Advancing Human-Centered Engineering (HCE): A Framework for Defining and Building the Emerging Discipline

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Abstract: This paper examines the emerging field of Human-Centered Engineering (HCE), an interdisciplinary approach that integrates engineering, human-centered design, social sciences, and creative practices. While drawing from Human-Centered Design (HCD), HCE distinguishes itself by embedding human-centered values systematically into engineering processes, balancing empathy, ethics, and societal impact with technical rigor and system performance. HCE also builds on earlier traditions within engineering that have long advanced social justice, sustainability, and interdisciplinary collaboration. We explore HCE's foundational ontology, epistemology, and axiology to establish a working definition of the field, distinguish it from adjacent domains, and outline the opportunities and challenges it faces in becoming a recognized discipline. The growing number of undergraduate and graduate programs reflects an important shift, yet defining boundaries, developing assessment strategies, and aligning with accreditation standards remain critical tasks. Drawing from a series of community dialogues, we summarize efforts to create a shared language, identify best practices, and foster an inclusive Community of Practice connecting academic, industry, and policy leaders. We conclude with a call to action, inviting broader contributions toward building a formalized and sustainable future for Human-Centered Engineering.

I. Introduction

This *Intersection of Design and 'X'* paper explores Human-Centered Engineering (HCE) as an emerging discipline. HCE integrates engineering design, social sciences, business, and the arts and humanities. Its core mission is to emphasize empathy, user-centered design, and collaborative problem-solving to develop products, systems, and processes that are both functional and deeply attuned to human needs and aspirations. HCE is distinct in its commitment to balancing technical rigor with human-centered values, making it a transformative approach in engineering education and practice.

While traditional engineering approaches have implicitly acknowledged human concerns, HCE offers a more comprehensive and intentional framework. It explicitly integrates socio-emotional dimensions, cultural contexts, and human experiences into engineering, establishing a foundation for greater impact. Through the strategic integration of validated methodologies from both natural and human sciences, HCE synthesizes diverse knowledge domains—including qualitative research, psychology, and aesthetics—to address the intricate complexities of human-system interactions.

Central to HCE is a reevaluation of how human elements are integrated into engineering. Historically, engineering has prioritized technical solutions, often relegating human considerations to secondary status. However, as societal challenges become more interconnected and multidisciplinary, the need for an engineering framework that places human well-being at its core has grown. HCE aims to refocus the engineering mindset to tackle not just technological challenges but also the socio-emotional and cultural dimensions of these problems.

This reorientation acknowledges engineering's inherent potential for human-centeredness while recognizing that modern complexities necessitate an expansion of traditional priorities. Rather than diminishing analytical rigor, HCE elevates empathy, user experience, and societal impact—elements often viewed as "soft"—and establishes them as essential components of engineering excellence. This integration creates a more holistic approach that enhances, rather than replaces, traditional engineering methodologies.

Beyond technical considerations, HCE incorporates questions of social and emotional well-being, cultural resonance, and ethical alignment. It challenges us to ask: How centered is the human in our engineering processes? What impacts does HCE seek to create? Whose needs, values, and perspectives are prioritized, and whose are overlooked? By addressing these dimensions, HCE enables engineers to develop more nuanced, inclusive, and effective solutions.

We address these considerations in the following sections. Section II outlines the motivation for this work and discloses author positionality. Section III examines the State of the Field of HCE by probing its foundational ontology, epistemology, and axiology, differentiating it from related domains. Section IV discusses the role of a global community of practice in advancing HCE, emphasizing interdisciplinary collaboration and shared learning. Section V highlights challenges and opportunities in integrating HCE into engineering curricula and accreditation frameworks, focusing on innovative pedagogical strategies and metrics that balance technical and human-centered competencies. Section VI identifies opportunities for growth and concludes with a call to action, urging stakeholders to contribute to HCE's formalization and adoption as a transformative approach to addressing complex societal challenges. Finally, Section VII concludes with a summary of key points.

II. Motivation and Position

The field of HCE is rapidly evolving but remains loosely defined, with limited cohesion among existing programs. We seek to address several critical gaps and opportunities:

Formalizing HCE as a Discipline: While elements of HCE exist within various engineering and design practices, there is an urgent need to define it as a cohesive discipline—especially with the emergence of new degree programs. This includes clarifying its boundaries, methodologies, and core values to ensure integration into mainstream engineering education and practice. By establishing HCE as a recognized field, we aim to provide a structured framework that fosters consistency and innovation across programs.

