Positioning Human-Centered Engineering Within Engineering Education: Presenting a Picture of an Emerging Discipline

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Abstract: Human-centered engineering (HCE) is being included in the different engineering curricula and disciplines in different ways. The notable scale-up in recent years is manifested in different publications, academic degrees, research agendas and available funding. The presence of a "human" in the engineering of today's products, systems and services means different things for different stakeholders and is approached differently depending on norms and traditions of different scholarly and practice communities. Realizing the pressing need to clarify goals and objectives of HCE as a discipline, and in relation to engineering education, we seek to trace its emergence within the engineering education community. Specifically, in this work, we seek to examine how published articles in conference proceedings of the American Society of Engineering Education have conceptualized and engaged with HCE as a discipline and as a community of practice. Emerged themes indicate that (1) tools and structures are increasingly emerging to make HCE more scalable; (2) partnerships, community engagement, and authentic contexts strengthen HCE learning; (3) early and sustained exposure to HCE fosters deeper engagement, and reshapes the identity of learners; (4) power, ethics, and social justice are essential dimensions of HCE; and (5) HCE learning requires various forms of evidence to assess learning. Findings have implications for research seeking theory-building and for the community to strengthen a shared identity of scholarly practice.

1. Introduction

Human-centered engineering (HCE) has been increasingly emphasized in different curricula in the past 25 years (Baker & Moukhliss, 2020), while integrating, to different levels, engineering design, humanities, social sciences, the arts and business (Craft et al., 2025). One could argue whether HCE is a creative problem-solving approach, a valuable business tool, or an effective educational pedagogy (Kelley, 2001; Brown & Katz, 2009). Despite the variation in perspectives, there seems to be a common emphasis on empathy, user-centeredness and the attention to human needs at the system level. In this paper, we seek to explore the different ways characterizing how HCE is emerging within the engineering education community. Our work is part of a larger effort to position HCE as an emerging discipline within engineering education, with implications on engaging different stakeholders, creating a robust community of practice and formalizing HCE as a discipline.

1.1 The Motivation to Formalize Human-Centered Engineering as a Discipline

The recent growing recognition of the scholarly pursuit of engineering education has been accompanied by a demonstrated impact on students' learning, mainly through demonstrated robust skills (Love, 2000; Irbite & Strode, 2016). Engineering education programs that are leading globally are ones that effectively integrate interdisciplinary design in the curriculum while addressing societal challenges (Graham, 2018). However, the variations in understanding what HCE is presents a challenge for educators, students, employers and policy makers alike. The need to formalize HCE as a discipline is an effort to recognize the opportunity of becoming a recognized discipline with common frameworks that are distinguishable from adjacent domains (Craft et al., 2025). In addition, the effort is an attempt to address challenges of assessment and standardization to further enhance the educational outcomes.

Design, as a central attribute to the practice of HCE, opens up the creative process of problem-solving to attune to human needs and aspirations (Cross, 2001). When a user is engaged in the design process, observed or inferred feedback on prototypes throughout the design process helps in situating the design challenges around user needs (Dorst, 2015). The variety of approaches of problem framing (Weick et al., 2005), experimentation (Kelley, 2001), and engaging diverse perspectives (Carlgren et al., 2016). demand a collective approach, especially if human-centered values are to be integrated in balance with the traditional technical rigor of the engineering curriculum (Baker III, 2014).

Formalizing HCE as a discipline will contribute to its recognition as it stands along with other elements of the engineering curriculum. In some accounts, HCE is characterized as reflective, iterative and a creative process which builds on the moral reasoning of a designer to solve complex problems (Love, 2000; Irbite & Strode, 2016). These are activities that require a new level of learning that appeals to interdisciplinarity in harnessing a broad range of skills (Boy, 2017). Furthermore, formalizing HCE as a discipline will foster a discourse on complex design decisions which can be enabled by common frames of reference and venues for collaboration. Without the formalization of HCE as a discipline, decision making will always over-emphasize the technology, overlooking the priority of the humans this technology serves (Craft et al., 2025). In today's world, which is infused with systems that connect humans and technology in unprecedented ways, the need to equip engineers with decision making tools, frameworks and professional skills is ever increasing (Graham, 2018). As a discipline, HCE will establish both the community and the frameworks for examining the centeredness of humans in decision making around the impact of design and engineering of technology.

