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Review

Role of Empathy in Engineering Education and Practice in North America

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Abstract: Does engineering design education in North America prepare students to address the major issues of our time? In today's political and social climate, engineers are part of multi-disciplinary teams tasked with finding solutions to complex issues like poverty, climate change, the housing affordability crisis, resource depletion, and water shortages. By definition, these problems are "wicked". If engineers are to play a role in addressing issues that exist at the intersection of technology and society, they must have a deep understanding of both technical competencies and of human factors. They must have the ability to empathize. In consideration of today's social, political, and environmental challenges, it has never been more important to instill social competencies into engineering education and practice, particularly around engineering design. This paper analyzes the previous literature on empathy in engineering education in North America and synthesizes the data to present the conceptualization that engineers have of empathy in education and practice.

Keywords: engineering education; empathy; wicked problem; tame problem

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1. Introduction

> *"One doesn't have to operate with great malice to do great harm. The absence of empathy and understanding are sufficient."* —Charles M. Blow

As the world becomes more interconnected, engineers are increasingly confronted with ill-structured problems at the intersection of technology and society [1]. The problems that 21st century engineers face are "inescapably social and technical" [2]. If engineers are expected to play a role in addressing these issues, they must have a deep understanding of both technical competencies and of human factors. Without such an understanding, intended results can diverge significantly to achieved outcomes. There are numerous examples of well-meaning initiatives where the achieved outcomes were diametrically opposed to intended results. Consider the following to name a few:

Although there have been significant advancements in energy efficiency measures (both in primary source energy generation and end-user efficiencies) over the last 50 years in attempts to reduce energy use, global aggregate energy consumption has increased dramatically. In general, improvements in efficiency have led to increases in energy consumption, not decreases. This is known as Jevon's Paradox [3]. In North America, we consistently spend 0.72% of GDP on lighting, a figure that has held constant since about 1700 [4]. Additionally, although there have been significant advancements in the way we build our homes, per capita heating energy consumption has not decreased with efficiency improvements [5]. This has direct implications to global climate change. In the face of overwhelming scientific evidence of the impending detriments of global climate change, countries around the globe have banded together to set aggressive targets to reduce greenhouse gas emissions and then have persisted with the same objectives for continual economic growth that created the problem in the first place.

In her book "Dead Aid", Dambisa Moyo explained that, even though one trillion US dollars in "development assistance" has been funneled into developing countries through numerous aid initiatives, "the recipients of this aid are worse off, much worse off. Aid has helped make the poor poorer and growth slower... millions in Africa are poorer today because of aid. Misery and poverty have not ended but have increased because of Aid. Aid has been, and continues to be, an unmitigated political, economic, and humanitarian disaster for most parts of the developing world" [6].

Although there have been efforts to address the growing housing crisis on-reserves and to stem the hemorrhage of negative socio-economic effects that come from it, housing outcomes for Indigenous peoples have been deteriorating year-over-year since the 1960s [7]. It is not an exaggeration to say that the current state of Indigenous housing is in a state of crisis [8]. Government intervention and oversight led to the creation of deplorable living structures made from government delivered packets of materials barely suitable to construct a rudimentary shack [7]. More recently, building designs that were inappropriate for the climatic regions in which they were built is continuing to lead to a mired of structural issues [7,9], health issues [10,11], and socio-economic problems for the occupants [10,12].

How is this possible? The examples above are "wicked" and wicked problems (i.e., ill-defined, complex and interconnected) demand a very different approach to produce solutions. The problems that engineers are trained to address are "tame" problems (i.e., are well defined and have definitive solutions) [13]. For a tame problem, "an exhaustive formulation can be stated containing all the information the problem-solver needs for understanding and solving the problem" [13]. As described by Rittel and Webber, wicked problems are a "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing" [14]. As Rittel and Webber explain: "the information needed to understand the problem depends upon one's idea for solving it and one cannot understand the problem without knowing about its context; one cannot meaningfully search for information without the orientation of a solution concept; one cannot first understand, then solve" [13]. Society looks to engineers to help develop solutions to wicked problems; however, these problems can never be fully solved [13,15]. There is no defined end-state at which to arrive; therefore, solutions cannot be right or wrong, only good or bad [15]. Solutions to wicked problems should not be thought of as ways to solve a problem, but rather to improve a situation. The impacts of wicked problems can be mitigated through a process of design that emphasizes empathy, abductive reasoning, and rapid prototyping [15]. What is missing in these three cases presented above? It can be argued that the missing component is a true understanding of human behavior, culture, and mindsets—an absence of empathy. It is clear that engineers have the capacity to produce solutions that lie within the technical realm, but if society is placing its collective hopes, even partially, in engineers to help design a way out of the human-made problems such as global climate change, the question must be asked: are engineers prepared to fully understand the human side of socio-technical issues?