Creating a Robust Community of Practice (CoP): Collaboration lies at the heart of advancing HCE. A well-connected CoP can unite educators, researchers, industry professionals, and policymakers to share best practices, develop interdisciplinary approaches, and address common challenges. We advocate for the establishment of such a community to drive collective learning and growth in the field.

Engaging Stakeholders: Academia, industry, and policymakers play crucial roles in shaping the future of HCE. By highlighting the value of HCE in addressing contemporary challenges—such as sustainability, equity, and technological innovation—we call on stakeholders to actively

participate in its development. Engagement can include funding research initiatives, integrating HCE into curricula, and advocating for its adoption in engineering standards and accreditation.

Addressing the Needs of a Changing World: The rapid pace of technological advancement and increasing complexity of global challenges demand a human-centered approach to engineering. HCE provides the tools to meet these demands by emphasizing empathy, inclusivity, and real-world impact. We underscore the importance of adapting engineering education, research, and practice to remain relevant and effective.

By pursuing these objectives, we aim to lay the groundwork for a future in which HCE is not only a recognized discipline but also a driving force in creating engineering solutions deeply aligned with human values and needs.

Position Statement

The authors of this paper are a group of educators and researchers in the HCE community who are leading members of the Human Centered Engineering Consortium (HCEC). Our mission is to create an inclusive and interdisciplinary Community of Practice: to recognize stakeholders already practicing in the domain, to break down silos, and to bring together isolated communities. The HCEC's key objectives include fostering global partnerships among academic leaders, industry professionals, and policymakers through leadership workshops, summer institutes, and regular dialogues to exchange ideas and best practices. Our affiliations span several institutions of higher-education at a variety of scales, extents of human-centeredness, and program maturity. Our programs also vary in scope and balance of traditionally technical and human-centered considerations. Our viewpoints are informed by collaboration among this group and with the broader community of practice.

III. State of The Field: Human-Centered Engineering

Building a Working Definition of HCE

To grasp the evolving conceptions of HCE, we examine three philosophical dimensions that shape its development: ontology, epistemology, and axiology. In this section, we address each.

Ontology addresses what HCE is and how it differentiates itself from related disciplines. Scholars and practitioners are still debating its boundaries and core characteristics, making HCE a concept in development rather than a universally agreed-upon framework. Shaped by ongoing discussions, this evolving definition inherently underscores HCE's focus on centering human concerns within technological advancements. HCE recognizes a broader view of engineering not just as technical problem-solving but as a socio-technical practice inherently situated within human, cultural, and ethical contexts. To more precisely position HCE within existing traditions of design and engineering, it is important to clarify how it relates to Human-Centered Design (HCD).

While Human-Centered Engineering (HCE) draws on principles from Human-Centered Design (HCD), it is not simply a technical application of HCD practices. HCD is a broad, interdisciplinary field concerned with innovation, design research, and user experience across many domains. In contrast, HCE operates specifically within engineering practice and integrates human-centered principles throughout the entire engineering lifecycle, including technical

specification, system architecture, safety, and performance requirements. HCE uniquely balances human needs with technical rigor, often navigating complex trade-offs where reliability, efficiency, and risk must be reconciled with ethical, cultural, and emotional considerations. Whereas HCD may prioritize user experience above other factors, HCE requires co-optimizing human-centered goals alongside critical technical outcomes, positioning it as a distinct and necessary evolution within engineering disciplines. HCE focuses on creating technological solutions that positively impact individuals and communities rather than technical problem-solving targeting efficiency or other technical metrics. The discipline seeks to understand stakeholders as complete beings with socio-emotional needs, rather than as purely rational actors, abstract problem-solvers, or technical components. Scholars such as Boy emphasize that HCE is rooted in principles of Human-Centered Design but applied within specific engineering contexts [1].

Although closely related, HCE and Human-Centered Design (HCD) differ in scope and application. HCD is both a discipline and a methodology focused on research, problem-solving, and experimentation, while HCE embeds human-centered principles throughout engineering practice and may leverage HCD to do so. While HCD informs HCE, the demands of engineering rigor, safety, performance, and system-level constraints require distinct practices and trade-offs not always present in broader design contexts. In practical terms, HCE could be considered a subset of HCD. In contrast, HCD practices might explore broader conceptual innovations and need not always focus on problem-solving, whereas HCE applies these strategies to achieve specific engineering objectives. According to Zoltowski *et al.*, HCD can involve participatory practices and empathic understanding, essential components of HCE [2]. However, HCE tends to be more targeted and intentional in integrating these human-centered values within engineering solutions. The two domains are complementary but have different foci. While elements of HCD have been applied in various engineering fields, HCE represents a more deliberate and structured integration of these principles into the engineering process. Many educational institutions have incorporated HCD frameworks to encourage future engineers to prioritize societal impact alongside technical performance. [2].

