E., & Conway, T. A. (2016, June). The importance of incorporating designer empathy in senior capstone design courses. In 2016 ASEE Annual Conference & Exposition.	Conference	Engineering	✓	✓	✓								✓
Catalano, G. D. (2016, June). Integrating Compassion into an Engineering Ethics Course. In 2016 ASEE Annual Conference & Exposition.	Conference	Engineering	✓	✓	✓	✓					✓		
Dodson, L., DiBiasio, D., Quinn, P., Bergendahl, J., Boudreau, K., Gaudette, G., & Abel, C. (2017, June). How Role-Playing Builds Empathy and Concern for Social Justice. In 2017 ASEE Annual Conference & Exposition.	Conference	Engineering	✓	✓	✓	✓						✓	
Morgan, K. L., Bell-Huff, C. L., Shaffer, J., & LeDoux, J. M. (2021, July). Story-Driven Learning: A Pedagogical Approach for Promoting Students' Self-Awareness and Empathy for Others. In 2021 ASEE Virtual Annual Conference.	Conference	Engineering	✓	✓	✓		✓	✓					
Yeaman, A. O. (2020). Understanding Empathy in the Experiences of Undergraduate Engineering Students in Service-Learning Programs (Doctoral dissertation, Virginia Tech).	Thesis	Engineering	✓	✓	✓						✓		
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.	Conference	Engineering	✓	✓	✓								✓
Gray, C. M., Yilmaz, S., Daly, S. R., Seifert, C. M., & Gonzalez, R. (2015). Idea generation through empathy: Reimagining the 'cognitive walkthrough'.	Conference	Engineering	✓	✓	✓			✓					✓
Fila, N. D., & Hess, J. L. (2015). Exploring the role of empathy in a service-learning design project. Analyzing Design Review Conversations, 135-154.	Symposium	Engineering	✓	✓	✓						✓	✓	✓
Johnson, D. G., Genco, N., Saunders, M. N., Williams, P., Seepersad, C. C., & Hölttä-Otto, K. (2014). An experimental investigation of the effectiveness of empathic experience design for innovative concept generation. Journal of Mechanical Design, 136(5), 051009.	Journal	Engineering		✓	✓								✓
Zoltowski, C. B., Oakes, W. C., & Cardella, M. E. (2012). Students' ways of experiencing human-centered design. Journal of Engineering Education, 101(1), 28-59.	Journal	Engineering	✓	✓	✓			✓					✓
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.	Conference	Engineering	✓	✓	✓			✓		✓		✓	
Yeaman, A., Bairaktarova, D., & Reid, K. (2020, June). A Qualitative Study of Empathy in the Experiences of Students in a First-Year Engineering Service Learning Course. In 2020 ASEE Virtual Annual Conference.	Conference	Engineering	✓	✓	✓						✓		
Prabhu, R., Starkey, E. M., & Alzayed, M. A. (2021, July). Student Reflections on Sustainability and Empathy: The Outcomes of a Sustainability Workshop in First-year Design Courses. In 2021 ASEE Virtual Annual Conference.	Conference	Engineering	✓	✓	✓								✓
Sulzer, S. H., Feinstein, N. W., & Wendland, C. L. (2016). Assessing empathy development in medical education: a systematic review. Medical education, 50(3), 300-310.	Journal	Medicine	✓	✓	✓								
Tsao, P., & Catherine, H. Y. (2016). "There's no billing code for empathy"-Animated comics remind medical students of empathy: a qualitative study. BMC medical education, 16(1), 1-8.	Journal	Medicine	✓	✓	✓								
Shah, D., Morkos, B., & Yang, X. (2020, June). Can Empathy Be Taught? The Results of an Assignment Targeted at Improving Empathy in Engineering Design. In 2020 ASEE Virtual Annual Conference Content Access.	Conference	Engineering	✓	✓	✓								✓
Bell-Huff, C. L., & Morano, H. L. (2017, June). Using simulation experiences, real customers, and outcome driven innovation to foster empathy and an entrepreneurial mindset in a sophomore engineering design studio. In 2017 ASEE Annual Conference & Exposition.	Conference	Engineering	✓	✓	✓			✓					✓
Mitchell, L., & Light, L. (2018, June). Increasing student empathy through immersive user empathy experiences in first-year design education. In 2018 ASEE Annual Conference & Exposition.	Conference	Engineering	✓	✓	✓								✓
von Unold, B., Böhmer, A. I., Björklund, T. A., Ledl, N., Lindemann, U., Toye, G., & Sheppard, S. (2018, June). Implications of contextual empathic design for engineering education. In 2018 ASEE Annual Conference & Exposition.	Conference	Engineering	✓	✓	✓								✓
Gray, C. M., El Debs, L. D. C., Exter, M., & Krause, T. S. (2016, June). Instructional strategies for incorporating empathy in transdisciplinary technology education. In 2016 ASEE Annual Conference & Exposition.	Conference	Engineering	✓	✓	✓								✓
Cavanagh, D. P., & Tranquillo, J. (2017, June). Diseases, Devices, and Patients: Exposing BME Students to the Patient Experience. In 2017 ASEE Annual Conference & Exposition.	Conference	Engineering	✓	✓	✓			✓					
Sanders, E. A., Goldstein, M. H., & Hess, J. L. (2021, July). Assessing Ways of Experiencing Human-centered Design via Student Reflections. In 2021 ASEE Virtual Annual Conference.	Conference	Engineering	✓		✓								✓

