

From Technicians to Leaders: The Role of Humanities and Social Sciences in Shaping Socially Responsible Engineers

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Abstract:

Engineering professionals are expected to face increasingly complex challenges, environmental sustainability and social issues. However, if we consider traditional engineering education, focused mainly on technical skills, social, ethical, and cultural issues are often ignored. One possibility for such issues to be considered by engineers is the integration of the Humanities and Social Sciences (HSS) into the Engineering curricula. Based on articles and case studies, this article explores the role that HSS can play in training engineers with the critical thinking and ethical leadership needed to deal with contemporary problems. Even with significant challenges, such as teacher and student resistance and rigid curricular structures, this article seeks to present alternatives to overcome these barriers. By restructuring curricula to emphasize the social impact of engineering, higher education institutions can provide students with experiences to become engineers who are able to lead innovative and socially responsible solutions. Considering, then, the challenges facing engineers, the integration of HSS into engineering education may mean a necessary change in course curricula to ensure that future engineers contribute to a more just and sustainable world.

Keywords: Engineering Education, Humanities Integration in Engineering Education, Ethical Leadership.

1. Introduction: The Need for a Holistic Approach in Engineering Education

Since the beginning of engineering education, the focus has been on developing technical skills, such as mathematics, physics, and technical problem-solving. However, the complex challenges of the 21st century, such as climate change, social inequality and ethics related to

technological advances demand a more comprehensive educational approach. Engineers today is required not only to be technically proficient but also to possess critical thinking, social awareness, and ethical leadership skills that allow them to navigate and address global challenges. In this context, integrating Humanities and Social Sciences (HSS) into engineering curricula has emerged as a crucial step toward creating well-rounded professionals capable of understanding the broader impacts of their work (Rojter, 2018).

In "Branches from the Same Tree" (National Academies Press, 2018) the historical interconnectedness of science, arts, and humanities are highlighted arguing that technical disciplines should not exist in isolation but should be integrated with HSS in such a way that students can fully comprehend global challenges. This interdisciplinary approach fosters creativity, problem-solving, and leadership qualities in future engineers, preparing them to face increasingly interconnected global challenges with a holistic perspective.

Pasini & Barreto (2023) emphasize that technical education alone is no longer sufficient to meet society's demands. Future engineers need to understand the ethical and social dimensions of their work. The inclusion of disciplines such as philosophy, sociology, and ethics into engineering curricula helps foster a critical mindset and a deep sense of responsibility regarding the broader impacts of technological innovations.

One of the major concerns in traditional engineering education is the predominance of the culture of disengagement. Cech (2013) describes this phenomenon as a cultural norm in many engineering programs that marginalize public welfare and ethical considerations in favor of technical skills. This culture often leads students to graduate with strong technical abilities but without a commitment to addressing social issues. According to Cech, this disengagement reinforces the idea that public welfare is peripheral to engineering practice, which poses a significant challenge to the development of socially conscious professionals.

Malykhin et al. (2023) also support this argument by demonstrating that the integration of HSS into engineering programs helps the development of essential skills such as empathy, critical thinking, and social responsibility. These competencies are recognized as essential to addressing the complexities of engineering challenges, where the development and application of technology has to occur thinking about its impact on society and environment.

Thus, the integration of HSS into engineering education is not simply a matter of adding concepts but rather it is essential in preparing engineers for the global, ethical, and social challenges of the 21st century. This approach prepares future professionals with the necessary

tools to go beyond technical expertise and become ethical leaders capable of addressing the broader impacts of their work on society.

2. The Interrelationship Between Engineering and Society

The relationship between engineering and society is deeply intertwined. Technological innovations shape social structures, behaviors, and economies as well social needs influences engineering developments. This reciprocal relationship emphasizes the importance of engineers understanding the broader social context in which their work is embedded. As Sunder (2018) explains, engineering design has significant consequences for social structures and often produces unintended effects. The complexities of these interactions make it essential for engineers to be provided with a more comprehensive understanding of how their work impacts society.

Historically, engineering education has emphasized technical skills, often to the detriment of broader social, ethical, and environmental concerns. Rojter (2018) points out that this technocentric approach, which has long dominated engineering education, limits engineers' ability to anticipate the social consequences of their work. This narrow focus often fails to take into account the rapidly changing social and global landscape, where engineers are expected to contribute solutions to issues such as sustainability, social justice, and ethical technological development.

Cech (2013) presents a study of some engineering schools that reveals a tendency among engineering students to become less engaged with issues such as public welfare. This result is due in part to curricula that prioritize technical skills while neglecting social and ethical considerations and to a certain bias between engineering and humanities fields. This disengagement, in turn, may have long-term implications not only for individual engineers but also for the profession as a whole, as it fosters a generation of engineers who are less likely to engage with the social impacts of their work.