Epistemology explores the knowledge frameworks shaping HCE practices. It recognizes that engineering problems cannot be fully addressed through technical expertise alone. Rather, HCE emphasizes the importance of human values, lived experiences, and socio-emotional contexts in developing engineering solutions. Unlike many design disciplines that prioritize generative ideation, HCE requires integrating lived human experiences with system performance, regulatory standards, and technical constraints. This epistemology calls for incorporating qualitative methods aimed at understanding the complexities of human experience in addition to more traditional quantitative metrics. For example, in their case study of ontology engineering, Kotis and Vouros argue that human-centered engineering requires knowledge frameworks that prioritize empathy, inclusivity, and collaboration across disciplines to create meaningful solutions [3].

HCE's epistemological approach bridges the gap between technical problem-solving and human-centered perspectives by prioritizing methods that capture human experiences and social contexts. Empathic communication becomes essential for engineers to better understand the emotions, needs, and behaviors of the individuals affected by their work. This involves moving beyond methods such as surveys and performance metrics to incorporate in-depth additional

approaches such as interviews, ethnographic studies, and participatory design workshops, to name a few [4]. These qualitative methods allow engineers to grasp the lived realities of users, recognizing them as active partners in the design process rather than passive recipients of technological solutions.

Moreover, interdisciplinary collaboration is central to HCE's epistemology. Because engineering challenges are rarely confined to one field, HCE encourages partnerships with psychology, sociology, anthropology, and design to capture a holistic view of problems. This collaborative approach enriches the knowledge base available to engineers, allowing for more comprehensive and human-centered solutions. As Boy [1] highlights, 21st-century engineering requires a human-centered approach integrating a wide range of perspectives to address modern complexities.

Participation of end users and stakeholders in the design process is central to HCE's epistemology. Participatory design methods, where stakeholders are involved in ideation, prototyping, and evaluation, ensure that solutions meet real needs. By involving users from the early stages of development, HCE moves away from a top-down approach and toward a more democratic, inclusive process. This participatory focus ensures that technologies are functional, emotionally resonant, and better adopted by users.

Axiology focuses on the values guiding HCE. Understanding these dimensions provides a holistic perspective on HCE as a discipline prioritizing human well-being alongside technical innovation [5]. Engineering values can be divided into internal and external categories [6]. Internal values—such as functionality, reliability, precision, and safety—focus on technical performance. External values address broader societal concerns, including ethics, sustainability, and social justice. Traditional engineering has prioritized internal values, treating external values as secondary or imposed constraints. HCE shifts this approach by integrating external values into the core of engineering practice. Prihatmanto *et al.* argue that incorporating external values is essential for engineering next-generation smart systems that address human needs [7].

Traditionally, aesthetics has been treated as secondary to utilitarian goals related to marketing or technical functionality. HCE takes a more holistic view, integrating ethical considerations and cultural contexts into engineering. HCE seeks to create designs that resonate emotionally and culturally with users, making them more effective engineering solutions. Dias emphasizes that aesthetics and ethics in engineering are interconnected, as both are concerned with human experiences and societal impacts [8]. HCE designs reflect users' cultural preferences, lived experiences, and emotional responses, recognizing that preferences are often situated and contextual. Thus designs must adapt to the particular needs and values of different communities.

The Expanding Landscape of HCE

The landscape of HCE is characterized by rapid growth, diversification, and increasing recognition as a critical component of modern engineering education and practice. Programs are emerging globally, reflecting diverse approaches that align with institutional priorities and regional needs. Some programs focus on foundational Human-Centered Design principles, while others emphasize interdisciplinary applications to address complex socio-technical systems and real-world problems. A notable trend in this evolving landscape is the integration of HCE into traditional engineering curricula. Historically, engineering education prioritized technical rigor,

analytical problem-solving, and quantitative metrics, often leaving little room for qualitative, human-centered methodologies. As global challenges become increasingly interconnected and human-centered, institutions recognize the importance of empathy-driven, inclusive design practices grounded in the human sciences and humanities.