Table 4: Publications and Topic

B Measures Utilized in the SLR

The publications identified, applied the measures described in Figure 5.

Assessment Name	What Does it Evaluate?	Original Reference of Measure	Publications that Utilized
Active-Empathic Listening Scale (AELS)	Active empathetic listening	Bodie, G.D. (2011). The Active-Empathic Listening Scale (AELS): Conceptualization and evidence of validity within the interpersonal domain. Communication Quarterly, 59(3), 277–295.	[91]
Attitudes towards Sustainability	Sustainability	Tang, K.H.D. (2018). Correlation between sustainability education and engineering students' attitudes towards sustainability. International Journal of Sustainability in Higher Education.	[27]
Attitude-toward-the-Humanities Measure	Attitudes towards humanities	Shapiro, J. (2002). How do physicians teach empathy in the primary care setting?. Academic medicine, 77(4), 323-328.	[74]
Balanced Emotional Empathy Scale (BEES)	Empathy	Mehrabian, A. (1996). Manual for the balanced emotional empathy scale (BEES). Available from Albert Mehrabian, 1130. Mehrabian, A., Young, A. L., & Sato, S. (1988). Emotional empathy and associated individual differences. Current Psychology, 7(3), 221-240.	[74]
Cech's survey	Effect service learning and humanities-based instruction has on students' engagement with public welfare	E. Cech, "Culture of disengagement in engineering education?" Sci., Technol. & Human Values, vol. 39, no. 1, 2014, pp. 42–72.	[88]
Civic-Minded Graduate Scale (CMG)	Civic-mindedness	K. S. Steinberg, J. A. Hatcher, and R. G. Bringle, "Civic-minded graduate: A north star," Michigan Journal of Community Service Learning, vol. 18, no. 1, pp. 19-34, 2011	[83]
Defining Issues Test 2 (DIT2)	Ethical reasoning and moral judgement	Rest, J. R., Narvaez, D., Thoma, S. J., & Bebeau, M. J. (1999). DIT2: Devising and testing a revised instrument of moral judgment. Journal of Educational Psychology, 91(4), 644–659. http://doi.org/10.1037/0022-0663.91.4.644	[78, 83]
Emotional Empathy Scale	Empathy	Caruso, D.R., & Mayer, J.D. (1998). A measure of emotional empathy for adolescents and adults [Unpublished manuscript]. Durham, NH: University of New Hampshire.	[91]
Emotional Intelligence Self-Assessment	Perceived emotional intelligence	Weisinger, H. (1998). Emotional intelligence at work: The untapped edge for success. San Francisco, CA: Jossey-Bass Publishers.	[91]
Empathy Construct Rating Scale (ECRS) (20-item version)	Empathy	LaMonica, E. L. (1981). Construct validity of an empathy instrument. Research in nursing & health, 4(4), 389-400. LaMonica, E. L. (1996). Empathy construct rating scale. Santa Clara: Xicom Inc, 8.	[74]
Emotional Competence Inventory (ECI)	Emotional competence	Goleman, D. (1995). Emotional Intelligence. New York (Bantam) 1995.	[22]
Thematic Apperception Test and a Motivation Styles Survey	Values and personal goals that drive and motivate	Not described	[22]
Empathic Design Tendency Survey	Empathic design tendency based on interpersonal reactivity model of empathy's dimensions	Kong, N., Purzer, S., Payne, L., Kim, E., & Vivas-Valencia, C. (2020, June). Research Initiation: Enhancing the Learning Outcomes of Empathic Innovation in Biomedical Engineering Senior Design Projects. In 2020 ASEE Annual Conference & Exposition, Montréal, Quebec, Canada. Kim, E., Purzer, S., Vivas-Valencia, C., Payne, L., & Kong, N. (2020, June). Problem Reframing and Empathy Manifestation in the Innovation Process. In 2020 ASEE Annual Conference & Exposition, Montréal, Quebec, Canada	[10, 50]