The Call for a More Empathetic Engineer

Since the 1960s, the approach to engineering education has been "heavy on science, light on design and practicality" [16]. Today, the culture of engineering is "fundamentally misaligned with the times" [16]. In the recent years, professional bodies and engineering educations have been having discussions around what kinds of qualities future engineers must possess [17]. A broader view of competencies that engineers need regarding knowledge, abilities, and ways of knowing is being adopted in an effort to change the public's perception of engineering by highlighting that, as a profession, engineers solve human problems and thereby improve the lives of people [18]. In order for the profession to evolve and meet the changing needs of society, engineers must be socially responsible [19]. They must be able to understand the human dimension of engineering issues. Increasingly, empathy is gaining attention as a way to meet the changing demands of the profession. Empathy "plays an essential role in such social interactions within the personal and professional contexts" [20]. The world is changing rapidly. We now face "substantial challenges that require the technical capabilities of engineers to be augmented with a broader view of how engineers think, feel, and show up in the world" [16].

There are indeed groups encouraging future engineers to consider human factors and the "broader picture" of their designs. For example, the Centre for Socially Engaged Design at the University of Michigan's College of Engineering "empowers students and practitioners with perspectives and skills needed to design effective technology interventions that are good for the world" [21]. They do extensive research to inform socially engaged design principles and methodologies. Through their Socially Engaged Design Academy, they encourage students to integrate human considerations into engineering design. In addition, the book "A Whole New Engineer" by David E. Goldberg and Mark Sommerville outlines the experiences of Franklin W. Olin College of Engineering and the iFoundry at the University of Illinois. However, despite the growing global discourse on empathy in engineering, engineering education in North America remains largely derivative of engineering sciences approaches that emerged during the 1950s [16].

2. Materials and Methods

In order to find out how empathy is perceived in engineering practice and education, a literature review was conducted into the subject using engineering literature databases such as Compendex (Engineering Village—Elsevier Engineering Information), IEEE Xplore, and Geobase. This approach is consistent with the literature review done by Hess et al. in 2012. These databases were chosen because of their relevance to engineering subjects. Geobase was included to be consistent with the review noted in 2012. A search for "empathy in engineering" received 785 records. Further refinement using a keyword search to include "students, human engineering, engineering education, product design, engineers, education, or design" narrowed this to 192 articles. In depth literature reviews on the subject were conducted in 2012 [22] and 2013 [23]; therefore, this initiative restricted the search to records published between 2012 and 2020. This limited the search results to 146 records (118 conference papers, 27 journal articles, and 1 book). To further refine the search, abstracts of the 146 records were reviewed to identify the records that (1) explicitly discussed the conceptualization of empathy in engineering education or practice, (2) discussed how engineering education changes student engagement with issues of Social Responsibility, (3) described the implementation of interventions intended to increase social competencies in engineering and directly measured changes in empathy through quantitative or qualitative means. This significantly narrowed the search as this is a fairly nascent research area. Much of the available literature on this topic is written by a relatively small number of authors, which may introduce bias into this synthesis exercise. In addition, this synthesis exercise focused on the North American context from a general perspective. In addition, much of the literature describes engineering as a monolith; however, there are statistically significant differences in the levels of empathy and social concern between the sub disciplines of engineering, with civil and environmental engineers rating higher than their peers in mechanical engineering [19].