Programs that successfully integrate Human-Centered Engineering (HCE) principles often adopt innovative pedagogical approaches, including project-based learning, interdisciplinary collaboration, and experiential education. Institutions such as the University of Washington and the University of Michigan Dearborn have developed degree programs that embed human-centered values into engineering curricula. Others, including Dartmouth, Olin College of Engineering, Arizona State University, Purdue, Georgia Tech, Northwestern, Colorado School of Mines, and Boston College, have also emphasized HCE principles in their programs. Collectively, these efforts reflect a broader shift toward a more empathetic and inclusive model of engineering education, preparing students to navigate complex socio-technical challenges and address human and environmental needs.

While these contemporary developments signal important progress, it is essential to recognize that efforts to humanize engineering practice have a much longer history. For several decades, critical traditions within engineering have advanced conversations around social justice, sustainability, interdisciplinary collaboration, and the use of qualitative methods. Movements such as engineering for sustainable community development [9], engineering and social justice [10], and engineering justice [11] have challenged conventional notions of engineering education and practice. HCE builds upon these efforts by proposing a systematic integration of human-centered values directly into the technical and procedural core of engineering. Rather than replacing earlier initiatives, HCE seeks to broaden and deepen their insights, embedding human-centered considerations into every level of engineering decision-making and system design.

Challenges to formalizing HCE as a Discipline

Defining Scope and Boundaries: HCE encompasses a constellation of activities intersecting engineering, social sciences, and design. Its emphasis on empathy, equity, and socio-cultural impact distinguishes it from traditional engineering disciplines. However, resistance from traditional practitioners, who may view HCE as peripheral to core engineering practice, can hinder its adoption. Establishing clear frameworks and shared understanding is essential for formal recognition. Moreover, traditional disciplines must recognize HCE's potential to enhance their relevance and effectiveness.

Despite its growth, HCE faces challenges in defining a distinct identity within the broader engineering and design landscape. Positioned at the intersection of engineering, design, and social sciences, HCE often overlaps with adjacent fields like Human-Centered Design, Human-Computer Interaction (HCI), Systems Engineering, Industrial Design, and User Experience (UX). This overlap can create ambiguity about what makes HCE unique.

Embracing Subjectivity in Engineering: Engineering has traditionally been associated with objectivity, precision, and quantifiable outcomes. While subjective decisions are common in engineering—such as problem-solving approaches, ecosystem choices, or trade-offs—they are

rarely emphasized. HCE requires acknowledgment of subjective and experiential dimensions, such as user emotions, cultural values, and ethical considerations, recognizing that the human sciences are vital components of human-centered solutions. Integrating these aspects requires cultural shifts within the profession and pedagogical innovations that prioritize qualitative understanding alongside technical proficiency.

Assessments in Education, Research, and Design: Evaluating the impact of HCE principles requires addressing gaps in current assessment practices across education, research, and design. Traditional engineering metrics prioritize technical performance and efficiency, often focusing narrowly on outputs rather than processes. These metrics inadequately capture HCE's broader scope, which values user involvement, equity, and socio-cultural impact. Developing assessment tools that balance technical outcomes with human-centered dimensions is essential.

In education, assessments should include formative measures—such as evaluating skill development, collaboration, and empathy—alongside summative evaluations of students' ability to create solutions with societal and emotional resonance. In research, methodologies must evolve to measure interdisciplinary and participatory approaches, focusing not only on technical innovation but also stakeholder engagement and community relevance. In design, assessment frameworks should emphasize iterative processes, stakeholder inclusivity, and cultural appropriateness.

By adopting holistic assessment strategies, HCE can ensure that competencies like understanding user needs and addressing socio-cultural contexts are valued alongside traditional technical metrics, better preparing engineers to address modern societal challenges.

Standardization: Establishing clear standards is equally important to ensure consistency and legitimacy in HCE programs. Standards can define the competencies engineers should acquire, including empathy, ethical reasoning, and participatory design skills. Collaborative efforts among academic institutions, professional organizations, and industry stakeholders are necessary to develop these standards and integrate them into accreditation frameworks such as those of the Accreditation Board for Engineering and Technology (ABET).

Aligning HCE standards with existing accreditation criteria, or developing specific program criteria tailored to Human-Centered Engineering, will enhance the discipline's credibility and support wider adoption by embedding human-centered values in measurable ways.

