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Transdisciplinary STEAM education: Advocating for compassion as a core value in engineering

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Introduction

Transdisciplinary STEAM education might help introduce compassion as an internal core value of engineering. Currently, a utilitarian perspective of ethics and a Rawlsian approach to justice dominate engineering and are prevalent in the undergraduate curriculum. As a result, engineers who learn under these approaches may design technologies that produce suffering that fosters injustice, inequity, or exclusion. Technically, the utilitarian ethical perspective focuses on the concept of happiness, privileging effectiveness and efficiency to seek maximum benefits and few costs. On the other side, the Rawlsian justice approach brings rigid disciplinary boundaries, creates the concept of expert, and supports the engineer's voice as the primary one in technological development. Thus, engineering as a subculture allows negative impacts if the benefits are considered more significant. However, these perspectives do not construct engineering identity by themselves. Engineering associations and engineering higher education have educated engineers in ways that support the formation of this sort of engineering identity. They have maintained and unquestioned technology as a core concept usually associated with engineering and value-neutral artifacts developed to solve problems by applying only specialized knowledge.

Nevertheless, this conception of technology is far from reality. As currently accepted, technology is a corpus of sociohistorically contextualized knowledge that embodies its creator's culture, opening the door to diverse engineering conceptions [1]. In that sense, if a monolithic perspective of engineering continues, it is possible to consider technology as one kind of material manifestation of the engineering subculture, which includes only one set of shared common goals, particular priorities, beliefs, values, and the specific jargon. Given this framing of engineering, how engineers consider ethics and justice impact technological development and, in turn, affects society. This paper unwraps the ethical origins of engineering concerning technology and the engineering educational process thoroughly, advocating for the active inclusion of the Deweyan perspective of ethics and justice to embrace more perspectives and voices in engineering practice and education. Among the possible voices to incorporate, we propose compassion as a potential core value in engineering to construct a constant and aware engineering education that includes and interacts with different perspectives from inside and outside engineering.

Engineering and technology

Technology is a concept that society usually associates with engineering and the development of value-neutral artifacts that solve problems by applying knowledge and using a standardized design process [2]. However, this conception of technology is very far from reality. As currently conceived, technology is a corpus of sociohistorically contextualized knowledge that embodies

its creator's culture. In that sense, technology is a material manifestation of an engineering subculture that presents the shared common goals, particular priorities, beliefs, values, and specific jargon that help make sense inside the engineering community of practice [1]. In a sense, technology is an embodied engineering identity's symbol. When this analysis is made from the ethics level, it is possible to identify that the values engineering practice implicitly shares give guidelines for technological development. According to Van de Poel [3], engineering materializes two types of typical values through technology. On the one hand, engineering has *internal values*, such as technological enthusiasm, effectiveness, efficiency, reliability, robustness, maintainability, compatibility, and rationality, which bring the occupation's current structure. On the other hand, engineering has *external values*, such as safety and health, human well-being, sustainability, justice and democracy, and inclusiveness, which are desirable consequences of implementing the other.

Currently, engineering's internal values have prevailed inside the engineering practice and education, following a Rawlsian perspective of justice that, according to Noddings [4], is based on rationality and the procedures from the logical processes. This perspective of justice considers the *right* over the *good*, based on the protection of the individual rationality to make correct decisions in line with their original position in society. However, it also considers that only one person is needed to deliberate what *right* is, creating authority positions in the decision-making process and where the other rational individuals have to agree. Suppose this logic is translated to the engineering subculture. In that case, the engineer is the individual who has to make rational decisions to solve the problems as part of their original position in society, following what authorities, such as engineering societies and associations, have decided about its practice. In Western societies, this premise of engineering practice is also found in broader cultural settings, determining that engineering reproduces a rational perspective of justice that supports a hegemonic sociopolitical and economic system that focuses on the individual as a rational machine.

Nevertheless, a conception of justice focused on the *right* gives only a theoretical frame of action for the individuals and not a reason to practice it. For the current hegemonic discourse in society, happiness is the only *good* that should be promoted by production and maximation processes to contrast the pain relief as much as possible, calculating every time the utilities to obtaining it [5]. Consequently, utilitarianism impacted the construction of an engineering identity based and focused on how much happiness can be achieved by its practice, choosing those supportive values and rational procedures that, through standardized practices imposed by a few, are transmitted to the technological solutions.