Empathy Assessment Index (EAI)	Self-reported empathy levels	Segal, E. A., Gerdes, K. E., Lietz, C. A., Wagaman, M. A., & Geiger, J. M. (2017). Assessing empathy. Columbia University Press.	[60]
Empathy Formative Questionnaire	Empathy	Gaumer-Erickson, A., Soukup, J., Noonan, P., & McGurn, L. (2015). Empathy formative questionnaire [Measurement instrument].	[92]
Engineering Ethical Reasoning Instrument (EERI)	Ethical reasoning	Zoltowski, C. B., Buzzanell, P. M., & Oakes, W. C. (2013, June). Utilizing an engineering ethical reasoning instrument in the curriculum. In 2013 ASEE Annual Conference & Exposition (pp. 23-1350).	[78]
Innovation Self-Efficacy Survey	Innovation self-efficacy	Schar, M., Gilmartin, S., Harris, A., Rieken, B., & Sheppard, S. (2017, January). Innovation Self-Efficacy: A Very Brief Measure for Engineering Students. In Proceedings for the American Society for Engineering Education Annual Conference, June 25-28. Columbus, OH.	[10].
Innovative Behaviors Scale	Innovative behaviors	Dyer, J. H., Gregersen, H. B., & Christensen, C. (2008). Entrepreneur behaviors, opportunity recognition, and the origins of innovative ventures. Strategic Entrepreneurship Journal, 2(4), 317-338.	[52]
Interdisciplinary Education Perception Scale (IEPS)	Perceived readiness for interprofessional learning	Luecht, R.M., Madsen, M.K., Taugher, M.P., & Petterson, B.J. (1990). Assessing professional perceptions: Design and validation of an Interdisciplinary Education Perception Scale. Journal of Allied Health, 19(2), 181–191.	[91]
Interpersonal Reactivity Index	Empathic concern and perspective-taking	Davis, M. H. 1983. "Measuring Individual Differences in Empathy: Evidence for a Multidimensional Approach." Journal of Personality and Social Psychology. 44 (1):113–126. doi:10.1037/0022-3514.44.1.113.	H[8, 20, 27, 52, 65, 71, 78, 79, 83]
Jefferson Scale of Physician Empathy (JSPE)	Physician empathy	Hojat, M., Mangione, S., Nasca, T. J., Cohen, M. J., Gonnella, J. S., Erdmann, J. B., ... & Magee, M. (2001). The Jefferson Scale of Physician Empathy: development and preliminary psychometric data. Educational and psychological measurement, 61(2), 349-365.	[72]
Team Skills Scale	Perceived teamwork competence (communication, collaboration)	Hepburn, K., Tsukada, R., & Fraser, C. (1998). Team skills scale. In E.L. Siegler, K. Hyer, T. Fulmer, & M. Mezey (Eds.), Geriatric interdisciplinary team training (pp.264–265). New York, NY: Springer Publishing Company.	[91]
The Toronto Empathy Questionnaire (TEQ)	Affective and cognitive empathy	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.	[88, 92]
Two-question survey derived from work by Raviselvam et al	Empathic self-efficacy	Raviselvam, S., Hölttä-Otto, K., & Wood, K. L. (2016, August). User extreme conditions to enhance designer empathy and creativity: Applications using visual impairment. In International Design Engineering Technical Conferences and Computers and Information in Engineering Conference (Vol. 50190, p. V007T06A005). American Society of Mechanical Engineers.	[8]

Table 5: Measures Utilized in Studies