Addressing these challenges will require a unified effort to establish robust assessment frameworks and cohesive standards. By formalizing these structures, HCE can transition from an emerging concept to a recognized discipline, fostering an engineering culture that prioritizes empathy, inclusivity, and societal impact alongside technical excellence. This transformation will better equip future engineers to address the interconnected challenges of the 21st century [12], [13].

IV. Community of Practice Framework

The interdisciplinary nature of HCE demands a pluralistic approach, integrating diverse viewpoints and engaging stakeholders to shape the community's culture. While bringing human-centeredness into engineering may seem natural to some scholars and practitioners, others may see it as redundant or superfluous. A major function of a Community of Practice (CoP) is to provide a systematic context for critique and collaboration, establishing the culture and traditions of HCE as a discipline. Boyer's model of scholarship [14] extended traditional conceptions of scholarship to include discovery, integration, application (or engagement), and teaching and learning. This framework helped establish cross-disciplinary dialogue among stakeholders, particularly to enhance the quality of national university outcomes at the research-teaching nexus.

For example, the *How People Learn* framework built on these ideas, providing practical connections between classroom activities and learning behavior while illustrating the reciprocal relationship between theory and practice [15]. A Community of Practice brings together people who collectively care about a domain, advancing its definitions and understandings through social positions and interactions [16]. Participation in a Community of Practice provides explicit opportunities to become preoccupied with focused activities even when having ambiguous affiliations and diverging interests.

The conceptual framework of a Community of Practice emerged during the same era as Boyer's model and originated in situated learning [17]. It has since been translated into various other contexts [18]. Creating a Community of Practice in engineering is particularly challenging because it requires scholars to shift attention from established domains to emerging ones, often during periods of institutional change that question existing paradigms. Moreover, a successful CoP requires both a pull from the profession for a new practice area and a push from faculty willing to create change [19].

Establishing a Community of Practice is a process, not a product by itself. According to Wenger [20], a Community of Practice is different from other groups "in the way they define their enterprise, exist over time, and set their boundaries". The group defines itself as its members continue to refine their understanding of their character as a group. The process is dynamic and a living one requiring flexibility as members come in at different times during the emergence of the community, enabling the boundaries of the community to continuously emerge. Over time, participants come to recognize and appreciate the learning that takes place in the process, especially as new members join and interact with more engaged participants [21]. Furthermore, a Community of Practice is not necessarily a team with shared tasks; rather, the group is one that is characterized by shared learning, valuing the network of participants as they collectively engage in activities that have the nature of a learning process [19]. While members of the CoP may belong to different organizations and academic norms, programming and activities help develop relationships and structures that ultimately shape the domain of knowledge. Fostering a self-aware Community of Practice in Human-Centered Engineering is essential for the field's advancement, and such efforts are beginning to emerge.

Community Building: An Example from Practice

An example of an emerging Community of Practice in HCE is the Human Centered Engineering Consortium, to which the authors contribute as described in the *Position Statement*. One way we seek to build the Community of Practice has been to foster conversation among constituencies

through an ongoing series of virtual dialogue sessions about topics of shared interest in HCE. These dialogues provide a venue for an interdisciplinary community to refine the field's identity, share best practices, and build a collective vision. They bring together participants in virtual sessions from diverse academic institutions, disciplines, and professional backgrounds to explore HCE's challenges and opportunities.

The dialogues have underscored several critical needs and insights for advancing HCE:

- *Developing a Common Language and Vision:* A shared understanding of HCE's principles, scope, and terminology is essential for building coherence across programs and disciplines. Participants emphasized the importance of articulating HCE's unique identity while respecting its interdisciplinary nature.
- *Centering Empathy and User-Centered Principles:* Empathy remains a cornerstone of HCE, distinguishing it from other disciplines. Dialogues have emphasized designing with rather than for users, involving communities directly in the development process to ensure solutions address real needs and promote equity.
- *Leveraging Qualitative Methods and Community Partnerships:* Participants highlighted the value of qualitative methods, such as ethnographic studies and participatory design workshops, in understanding user contexts. They also stressed the importance of meaningful community partnerships, which require mutual benefit and sustained collaboration.

Structure and Focus of HCE Dialogues
Each dialogue session is structured to encourage active participation and collaboration. Sessions typically begin with an orientation, followed by breakout discussions addressing guiding questions, sharing experiences, and proposing actionable insights. Discussions are synthesized through group share-outs to promote collective learning.