The prevalence of these discourses results from their reproduction through the practice, where the university has mainly accomplished a vital role. Traditionally, engineering education has focused on maintaining the engineer's social role (social contract) as the master of technology

and its non-controllable or predictable changes [6]. Thus, engineering education sustains engineers as an authority and in charge of all its decisions, considering them as masters of engineering's internal values (effectiveness, efficiency, reliability, robustness, maintainability, compatibility, and rationality), creating an inequality-related gap with society. In essence, mastering these values in engineering means searching for the maximation of happiness, independently of the suffering it generates in some people and the means to achieve it because their conception is mainly focused on the technological solutions' utilities. As a consequence of focusing on the transmission of the internal values, the external values, except safety and health, are seen as a grateful result but not the primary *good* to achieve.

Positioning happiness as society's most significant *good* states implicitly that the community is a static and fixed concept, excluding the idea that real people are moved by other values [7]. Except for the most technical ones, such as safety and health, the external values of engineering (human well-being, sustainability, justice and democracy, and inclusiveness) have not been conceived traditionally as crucial to the engineering identity. In fact, contrary to their own beliefs, engineers are not the authority to discuss technology. They follow the rules positioned by more significant and hegemonic economic and political interests that search for happiness rather than other values. Consequently, engineers have to accept values that inevitably result in social issues in the form of suffering because suffering is necessary to achieve happiness. In other words, unaware and standardized engineering produces suffering, and technology is the means to create it in society.

Different values as the center of engineering education

For Dewey [7], justice is located in the consequences, not the procedures or only final goods. To this author, means and ends are the subject of ethical analysis and depend on the sociohistorical moment where a community is located. In that sense, community is under constant construction, and its values result from consensus as a product of the dialogue inside the community and the evaluation made by other communities about them. In engineering, this perspective of justice would mean creating more inclusive spaces to involve diverse voices that shape professional values and blur the hierarchical positions. In other words, Dewey's conception of justice is an invitation to the continuous construction of equality inside and outside the engineering community by an inclusive dialogue. Through a democratic communitarian perspective of justice, external values become visible and essential in engineering practice and education.

Transdisciplinarity and new values

Involving and valuing as equal the different voices inside engineering means eliminating the hierarchies imposed by a rational model of decision making proposed by Rawls. However, new knowledge, practices, and values emerge when this dialogic exercise is with other communities. Engineering boundaries start to blur, and the previously ignored or hidden voices become valuable as those inside engineering recreate an integrated theory of knowledge, also called

transdisciplinarity [8]. However, at this point, the quality and number of the relations between different communities of knowledge turn very important for the construction of knowledge itself. According to [4], an approach to constructing values from the perspective of caring, an ethic of care, guarantees good quality and number of relations. For this author, caring involves giving the voice mainly to those affected in the discussion, which means also involving the society impacted by the engineering practice. The knowledge of those outside engineering becomes as essential as the one inside engineering. Moreover, the 'Other' awareness becomes relevant to construct its identity [9].

Consequently, non-hegemonic discourses become visible, bringing new perspectives to the engineering practice. One example is the inclusion of values such as compassion in the internal values of engineering. For Williams [10], compassion is one way to relieve suffering and a component of care that can be taught. In engineering education, Campbell [11] defined care as the "active compassion, empathy, and concern for the well-being of other living (and in some cases non-living) things" (p. 112), where compassion is an aspect of the construction of social justice. In that sense, for engineering, the integration of compassion as an internal value could be an opportunity to fall down a utilitarian perspective of engineering to a perspective of care based on concrete and reflective actions against technology's negative impacts on society. In a certain way, compassion is an expression of peace [12] and activism [13].

Compassion and engineering education

Although compassion is just an example of the myriad of possible values that transdisciplinarity could bring to structure the engineering practice, it is undoubtedly a feasible opportunity to balance the scale of values in engineering practice. For Berne [14], compassion is a skill that could be included in engineering education and practice to support social justice, sustainability, and human well-being, the external values of engineering. Thus, fostering compassion in engineering education, as one of the internal values of engineering, could transform the engineering practice and construct an egalitarian world. However, this change is impossible with the current engineering education model, where memory retention and concept understanding, related to utilitarian goals, are the primary learning goals. For that, besides conceiving each student's interests and abilities is necessary to focus on learning goals that, according to Fink's taxonomy [15], explore the caring dimension of the student to develop new feelings, interests, and values that will impact engineering practice and society positively.

Following these ideas, Kohler-Evans and Barnes [16] created a Model of Influence (MOI) as a framework that defines four levels to facilitate the development and teaching of value-oriented concepts such as compassion: Developing consciousness, acknowledging perspectives and affirming beliefs, realizing the benefit to oneself and others, and taking action and embracing influence. This model states that compassion can be taught purposefully and that learning objectives and pedagogic strategies can be associated with these levels. Among the specific

content related to this model's value-changing use, Berne [14] mentioned those related to suffering, empathy, and desire to help, which are elements of compassion. Likewise, this author suggests using active learning methods, such as mindfulness, to develop meaningful learnings related to compassion.