A brief survey of a 2018 European study on global engineering competencies was reviewed to determine similarities and differences between the North American and European contexts.

3. Results

Despite the 785 records that mention empathy in engineering, there are very few entries that explicitly outline the conceptualizations of this phenomenon in engineering and describe the direct, measurable impact of interventions on the empathy of engineers. This observation is also noted many times in the existing literature [24]. There were 24 records that were read in-depth and synthesized using data clustering techniques and coding in NVIVO 12. NVIVO is purpose-built for qualitative and mixed methods research. It helps researchers organize, store, retrieve, and analyze data. NVIVO was used to aid in making connections between the selected documents and understand underlying themes and patterns in their content to inform and support decisions. Data Clustering techniques were also used to visualize the connections in the data. There were several recurring themes within the papers which would indicate concept saturation despite finding only 24 articles that explicitly met the objectives of this review. Justification for the small number of selected papers is made based on data saturation in qualitative research. Much of the research that has been done has been of a qualitative nature. The studies in this review included between 7 and 146 participants. Studying data saturation and variability in qualitative inquiry, it was found that "saturation occurred within the first twelve interviews" and "basic elements for meta-themes were present as early as six interviews" [25]. Despite the fact that scholars seldom articulate their conceptualizations of the phenomenon of empathy in engineering, the articles that do are based on a rich source of data that includes qualitative interviews as well as previous literature reviews in order to triangulate findings and create generalizations on the conceptualizations of empathy within engineering through a grounded theory approach.

The following table (Table 1) shows the main themes that emerged from this synthesis.

Table 1. Engineer's conceptualizations of empathy and its place in education and practice.

Themes	Key Cites	Example
A well-defined theoretical conceptualization of empathy	[20,22–24]	"(engineers) described empathy as perspective taking or imagining what another is experiencing and empathy as embodiment or seeing the world from another's or others' viewpoint. Outcome-specific themes described empathy as interconnectedness with the surrounding world context and understanding another's or others' thoughts or feelings" [20].
A utilitarian view of empathy to improve abilities related to: • Communication • Leadership and management abilities • Attaining personal goals • Attracting and retaining diversity in education • Improving designs • Altruistic pursuits • Improving technical abilities • Promoting safety	[2,20,22–24,26,27]	"This review of the literature presents empathy in engineering as, first and foremost, a means to an end, or 'tool to take off the shelf,' when there is likely to be some personal or professional benefit from doing so" [2].
		"...empathy and care enable one to accurately understand the view or perspective of colleagues and clients, including their thoughts and desires" [20].
		"The team can't work if you don't understand what the other person is really thinking what drives them..." [22]
		"...engineers we interacted with suggest empathy and care have the most value to engineers working in managerial or leadership roles" [23].
		"I think your chances of moving ahead, in whatever field of study you are in, are going to be better if you get along well with others" [22].
The profession is inherently empathetic	[17,20,23,24,27,28]	"You could make an argument that pretty much all of engineering is about improving society, and therefore at some level there is some element of empathy and caring" [23]
		"...participants held several beliefs highlighting the fact that empathetic and caring traits exist in engineering already (primarily in the academic realm)" [22].
A recognition of the importance of empathy but a reluctance to include it as a core competency of engineers	[2,17,22–24,27,29]	"Results show that participants perceived empathy and care to be important in multiple respects, most notably in relational aspects of engineering practice. Engineers with more engineering experience were more likely to perceive empathy and care as existing in engineering practice and as important to their work" [24].
		"Findings of this literature review suggest that empathy and care are rarely explicitly represented in engineering education literature, although associated terms are used more commonly" [23].
A tendency to undervalue empathy within engineering despite a recognition of its importance	[17,22,23,29–33]	(empathy is) "Valuable, but not absolutely necessary" [23].
		"...this aspect of engineering is often downplayed as pertaining to necessary, but peripheral, 'soft' or professional skills" [2].

4. Discussion

From this study, it was determined that the conceptualizations of empathy in engineering education and practice can be described in the following thematic points: (1) a solid theoretical conceptualization of empathy, (2) a utilitarian view of empathy, (3) a belief that engineering is inherently empathetic, (4) a recognition of the importance of empathy but a reluctance to include it as a core competency of engineers, and (5) a tendency to devalue empathy despite the recognition of its usefulness.