The key themes of these dialogues are related to the emergent interests of the HCE community, including these topics, for example:

- *"What is HCE?"*: Participants explored foundational definitions and the core principles that differentiate HCE from traditional engineering disciplines. They examined how HCE integrates technical problem-solving with socio-emotional and cultural considerations.

- *"What Separates HCE from Other Practices?"*: This session centered on HCE's distinctiveness, emphasizing empathy, interdisciplinary approaches, and the value of qualitative methods. Participants discussed how HCE bridges human needs and engineering practices, fostering solutions that resonate with users and communities.

- *"A Landscape of HCE Programs": Focused on mapping the existing HCE academic landscape, this session highlighted program structures, pedagogical approaches, and assessment methods. Participants shared how their programs integrate human-centered principles, such as project-based learning, community partnerships, and interdisciplinary collaboration.*

- *"ABET Accreditation and HCE": Exploring how HCE principles align with accreditation criteria and how they can be integrated into traditional engineering frameworks.*

- *"HCE in Traditional Engineering Programs": Addressing strategies for embedding HCE within existing engineering curricula while maintaining technical rigor.*

- *"Community-Led Discussions": A participatory "Birds of a Feather" session to co-create agendas and strategies for the HCE community.*

V. Curriculum and Accreditation

Curriculum Evolution
Solving problems has long been the focus of the engineering profession—serving humankind through the artful and efficient application of scientific knowledge. However, engineering curricula have traditionally emphasized theoretical models of nature, offering relatively little training in applying engineering principles to real human problems informed by the human sciences. The 2018 Graham report on the Global State of the Art in Engineering Education [22] illustrates this argument. It observed that "current leaders" in engineering education are distinguished by educational practices including user-centered design, technology-driven entrepreneurship, active project-based learning, and a focus on rigor in engineering fundamentals (pp. ii–iii). The report clearly articulates the need for greater emphasis on user-centered design within engineering curricula. The Graham report characterizes a path forward for educational institutions to change engineering curricula in ways that prepare graduates to serve society more effectively.

Change is, therefore, inevitable if HCE is to bring the human to the center of engineering education. Based on work by Henderson, Beach, and Finkelstein [23], change strategies include disseminating new pedagogy, developing reflective teachers, enacting policy, and building a shared vision. These four strategies were identified through a review of 191 journal articles published between 1995 and 2008 on the topic. Across all these strategies, faculty emerge as the central stakeholders in enacting change [24]. Advancing HCE requires active engagement from faculty as key stakeholders, along with creating enabling contexts that support curricular change.

Accreditation and Human-Centered Engineering
While redesigning and creating engineering curricula to incorporate human-centered values is a crucial step toward advancing HCE as a discipline, ensuring the legitimacy and consistency of these efforts requires alignment with established accreditation frameworks. Accreditation not only validates program quality but also provides a structured mechanism for embedding HCE principles into engineering education at scale. Identifying how human-centered competencies relate to accreditation standards enables institutions to formalize curricular changes and reinforce their commitment to producing socially responsive engineers. Aligning HCE with frameworks such as ABET presents both challenges and opportunities. Traditional frameworks emphasize technical knowledge, quantitative metrics, and narrowly defined competencies, whereas HCE prioritizes interdisciplinary, human-centered outcomes such as empathy, ethics, and societal impact.

Accreditation can serve as a critical mechanism for ensuring the legitimacy, consistency, and quality of HCE programs. Aligning HCE with established accreditation frameworks, such as ABET, presents both challenges and opportunities. These frameworks have traditionally emphasized technical knowledge, quantitative metrics, and narrowly defined engineering competencies, while HCE operates within a broader interdisciplinary space that prioritizes qualitative outcomes such as empathy, societal impact, and user-centered design.

One of the main challenges for accrediting HCE programs lies in integrating these human-centered and interdisciplinary dimensions into frameworks that are historically grounded in technical rigor. Traditional metrics, such as problem-solving proficiency or mastery of core engineering principles, are insufficient to capture the essence of HCE which also values, for example, subjective experiences, ethical reasoning, and social equity. As a result, HCE programs must develop innovative methods to assess these human-centered competencies, such as reflective journals, ethnographic studies, and evidence of community impact. These qualitative tools not only complement technical assessments but also highlight the transformative potential of HCE in addressing societal challenges.