1.2 The Emergence of Human-Centered Engineering within Engineering Education

Problem- and project-based learning (collectively PBL) has grown in popularity in engineering education (Kolmos & Holgaard, 2008), arguably since the 1970s. Situating the emergence of HCE alongside the emergence of PBL is a useful way to reflect on the level of preparation of graduating engineering students to examine the consequences of their design decisions on society. PBL recognizes the efficacy of the development of professional skills, which is accompanied with active learning. PBL offers authentic, or semi-authentic experiences, for students to integrate technical theory with creative design in solving problems. The growing appreciation by employers in industry of the skills observed in students who have experienced PBL seems to have contributed to the widespread of PBL (Bielefeldt et al., 2009). Some of the recognized professional skills include teamwork, communication, information literacy and project management (Prince & Fedler, 2006). The adoption of PBL seems to have also been facilitated by the need of design educators to overcome limitations in institutional resources, including overly loaded curriculum (Al-Abdeli & Bullen, 2005). The engineering curriculum seems to have experienced a tension, from the engineering faculty, on the one hand showing interest and expertise in technical rigor, and from outside stakeholder, on the other hand showing appreciation of the non-technical skills of graduating engineers (Savin-Baden, 2007). However, a problem persists in how the outcomes of engineering education are defined and assessed, the alignment between content, assessment and pedagogy, and the challenges of offering quality problem- or project-based learning which offers the proper balance between the technical rigor (emphasized by engineering faculty) and the professional skills (in demand by external stakeholders).

In literature, three forms of change in the curriculum has generally been observed: modification, integration and transformation (Ali, 2021). In the *modification* form of curricular change, change happens primarily at the course-level where new knowledge is being accounted for by adapting to new theory or professional practice. This form of change emphasizes positivism and reductionism in the specialization of professions (Clark, 1983). New knowledge in this form is compartmentalized (Hopmann, 1991) within specific boundaries; these specific boundaries will end up defining academic disciplines and the relationships between them. In engineering education, *modification* as a form of curriculum change is the most common as new advances in technologies and changes in practice always call for the incorporation of new theory and professional practice. The *integration* form of curricular change counteracts the reductionist approach of the previous form. As a form of change, *integration* calls for unity, synthesis and the avoidance of fragmented structures of knowledge (Clark & Wawrytko 1990). The integrated curriculum received special attention in the 1980s and the 1990s (Boyer 1987). However, Toombs & Tierney (1991) noted that proposals for integrated learning tend to focus only on "a segment of the total curriculum, one constellation of courses" (p. 8). In engineering education, the 1990s, for example, witnessed the rise of calls to integrate engineering design with the engineering sciences (Dym et al., 2005). Other recent examples are the integration of sustainability into the engineering curriculum (e.g., Guerra, 2017; Thürer et al., 2018) and integrating the entrepreneurial mindset (e,g., Bekki et al., 2018; Kriewall & Mekemson, 2010). In this form of change, integrating content in a segment of courses in the curriculum is assumed to represent change at the curriculum-level. The *transformation* form of curricular change is characterized as one that is built upon extensive debates and negotiations among stakeholders on the purpose of the curriculum and how to achieve this purpose (e.g., Jamieson & Lohmann, 2009). Transformation is associated with the emergence of new issues, the impact of which is not always well-defined (Toombs & Tierney, 1991). While the need for new ways to deal with these issues are clear, "the process of curricular change and the breadth and depth of the challenges in such a setting are different and somewhat unfamiliar" (Toombs & Tierney, 1991, p. 9). This form of curricular change tends to be largely influenced by external factors that impact the curriculum (Lattuca & Stark, 2009). An example of calls to transform engineering education is the report by the National Science Board to address the emerging needs of the engineering workforce ("NSB", 2007). Similarly, the *Changing the Conversation* study engaged multiple stakeholders to provide a unique perspective on repositioning the perception of engineering in the society ("NAE", 2008).