4.1. A Solid Theoretical Conceptualization of Empathy

Although the concepts of empathy are "uncommon in the vocabulary of engineers" [23], a previous literature review notes that these "notions are embedded within the use of similar vocabulary" [23] such as "user's needs" and "compassion" [22]. The previous literature reviews and the additional qualitative studies on empathy in engineering show that engineers have a good theoretical understanding of empathy. Engineers see empathy from the themes of both a process component and an outcome component [22,23]. The process component was described as "perspective taking"—the ability to put yourself in someone else's shoes [22], while the outcome component was about creating connectedness [20].

4.2. A Utilitarian View of Empathy

Within engineering, empathy is seen as "first and foremost, a means to an end, or 'tool to take off the shelf'" [2]. In large part, "empathy is seen as a tool to use to enhance professional communication with which to "handle 'difficult' stakeholders" [32] or "whenever a project's success depends on inter-disciplinary relations amongst engineers" [23]. When considering the usefulness of empathy in engineering, "most respondents attached the greatest value to economic gains' [23] and that "empathy seems to be the means to attain personal goals such as becoming better in teamwork, communication, management, client relationships, and leadership" [23]. Additional perspectives showed that engineers perceived empathy as a means to increase diversity, improve design, promote safety, and even improve exiting technical abilities. The literature shows that "if engineers do not perceive empathy or care as having utilitarian advantages, such as producing economic gains, developing products more effectively, solving problems objectively, or enabling professional development, they see empathy and care as unimportant or even irrelevant" [23].

4.3. A Belief That Engineering Is Inherently Empathetic

Although empathy is not frequently discussed in the engineering literature, engineers frequently make the argument that the profession is inherently empathetic considering the roles engineers play in enhancing society [20,22,23]. Engineers perceive themselves as empathetic by providing solutions that benefit mankind [22]. The argument is that "pretty much all of engineering is about improving society, and therefore at some level there is some element of empathy" [23], and that effective engineers must have a certain level of trust and compassion to understand how designs fit into larger context [22].

4.4. A General Recognition That Empathy Is Important but a Reluctance to Include It as a Core Competency of Engineers

Although empathy and care appear to have a place within engineering "it appears that conversations and awareness of these two constructs may not often be explicitly stated within the literature or frequently addressed by academic and professional engineers" [23]. The literature showed some striking opinions about the relevancy of empathy in engineering education. Faculty interviews showed that empathy was, amongst other themes, "valuable, but not absolutely necessary" [23]. One participant stated that "... it's not part of the engineering culture" [23]. The literature showed that faculty participants stated empathic skills are 'very, very important" but that it is not their job to teach students to be empathetic or caring, continuing that "we don't need a course on it" [22]. Engineering practitioners describe empathy as key to their profession practices in a variety of areas. They describe many positive outcomes of integrating empathy into engineering practice including: the creation of higher quality solutions, improved interpersonal relations, more effective leadership abilities, and higher motivation to help others". They also suggested that a "greater inclusion of empathy and care within the culture of engineering has the potential to improve engineering along multiple facets" [20]. According to engineering practitioners "empathy and care tend to be overlooked or undervalued within engineering" [20] and there is a "profound need for integrating empathy and care into the education, training and (thereby) the practice of engineering" [20]. There is an overall devaluation of empathy and empathic abilities by engineering faculty, and it seems that the responsibility for teaching and discussing concepts of empathy openly are seen as periphery to the duties of an engineering educator. Much of the literature on human factors implies that human factors in engineering design are left to "someone else" or pushed to the end of the design process as a "last-minute add on" [34].

4.5. A Tendency to Devalue Empathy despite a Recognition of Its Usefulness

There is an overall devaluing of empathy and social competencies within engineering [20]. Perhaps the engineers reading this paper can recall times in their education or professional practice where discussions of an emotional nature were prefaced by comments such as "we as engineers don't normally talk about our feelings, but..." or a non-technical class that was seen as something to "get through to graduate". This is a symptom of what is described in the literature as a "culture of disengagement" [30].