The introduction of Humanities and Social Sciences (HSS) into engineering education can help reverse this trend. By exposing students to social issues, ethics, and cultural studies, engineers can develop a deeper awareness of how their work interacts with various social elements. As Boni et al. (2012) demonstrate, in a project at the Polytechnic University of Valencia, students from different fields developed greater social awareness and responsibility through collaborative work on real-world challenges, resulting in a significant increase in students' argumentative skills and sense of responsibility, as well as fostering the development of cosmopolitan skills among engineering students. These skills include empathy, a global

perspective, and a sense of responsibility to address inequalities. Such courses prepare engineers to consider the social and cultural implications of their work and make decisions that benefit not only local communities but the global population.

In Pasini & Barreto (2023), the authors emphasize how arts can be incorporated into engineering education, offering engineer student new perspectives about the historical and social impacts of technology. By the analysis of painting and photography that depict technological advances, the authors argue that it can help engineering students visualize social contexts of engineer innovations, fostering a differentiated approach to their responsibilities.

Engineering and society have mutual impact and contribution. Engineers shape the world through their innovations, but they are also influenced by social, ethical, and cultural frameworks. By integrating these frameworks into engineering education, future engineers can be better prepared to consider the complexities of society and contribute to sustainable and committed technological solutions.

3. The Importance of HSS-STEM Integration

The integration of the Humanities and Social Sciences (HSS) with Science, Technology, Engineering, and Mathematics (STEM) is increasingly seen as necessary to meet the challenges of the 21st century, as evidenced by the introduction of the “A” for arts in STEM, resulting in a new acronym, STEAM (Daugherty, 2013). However, this integration between the areas is seen in PK-12 education and rarely in engineering education. One thing that seems increasingly clear is that current and future challenges cannot be effectively solved through purely technical approaches. Instead, they require interdisciplinary solutions that incorporate both the analytical skills of STEM and the ethical, cultural, and social considerations provided by HSS (Husbands Fealing et al., 2021).

In "Branches from the Same Tree" (National Academies Press, 2018), the integration between HSS and STEM is very well demonstrated by a series of works and experiences, emphasizing that education should not be confined to disciplinary areas. As highlighted, integrating humanities and arts into technical education enhances students' critical thinking and improves the development of creative solutions to problems ability. In addition to providing examples of universities that have successfully integrated into these areas, it also reports improvements in student engagement, academic performance, and career preparation.

In addressing the risks of a disengaged engineering culture, Cech (2013) also supports the importance of HSS-STEM integration. As noted, when engineering education focuses exclusively on technical skills, students are less likely to develop the ethical and social awareness necessary to address public welfare concerns. In contrast, programs that integrate HSS disciplines tend to minimize the possibility of producing engineers who are less engaged with social issues and better prepared to make ethical decisions in their professional practice.

At the Polytechnic University of Valencia, for example, a program entitled Introduction to Development Aid has successfully fostered cosmopolitan skills in engineering students. This program emphasizes critical thinking, global awareness, and empathy, preparing engineers to work in diverse contexts and address issues of social justice and sustainability. As Boni et al. (2012) point out, students who participated in these courses showed a greater understanding of the global interconnectedness of engineering projects and a stronger sense of responsibility related to development.

Another example of HSS-STEM integration comes from Pasini & Barreto (2023), who highlight the role of the arts in fostering empathy and social awareness in engineering students. By using artistic representations, some related to technological development in different historical contexts, students can consider the impacts caused in society as well as analyze the evolution of engineering. In this way, they can develop a more diverse understanding of how their work influences different communities and environments. An interdisciplinary approach such as the one proposed by the authors not only enhances students' technical skills but also helps them cultivate the ethical and reflective capacities necessary for responsible innovation.

Others recent reports, such as those by the Royal Academy of Engineering (2024), reinforce the necessity for ethical and social competencies in future engineers, emphasizing the integration of humanities as crucial for addressing contemporary challenges. Furthermore, a comprehensive theoretical review by Staley and Bairaktarova (2022) clearly indicates that curricular integration of humanities significantly enhances essential engineering competencies, including critical, ethical, and intercultural thinking.