As HCE continues to shift the focus of engineering design, and in its relation to engineering, from the designing a product to solving a societal problem, the need to understand the emergence of HCE within engineering education is needed. However, without examining the various ways in which the engineering education community has been approaching HCE, the development of HCE as a discipline will remain limited.

2. Research Questions and Methods

This work grew out of a larger consortium effort that envisions a future where engineering across all disciplines prioritizes people, ethics, and societal impact. As our ongoing efforts seek to scholarly contribute to and sustain prior work, we want to understand developing themes and approaches in the literature on the topic. In this paper, we address two research questions:

(1) What are the current themes of human-centered engineering in engineering education?, and
(2) What methods have been used to increase the learning and application of human-centered engineering?

To answer these questions, we explore how human-centered engineering has been expressed within the community of the American Society of Engineering Education (ASEE). Using content analysis as a research method, we identify themes that present a picture of an emerging discipline. Emerged themes through content analysis enable us to review and examine ideas, topics and discourse around HCE within ASEE (Baker III, 2014).

Content analysis is a long-standing research method used to systematically identify, interpret, and categorize information (Hsieh & Shannon, 2005). It accommodates both qualitative and quantitative data, making it highly adaptable (Obilade & Burton, 2015). Scholars have widely applied it to examine trends, themes, and models across design (e.g., Cho & Parks, 2012), instructional design (e.g., Obilade & Burton, 2015), educational technology (e.g., Surry et al., 2014), and organizational studies (Lee & Evans, 2012). Prior work includes analyzing journal articles, reviewing instructional design models, comparing traditional and open-access publications, and identifying conceptual overlaps across textbooks. Its consistent success in revealing patterns within published literature demonstrates its suitability as a methodological approach for our study, seeking to understand themes, trends, and conceptual structures of HCE within the engineering education community.

2.1 Data Collection

In this study, and as part of a larger ongoing effort of systematic literature review, we focused on the ASEE PEER database (peer.asee.org), the archives of ASEE Papers on Engineering Education Repository which goes back to 1996 until today. The researchers searched the database to examine, first separately then collectively, how human-centered engineering was described, studied and approached within the engineering education community. Once the purpose, research questions and scope have been defined (Borrego, Foster & Froyd, 2014), we used the appearance of the phrase ‘human centered’ in the title of a publication as a criteria for inclusion, which is common in literature reviews in interdisciplinary fields (Li & Ma, 2010). The result was 67 articles; one was excluded from the analysis because the content of the paper was focused on computational fluid dynamics but had ‘human-centered’ in the title. In our framing, human-centered engineering envisions a future where engineering across all disciplines prioritizes people, ethics, and societal impact, through interdisciplinary collaboration, research, and education, and with the aim to advance engineering practices that are equitable, sustainable, and responsive to human needs. Overall, our data collection method follows “transparent, methodical, and reproducible procedures” (Borrego et al., 2014, p. 46) to select an appropriate collection of papers that help us address the research questions.

2.2 Data Analysis

Content analysis, as a form of thematic analysis, allows extracting trends, identifying patterns and recognizing relationships of the overall state of HCE as a field. Our content analysis focused on four major themes in the identified papers: the *population of interest* (e.g., faculty, students, etc.), the *level of analysis* (classroom, lab, camp, curriculum, institution, etc.), the *study design or pedagogy used*, and the *outcome of the study*. Our analysis also involved creating narrative reviews of the identified articles (Litzinger et al., 2011; Prince, 2004; Prince & Felder, 2006), aiming to describe the state of knowledge and practice on HCE within engineering education. Finally, each paper was described with a theme to offer a critique or appraisal to assess its quality (Borrego et al., 2014). This last step was a step of abstracting the key idea of the paper (Cook & West, 2012) to enable the building of summary narratives across emerged themes (Borrego et al., 2009; Koro-Ljungberg & Douglas, 2008; Shavelson & Towne, 2002).