4.6. A "Culture of Disengagement"

The "culture of disengagement" [30] in engineering education is a set of "beliefs, meanings, and practices" [30] that form the creation of professional identity and dominion of influence of an engineer. In turn, this culture frames "the day-to-day activities of problem definition and solution development, as well as more abstract understandings such as the meaning of engineering as an institution" [30]. This "culture of disengagement" [30] casts social concerns as illegitimate to the epistemologies of engineering. As a result, "public welfare commitments become less central to the student's understanding of their professional roles the longer the spend within engineering training" [30]. Once students are studying engineering, there is an emphasis on the development of technical capacities at the exclusion of other intelligences [16]. The "uniformity across diverse school contexts [and disciplines] in public welfare beliefs suggests that a culture of disengagement may be a profession-wide phenomenon in the broader culture of engineering" [30].

In the past, "the engineer's assumed perspective was outside the situation or problem—that of a disengaged problem solver who could confidently model the problem in objective, mathematical terms and then project a solution, framed largely in terms of efficiency and technical ingenuity, affecting a system uncontaminated by the frictions of human relationships or conflicting purposes" [23]. From interviews of practicing engineers, one participant in a 2013 study commented on what it takes to be a successful engineer: "I think there's a perception... to be really successful you have to be tough as nails and maybe suppress being a nice guy" [23]. One of the themes from the faculty interviews showed that empathy was seen as "valuable, but not absolutely necessary" [23] with one participant commenting that the place for empathy was in the "teamwork part of a design class", a statement that shows a very narrow understanding of empathy and how it fits into other aspects of design such as problem definition, solution development, and prototype testing. Another participant claimed "Our classes are adamantly, adamantly, technical and that's not going to change" [23] continuing that "[empathy] is not part of the engineering culture" [23].

In professional practice, engineers use a commonly held conceptualization of what an engineer is and does to decide what considerations are integral to their design responsibilities for a particular project and what considerations are tangential [30]. As such, non-technical elements of a project may be defined out. This type of approach to engineering design projects leads to a variety of concerns not considered directly "relevant" to the achievement of technical objectives to be omitted and neglected. These concerns may include socioeconomic factors, history, cultural context and global politics [30]. Much of the literature on "human factors" in engineering implies that human factors are left to "someone else" or pushed to the end of the design process as a "last-minute add on" [34]. This leads to a myopic view of the systems in which engineering projects are implemented, being blind to the interconnections and downstream effects of the implemented designs a paradox in the conceptualization of empathy.

It is interesting to observe that the culture of engineering holds a paradoxical interpretation of the need and place for empathy within engineering practice and education. On one hand, the profession seems to devalue "non-technical" concerns as irrelevant to "real" engineering work [30]. At the same time, there is a belief that engineering is inherently empathetic [23]. Further still, engineering practitioners recognized a multitude of benefits to empathy and stated that it has "the potential to improve engineering along multiple facets" [20]. An interesting trend is that increased years of work experience lead to a greater appreciation and recognition of empathy in engineering [24]. However, engineers state that they did not learn to be empathetic in their college years [24].

4.7. The Impact on Engineering Students' Professional Identity Formation

Engineering education focuses on the development of technical abilities [23], training graduates to see the word from a technically focused mindset [28], leading to a devaluation of social competencies [20,30]. The general consensus from the literature is that engineering schools fail to adequately teach non-technical competencies [32]. Narratives that arise explicitly or implicitly about what engineering is through the devaluation of social competencies may limit the ways in which students envision their future professional selves [17].

The model of engineering science that is prevalent in engineering schools today teaches students to apply scientific principles to technological problems; however, it produces graduates who have difficulty adapting their knowledge to complex real-world problems that are not as formulaic as the problems they face in text-books [35]. In fact, engineering students spend much of the first two years of their programs devoted to basic sciences and mathematics [36]. The resulting engineering graduates from this style of engineering education have been perceived by industry to be unable to participate in the engineering problems faced by engineering professionals [36].