4. Challenges and Solutions for HSS Integration in Engineering Education

Despite the growing recognition of the need to integrate Humanities and Social Sciences (HSS) into Science, Technology, Engineering, and Mathematics (STEM) curricula, significant

challenges remain. Perhaps the most significant obstacle is the cultural mindset embedded in many engineering institutions that largely emphasize technical expertise over social and human skills. This problem, as described by Cech (2013), leads to the marginalization of social and ethical concerns in favor of purely technical problem-solving. Such a narrow focus on technical skills perpetuates the idea that public welfare, environmental sustainability, and ethical considerations are peripheral to engineering practice, thus creating resistance to the integration of HSS. Institutional barriers also play a critical role in hindering this integration. Traditional academic structures often reinforce a centuries-old practice of engineering education in which disciplines are developed in isolation, with little or no integration between them. Furthermore, engineering departments operate independently of the humanities, largely encouraged by mutual prejudice observed between the fields, leading to a lack of collaboration in which the loser is the engineering graduate. It is also worth noting that faculty promotion and evaluation processes are often based on disciplinary research output, which can discourage interdisciplinary teaching and projects. Furthermore, the allocation of resources for interdisciplinary programs is often limited, making it difficult to sustain long-term integration efforts (National Academies of Sciences, Engineering, and Medicine, 2018).

Another challenge lies in student perceptions. Many engineering students view HSS courses as unrelated to their career goals, reinforcing a fragmented approach to their education. This resistance stems in part from the way curricula are designed, often positioning HSS courses as optional or supplemental. Without a clear connection between these courses and their future careers, students may not see the value and importance of engaging with topics such as ethics and social welfare (Cech, 2013).

However, there are solutions to these challenges. First, curricula need to be restructured to integrate HSS from the beginning of engineering programs. By incorporating social and ethical considerations into core technical courses, educators can demonstrate how these disciplines are interconnected. As Cech (2013) suggests, students should encounter discussions of public welfare, sustainability, and ethics as part of their education process, allowing them to develop a more holistic understanding of engineering practice from the beginning.

To support this integration, universities can adopt flexible program structures that encourage interdisciplinary learning. For example, offering programs that combine HSS and STEM courses allows students to explore these intersections without compromising their primary technical training. Institutions such as the Rochester Institute of Technology have successfully implemented such models, where students in interdisciplinary programs reported greater

engagement and problem-solving skills due to the combination of arts and technology (National Academies of Sciences, Engineering, and Medicine, 2018).

Another possible alternative is to promote collaborative, real-world projects that involve engineering and humanities perspectives. Malykhin et al. (2023) suggest that integrating hands-on activities such as debates, case studies, and community-focused projects can bridge the gap between technical and social education. Such activities create opportunities for students to engage with complex social challenges, encouraging them to apply both technical knowledge and ethical reasoning. By doing so, students develop critical thinking skills and a broader understanding of the impacts of their projects.

Furthermore, faculty development is crucial to overcoming barriers to interdisciplinary collaboration. Universities need to encourage and support faculty members to engage in interdisciplinary research and teaching. Promotion criteria should be revised to recognize and reward interdisciplinary contributions, and funding should be allocated to support interdepartmental initiatives. By fostering a culture that values both technical and social knowledge, institutions can create an environment conducive to HSS-STEM integration (National Academies of Sciences, Engineering, and Medicine, 2018).

In the case of students, overcoming resistance to HSS integration requires faculty to ensure that these topics are relevant. Case studies of successful engineering practices in which social awareness was the driving force behind impactful projects can be incorporated into the course, showing students, that ethical and social considerations are not just peripheral but central to engineering success. Programs such as related in Boni et al. (2012), illustrate how HSS integration prepares engineers to address social justice issues and work effectively in diverse cultural contexts.

While challenges to integrating HSS into engineering education persist, they are not insurmountable. Restructuring curricula, fostering interdisciplinary collaboration, engaging students with real-world societal challenges, and supporting faculty development may be the path for institutions to create an educational environment that prepares engineers to be not only technically skilled but also ethically responsible and socially conscious professionals. These changes are essential to producing engineers who are capable of leading in a world that demands innovation while maintaining ethical, environmental, and social concerns.

5. Examples of Successful Integration of Humanities and Engineering

Several higher education institutions worldwide have successfully implemented programs that integrate humanities into engineering education. The Polytechnic University of Valencia, for example, offers courses emphasizing empathy, global awareness, and social responsibility. These interdisciplinary courses have been shown to foster cosmopolitan abilities in engineering students, preparing them to work in diverse global contexts and address social justice issues (Boni et al., 2012).

In National Academies of Sciences, Engineering, and Medicine (2018) several experiences are reported as presented in Table 1.

Table 1. Examples of successful experiences.