Our synthesis building process can best be described as *mapping*; that is, reporting how “the work that has been done in a field or topic area” can be organized using “populations, theoretical frameworks, methods […] and other details as relevant (Borrego et al., 2014, p. 60). Gough (2004) notes that mapping “produces a useful product in its own right to describe what research has also been undertaken in a field (as defined by the inclusion criteria) and so can inform policies for future research” (p. 56).

As discussed previously, definitions of HCE remain negotiated and debated. Given the inherent interdisciplinary nature of the emerging discipline, our analysis seeks to reveal how the community has accepted various approaches and labeled them as HCE. We are not trying to offer a precise definition of HCE; however, we attempt to paint an emerging picture of HCE as an emerging disciple within the engineering education community.

2.3 Limitations

The study has three key limitations. First, it assumes the presence of the phrase “human centered” in the title to be the main criterion for inclusion, even though important HCE may exist in other work. Second, the analysis is based on a necessarily narrow slice of the literature (i.e., the ASEE conference proceedings publications) and shaped by the researchers’ own interpretations of themes within this collection of paper, which may create artificial boundaries and fail to capture the full complexity the emergence of HCE within the engineering education community. Third, the study limits the search on HCE without accounting for adjacent field, such as the broader area of design thinking. However, the rationale chosen is that there are nuanced differences between the two fields as Baker & Moukhliss (2020) suggest, where the design-oriented perspective of the latter may influence the applicability of the insights of the study by relying heavily on how design conceptualizes the field.

3. Findings

This section provides a meta-synthesis of the emerged themes after analyzing the published ASEE conference proceedings, Figure 1. The themes characterize how HCE was approached within the engineering education community as reported in these conference proceedings. The reported themes below seem to point to the conclusion of the emergence of HCE as a discipline, despite the variation in contexts, measures and effectiveness of implementation.

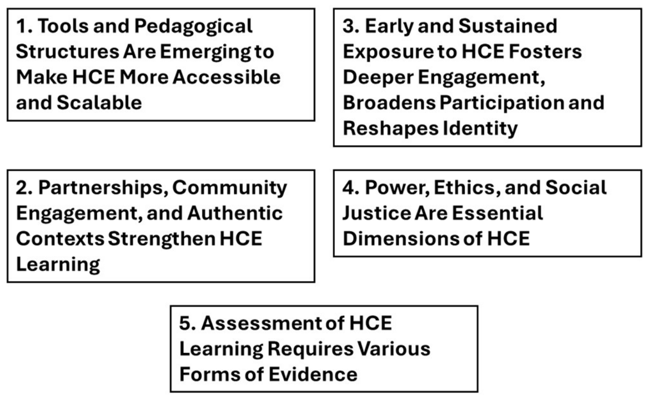

Figure 1. Emerged themes characterize how HCE was approached within the engineering education community as reported in these conference proceedings.

3.1 Tools and Pedagogical Structures Are Emerging to Make HCE More Accessible and Scalable

The field is building the infrastructure, which includes tools, assessments and faculty support, needed to scale HCE across engineering education. The analyzed papers introduced practical tools and models that helped educators implement HCE effectively across diverse contexts. For example, user identity cards were used to offer a scalable way to simulate diverse user interactions in early design courses (Jay & Zhou, 2025). In addition, faculty development programs provided structured support for integrating humanistic, caring, and accessible teaching practices [50]. Researchers have attempted to study learning progressions as a systematic way to track students' development from novice to informed designers (Parks et al., 2024). In HCE education, tools and environments were found not to be neutral; they actively shape what students perceive engineering to be. The material and digital ecosystems students interacted with influenced their professional identity and learning outcomes. For example, students associated ideation tools with planning and user understanding, and prototyping tools (especially Arduino) with realism and professional identity formation (Dickrell et al., 2022). In another study, human-centered learning analytics, where experts categorized learning management system content, produced more accurate and interpretable predictions than raw click data, revealing hidden instructional patterns (e.g., career exploration as a strong predictor of success) (Cruz Castro et al., 2022). A startup-like capstone environment integrating the internet of things, full-stack development, and entrepreneurship fostered systems thinking and employability in an HCE intervention (Khoshabeh & Gessner, 2021).