4.8. Attempts to Improve Social Competencies in Engineering Education

Attempts to improve the social competencies of engineering students are reported in the literature. An interesting case study in the literature showed that empathy and social considerations can decrease even in the face of interventions that attempt to improve social competencies [29]. This case was not large enough to produce generalizations from; however, it suggests that there may be more to consider in the methods of increasing levels of empathy in engineering than simply introducing more empathic learning modules, such as simultaneously attending to students' developing professional identities.

Decreasing levels of empathy in the face of interventions [29,30,37] may be explained by the presence of a dominant cultural of disengagement as noted in this review. Just as the three examples presented at the beginning of this article illustrate how gaps in the understanding at the systems level and at the level of human behavior can produce results diametrically opposed to intended outcomes, the same is true for attempts incorporate empathetic perspectives into engineering. Justification for this conclusion can be found in motivational, emotional, and organizational theory on self-schemas and organizational identification.

Self-schemas are domain specific cognitive generalizations about the self that are learned from past experiences [38]. As students progress through their engineering education, they adopt a self-identification with the cultural identity of an engineer as presented actively and passively by their institutions. Theories from the domain of motivation and emotion show us that, when confronted with information that conflicts with a deeply engrained self-schema, he or she will act to preserve previously held beliefs:

> *"Once an individual establishes a well-articulated self-schema in a particular domain, he will generally act to preserve that self-view. Once established, self-schemas become increasingly resistant to contradictory information"* [37]

Attempts to instill empathy within engineers without considerations of how to manage the formation of professional identity may have instead acted to reinforce dominant cultural beliefs. This phenomenon is displayed in a study on the implementation of a series of empathetic communication modules. The authors note the following:

> *"when some students felt challenged by the experiences of the modules, the snapshot of their development provided by the written reflection revealed that they, at least temporarily, retreated more firmly to previously held assumptions. Similarly, other students reported a disconnect between their experiences of empathy as an individual and as a future engineer, and their reflections simultaneously showed conflicting views and perceptions"* [17]

4.9. A Brief Look at the European Context

A brief survey of a 2018 study from five countries in Europe was conducted to determine broad similarities and differences between the North American and European Contexts. Based on research in five European countries (Spain, Italy, Sweden, France, and Hungary), this paper "detailed the understanding, requirements and perceived skill gaps of companies hiring engineering graduates, a first step towards improved and assessable global competence education for engineering students" [38]. In this study, 10 of the engineering companies that were interviewed identified social competencies as a missing in recently graduated engineers. Social competencies broadly were among the "most relevant global competencies" identified in these five countries. These included competencies such as: communication, teamwork, cooperation, and problem solving; attitudes such as: empathy, flexibility, openness, and adaptability; and personal traits such as: leadership, initiative, sociability, acceptance of differences, and openness.

It is interesting to note that empathy specifically was mentioned as an important attitude in three out of the five European countries (this category was absent in the responses from Hungary).

The engineering firms from these countries also indicated the competencies they felt were missing in new engineering graduates. These included: flexibility, sociability, personal awareness, emotional intelligence, and empathy.

This cursory glance at the missing competencies of engineering graduates as identified by engineering firms in these five countries shows that many of the same deficiencies in engineering education seem to be present in the European context. This warrants a further comparison between engineering education in North America and of Europe. This is outside of the scope of this paper.

The European Network for Accreditation of Engineering Education defines engineering design as:

> "... the systematic process of conceiving and developing materials, components, systems and processes to serve useful purposes. Design may be procedural, creative or open-ended and requires application of engineering sciences, working under constraints, and taking into account economic, health and safety, social and environmental factors, codes of practice and applicable laws" [39]

In Canada, the Canadian Engineering Accreditation Board defines it as:

> "... the process of making informed, thoughtful and creative decisions in devising a product, system, component, or process to meet specified needs. It is an open-ended and generative activity often iterative and multidisciplinary in which natural science, mathematics, and engineering science are incorporated into solutions that satisfy defined objectives within identified requirements and constraints. Typically, the constraints include economic, health and safety, environmental, societal, cultural, and regulatory aspects" [40]

The similarities in the educational deficiencies between these two contexts may stem from the way in which governing accreditation bodies define "engineering design", which may direct pedagogical approaches.