Institution	Strategy or practice	Results or evidence
Howard University – mechanical engineering students	Option of enrolling in a multidisciplinary capstone course with students from the departments of electrical engineering, marketing (in the business school), and art (in the Division of Fine Arts).	Without empirical evidence presented, faculty highlight that students gain knowledge about the practical aspects of engineering in the workplace, develop skills in working in multidisciplinary teams, experience a transitional stage between the classroom and industry, improve communication skills and their employment opportunities.
Dwight Look College of Engineering at Texas A&M University	The first-year curriculum integrates areas such as ethics, writing, graphics, problem solving, physics, calculus, and chemistry.	The students who participated in the first-year integrated program demonstrated better critical thinking skills, performed better in calculus and physics, exhibited higher overall GPAs, developed significantly better computer skills, and greater facility to work in teams than students who completed the traditional first-year curriculum.
Colorado School of Mines	Students of the first-year curriculum integrate project modules and active-learning strategies, participate in a two-semester interdisciplinary seminar that develops and exploring the interconnectedness of appropriate topics from each of the first-year science, humanities, and engineering courses and engage in peer study group systems.	The engineering students who participated in this program graduated at rates approximately 25 percent higher than students in the traditional curriculum. In a follow-up survey 5 years later, these students indicated that their experience enhanced their academic preparation by helping them make connections among course topics, improving their critical thinking abilities, increasing their awareness of ethical issues, and strengthening their communication skills.
Olin College	The faculty of Engineering offers two options to students taking an introductory materials science course: an integrated materials science-history course co-taught by faculty in engineering and history, or a non-integrated course taught only by an engineering professor. Both options using problem-based learning.	Students who participated in the integrated course demonstrated increased motivation and engagement in self-regulated learning strategies over the term compared with students in the non-integrated course. Also, students in the integrated course self-reported use critical thinking skills in their work more frequently and had higher self-efficacy and valuing of learning tasks than students in the non-integrated course.

As Rojter (2018) points out, programs like these produce graduates who are not only technically proficient but also socially and ethically aware.

Recent studies provide additional empirical validation regarding the benefits perceived by students and faculty regarding the integration of humanities in engineering courses. Munir (2025) demonstrated concrete improvements in students' interpersonal skills, such as empathy, teamwork, and communication, through qualitative interviews and pre-post intervention surveys. Similarly, Davis et al. (2021) confirmed, using structured pre- and post-course assessments, significant enhancements in students' systemic thinking and critical analysis abilities.

6. Conclusion

The rapidly evolving global landscape demands that engineers not only excel technically, but also have a broader understanding of the ethical, social, and cultural dimensions of their work. As the world faces challenges such as climate change, resource scarcity, social and technological inequality, and ethical dilemmas in innovation, engineers must take on a responsibility that goes beyond purely technical problem-solving. In this context, the integration of Humanities and Social Sciences (HSS) into engineering education is not only beneficial, but essential.

The integration of HSS and STEM provides engineers with the opportunity to develop capabilities such as critical thinking, empathy with diverse communities, and understanding the long-term social impacts of their technological innovations. As highlighted by several studies, engineers who receive training that includes HSS are better prepared to assess the ethical implications of their work, address complex global challenges, and contribute to the development of sustainable, inclusive, and equitable solutions. This is particularly important as engineering increasingly impacts issues related to social justice and environmental sustainability.

One of the main arguments for integrating HSS is its role in contributing to the education of engineers who can engage with the human aspects of technological development. Programs that combine technical education with humanistic perspectives have proven successful in fostering cosmopolitan skills, critical thinking, and a sense of ethical responsibility in students. By developing these skills, engineers are not only able to produce technically sound innovations, but also ensure that their creations benefit society, addressing the needs inherent in its diversity and considering long-term environmental impacts.

Breaking down disciplinary barriers is increasingly necessary. As globalization and technological advancement accelerate, the decisions made by engineers will increasingly influence not only regional but also global systems. Therefore, a comprehensive education that integrates the technical and humanistic aspects of engineering can enable future professionals to contribute significantly to a world that demands innovation and responsible development.

However, achieving this holistic vision requires overcoming challenges. Universities can embrace flexibility in their curricular structures, encourage interdisciplinary collaboration, and foster faculty development that values both technical excellence and social engagement. Furthermore, overcoming resistance from students and faculty accustomed to traditional technocentric models will require a concerted effort to demonstrate the long-term benefits of HSS-STEM integration. By fostering a new generation of engineers who are both technically skilled and ethically responsible, universities can ensure that the engineering profession continues to evolve to meet the challenges that lie ahead.

Integrating HSS into engineering education will not be achieved simply by adding additional content or courses to the field. A shift in mindset is required to prepare engineers for the complexities of the 21st century. By cultivating empathy, critical thinking, and social responsibility, along with technical proficiency, we can ensure that future engineers are equipped to lead in a world where technological innovation and social justice must go hand in hand. Engineering schools have a key role to play in this transformation, preparing the next generations of engineers to become ethical leaders capable of shaping a sustainable and equitable future for all.

For future research, it is suggested to perform a detailed bibliometric analysis regarding the curricular integration of humanities in engineering. This analysis can help identify trends, most addressed areas, and existing literature gaps, providing further theoretical and practical insights.

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