Transdisciplinary STEAM education to foster compassion

This paper has tried to unveil thoroughly how rational and utilitarian perspectives of justice in engineering education perpetuate injustice and individualism in engineering practice. Also, this paper has presented compassion as a new internal value that, together with the others, would balance the focus of engineering and help create an egalitarian environment for the construction of integrated knowledge. This last section presents science, technology, engineering, arts, and mathematics (STEAM) education, and more specifically, transdisciplinary STEAM education, as one way to integrate compassion as an engineering's internal value and change the focus of engineering practice.

According to Costantino [17], the origins of STEAM education come from the US Department of Education as a strategy that uses the arts to construct more meaningful learnings, motivating school students to pursue STEM areas in their professional lives and fostering innovation. From a macro perspective, STEAM education was aimed to support the authoritarian and individualist principles of justice and utilitarianism. In other words, STEAM education appeared to save the authoritarian discourse of STEM disciplines, appealing for the use of the arts to maximize students' happiness (motivation). Next to a perspective of compassion, STEAM education does not seem to be the best option to change engineering values. It looks quite the opposite. However, it depends on the level of the integration and the learning objectives.

For Perignat and Katz-Bounincontro [18], STEAM education has four levels of the relationship between disciplines: Cross, multi, inter, and transdisciplinary. The first one, cross-disciplinary STEAM education, "focuses on observing one discipline through the perspective of another, for example, the physics of music" (p. 35). The second one, multidisciplinary STEAM education, refers to the collaboration between disciplines, but not their integration. In the third one, interdisciplinary STEAM education, several disciplines are gathered around a common topic, but their boundaries are still evident. Finally, transdisciplinary STEAM education "includes fully merged disciplines without boundaries and lessons rooted in authentic problems or inquiry" (p. 34).

This categorization in the relationship level between the disciplines gives clues about other ways to use the STEAM education framework. On the one hand, the level of importance that one discipline has concerning the other generates one or another kind of relationship. Seeking relationships where the knowledge of each discipline is equally important is the only option to foster transdisciplinarity. On the other hand, transdisciplinary STEAM education can create lessons based on authentic social problems, bringing new and diverse voices outside academia.

For Martínez [19], without calling it transdisciplinarity, STEAM education centered on social-related issues can help students have meaningful learnings and change positively in their communities. In summary, transdisciplinary STEAM education based on solving social problems fosters the learning of compassion and STEM content.

This proposal impacts how the current engineering education is organized in university settings and the instructors' expertise for these aims. Initially, it requires a high education reform that, without eliminating each discipline's specific content, focuses on the problems to solve in each community or student's interest or broad *goods* such as social justice or peace, rather than universal and specialized content, which sometimes is not useful in the practice. This call for practice more than theory does not diminish the power of the last one; however, it implies teaching the students where to find it, when and how to use it, and why it is vital to use it regarding the problem they are solving. At the same time, this is an invitation to collaborate through the areas and fields to identify the abilities, skills, and knowledge that support each focused social problem's solution. In that sense, strategies such as co-teaching become essential to blur the boundaries, eliminating the boundaries of the disciplines in practice.

However, the biggest challenge consists in involving non-academic voices in the engineering education process. From the perspective of Martinez [19], to involve society in transdisciplinary STEAM education, service-learning is a strategy to integrate knowledge. For that, problem-based and project-based learnings would be essential strategies to identify real social problems to be solved by university students with an equalitarian community's participation. Several examples of service-learning exist [20]–[25], but none of them used transdisciplinary STEAM education as a framework to shape their educational interventions. In that sense, university instructors and professors should reflect on their teaching practice to understand their position in the academic chain and how to design transdisciplinary STEAM activities and explore new ways to teach in spaces where non-academic actors are involved. For the moment, only a few efforts are present in academic documents [26]–[28]; however, it is probable that other ones are currently happening inside the classrooms and are not documented yet. Teachers are one of the most critical pillars of forming engineers based on the production of knowledge that recognizes each discipline's limitations and their unique communitarian contributions. Finally, it is essential to constantly reflect on the role of engineering in society, not just as the discipline in charge of technology, but as one of the actors that intervene in its development. In the end, every voice, disciplinary or not, interacts with each other to make technology successful and supportive of a free of suffering society.

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