4.10. Recommendations for Future Interventions

There is a misalignment between the type of design that engineers are being taught during their education, and the type of design that engineers are using to address wicked problems, leaving engineering education "fundamentally misaligned with the times" [16]. These two types of design (engineering design vs design thinking) will be contrasted in-depth in a future paper. Rittel and Webber noted the "modification of school curricula" explicitly in their examples of wicked problems [13]. Integrating empathy and social competencies into engineering education is itself a wicked problem. This issue could be addressed through an action research approach, which is widely used by educators to "address areas of concern or redress" [41]. Action research is conducted by practitioners inside a social context who regard themselves as researchers. Because action research is always undertaken by practitioners within a specific social context, it is considered "insider" research (as opposed to outsider research), which means that the researcher will inevitably influence what is happening [42]. McNiff et al. describe how action research involves questioning at several levels—often called first, second, and third order learning [42]. For example, first order learning refers to learning about a situation [42]—"How is empathic thinking perceived in the culture engineering?". This question has been well explored by previous researchers and is presented in this paper. Second order learning is learning to question what has been learned [42]: "If empathy is devalued within the profession, how might we involve more empathic thinking in engineering to address this gap?". Third order learning is learning to ask why the situation exists as it does, and why it is important to shift the way one contextualizes the situation [42]—"Why is it important to consider the impact of devaluing empathic abilities within engineering education in the first place?" This situation now requires second and third order thinking to produce a fundamental shift in the way the engineering design education is delivered.

In addition to supporting the integration of social competencies into engineering education, future interventions should also focus on supporting students through any cognitive dissonance that may arise. Engineering educators have a significant influence on the cultural elements, narratives, and epistemological assumptions of engineering students [17]. As such, the locus of the change in action research should center on one's own pedagogical approaches within engineering education that are influential in the creation of students' professional identification.

5. Conclusions

This paper analyzed and synthesized available literature from the North American Context on empathy in engineering that: (1) explicitly discussed the conceptualization of empathy in engineering education or practice, (2) discussed how engineering education changes student engagement with issues of Social Responsibility, and (3) described the implementation of interventions intended to increase social competencies in engineering and directly measured changes in empathy through quantitative or qualitative means. Through this exercise, five themes for engineers' conceptualizations of empathy in education and practiced emerged: (1) a solid theoretical conceptualization of empathy, (2) a utilitarian view of empathy, (3) a belief that engineering is inherently empathetic, (4) a general recognition that empathy is important but a reluctance to include it as a core competency of engineers, and (5) a tendency to devalue empathy despite a recognition of its usefulness.

The literature suggests that engineering education focuses heavily on the development of technical competencies at the expense of social competencies such as empathy. As a result of the active and passive devaluation of social competencies in engineering, students exclude these concepts from their professional identities as engineers. The engineering science model of engineering design education that is taught throughout North America is leaving students ill-equipped to address the wicked problems that the engineers face in the 21st century. Engineering practitioners have stated that empathy and social competencies being integrated into the engineering curriculum have the potential to improve the profession along multiple facets and better equip students for the realities of professional practice. It is interesting to note that many of these same deficiencies are also found in the European context as well.

The literature noted some instances where interventions that attempted to improve empathy in engineering had an opposite effect. It was hypothesized that, in the presence of an overarching culture that devalued empathy, these interventions were challenging students' self-schemas of what it means to be an engineer, leading to cognitive dissonance and a rejection of the concept. From this abduction, it was hypothesized that future interventions to improve social competencies in engineering education must also attend to the students developing professional identities.

This is itself a wicked problem and should be addressed through a design approach equipped to handle complex social systems such as Design Thinking, Systems Thinking, and Action Research. Before future interventions are employed, additional work is needed to identify the best pedagogical approaches in the literature to support engineering identity formation. From this, a framework for integrating social competencies into engineering education can be created. In addition, most of the literature on this subject is qualitative in nature. In order to determine the success of future interventions, a reliable quantitative tool for measuring empathy should be used.

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