The interdisciplinary nature of HCE introduces additional complexity. By blending engineering with social sciences, design, and ethics, HCE operates at the intersection of domains that are often siloed within academic and professional contexts. This broader scope can make it difficult for programs to align neatly with accreditation criteria designed for traditional engineering disciplines. To navigate this tension, HCE programs must clearly define their unique contributions while demonstrating how these align with overarching accreditation goals.

Despite these challenges, accreditation also presents an opportunity for HCE to advance its recognition as an innovative and necessary approach to engineering education. Indeed, many of ABET's existing student outcomes are inherently aligned with HCE principles, offering a foundation for deeper integration, for example: applying engineering design to produce solutions, communication, engineering ethics, effective teamwork, and understanding the societal impact of engineering solutions (i.e., student outcomes 2, 3, 4, 5). By collaborating with accrediting bodies, the HCE community can help formalize new standards that emphasize human-centered methodologies. Case studies documenting the successful implementation of HCE in accredited programs can serve as compelling models for other institutions, demonstrating the feasibility and value of incorporating HCE principles into traditional curricula. These efforts can also inform the development of new accreditation metrics that balance technical and human-centered outcomes, such as evidence of participatory design processes or the impact of student projects on underserved communities.

In addition to defining and refining metrics, accreditation processes provide a platform for institutionalizing HCE's ethos within engineering education. By collaborating with accrediting bodies, the HCE community can formalize standards emphasizing human-centered methodologies. Case studies of accredited programs successfully implementing HCE principles can serve as models for broader adoption. Workshops, publications, and collaborative discussions can underscore how HCE addresses complex, real-world challenges that conventional engineering approaches may overlook. Programs can also advocate for revisions to

accreditation criteria, such as explicitly incorporating human-centered methodologies into the expectations for engineering graduates.

Ultimately, aligning HCE programs with accreditation is not merely procedural; it represents a transformative opportunity to redefine engineering education. Demonstrating the tangible benefits of human-centered approaches will strengthen HCE's credibility and signal a broader shift toward an engineering profession that balances technical excellence with human values.0

VI. Opportunities and Call To Action

The emergence of HCE presents an opportunity to expand the role of engineering in addressing human and societal needs. Its interdisciplinary nature offers the potential to broaden its appeal among diverse student populations by emphasizing not only technical excellence but also empathy, ethics, and social impact. This inclusive perspective can attract students from traditionally underrepresented groups, fostering a richer and more diverse engineering community. Furthermore, positioning HCE as a critical component of engineering education underscores its relevance in preparing engineers to tackle the complex, interconnected challenges of the 21st century.

Looking toward the future, we see the next decade as being pivotal in establishing HCE as a recognized and impactful discipline. By uniting stakeholders around a shared vision, the HCE community can drive meaningful change in both education and practice. The integration of HCE principles into engineering programs will not only enhance technical outcomes but also ensure that engineering solutions are equitable, ethical, and deeply attuned to the needs of humanity. We call on educators, researchers, policymakers, and industry leaders to contribute their expertise and vision to advance HCE as a transformative force within the engineering profession.

VII. Conclusion

In this paper, we explored Human-Centered Engineering (HCE) as an emerging discipline that redefines engineering by integrating technical rigor with human-centered values such as empathy, ethics, and societal impact. By examining HCE's foundational ontology, epistemology, and axiology, we proposed a working definition that distinguishes it from adjacent fields and positions it as a transformative approach to complex societal challenges. We also highlighted the global proliferation of HCE programs and the varied methodologies they employ, including project-based learning, interdisciplinary collaboration, and participatory design. Although the field is growing, significant challenges remain, including defining HCE's scope, developing standardized assessment frameworks, and integrating its principles into established accreditation systems like ABET.

Addressing these challenges will require coordinated efforts among academic institutions, industry stakeholders, and accrediting bodies to formalize HCE as a distinct and coherent discipline. Central to this effort is the cultivation of a robust Community of Practice that supports interdisciplinary dialogue, shared learning, and innovation in both education and professional

practice. A strong community framework will help refine HCE's identity and expand its impact across engineering and society.

We concluded with a call to action for educators, researchers, policymakers, and industry leaders to help advance HCE. By embedding human-centered principles into engineering education and practice, stakeholders can prepare future engineers to tackle the interconnected challenges of the 21st century with solutions that are equitable, inclusive, and attuned to human needs. The continued evolution of HCE offers an opportunity to transform the engineering profession, making it more responsive to societal complexities and more effective in improving the human condition.

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