Several papers argued that HCE is not an add-on but a system-level organizing framework that can reshape engineering programs, capstones, and pathways. Tucker and colleagues (2023) introduced an HCE framework that mapped engineering activities to HCE spaces, enabling curricular alignment and ABET connections. Goodman and colleagues (2024) showed that integrating HCE into a two-semester capstone improved students' fluency with stakeholder-driven design. Bonfert-Taylor and May (2024) used HCE to redesign foundational math pathways, positioning it as a cultural shift toward inclusivity. These studies show that HCE serves as a backbone for curricular coherence, professional identity formation, and institutional change. The analyzed papers show a strong movement toward formalizing HCE through mapping tools, rubrics, and integrated frameworks that make human-centered competencies visible and measurable. An HCE mapping tool, for example, was developed to track competency development and to supports ABET criteria (Parks et al., 2025). In another study, a two-semester capstone integrated HCE with entrepreneurial mindset frameworks, showing significant gains in students' self-efficacy across HCE elements (Goodman et al., 2025). A systematic rubric was developed to assess the depth of HCE thinking using design seeds and qualitative/quantitative indicators (Saleem et al., 2025). In addition, generative AI was used to create qualitative interview transcripts that supported structured empathy-building and rubric-based assessment (Isoghie et al., 2025). HCE is becoming more rigorous and assessable through tools that support consistency, transparency, and curricular alignment.

It is also shown across the papers that HCE education is most successful when supported by explicit frameworks, iterative cycles, and guided practice. A detailed, multi-phase design process supported service-learning teams and reduced frustration (Zoltowski et al., 2010). Similarly, a phased course structure, moving from identifying human capabilities, to a design primer, to workplace, public space design, helped students build comfort and competence (Trachtman et al., 1999). Clear project requirements and structured deliverables supported functioning prototypes and human-centered outcomes (Jordan & Lande, 2012), pointing to how HCE learning requires intentional scaffolding. In other words, students need structured opportunities to practice empathy, iteration, and contextual reasoning. Brief or lightly scaffolded HCE experiences tend to yield minimal shifts in self-awareness or social awareness. For example, a three-week HCE project produced small, non-significant changes in self-awareness and social consciousness, likely due to short duration and lack of reflection (Joslyn & Hynes, 2016). In comparison, longer, immersive summer programs showed stronger gains in confidence and skill application, including real-world implementation (Chalah et al., 2019). Depth and duration matter: HCE learning requires time, reflection, and iterative practice. Furthermore, large-scale or redesigned courses benefit from explicit frameworks, scaffolding, and attention to process. A five-step HCE process embedded across a multi-course first-year sequence ensured consistent exposure to user engagement and prototyping (Dodson et al., 2017). Redesigning a first-year course with clearer team structures and scaffolded activities improved collaboration and iteration (Dodson et al., 2018). Overall, this theme points to the fact that when HCE is treated as a structured practice, rather than an add-on, students develop stronger human-centered design habits, mindsets and skills.

3.2 Partnerships, Community Engagement, and Authentic Contexts Strengthen HCE Learning

Authentic, community-connected experiences deepen students' understanding of user needs and broaden participation. The papers show that real-world partnerships enhance engagement and learning, but require significant coordination, communication, and attention to power dynamics.

For example, a multi-organizational partnership (nonprofit, university, NBA team, Motorola) created rich, real-world HCD learning experiences for underrepresented youth (Carl et al., 2024). Long-term international HCE projects required deep collaboration with community partners and local universities, revealing both benefits and challenges (Jayakumar et al., 2024). Students valued the holistic, community-engaged nature of the HCE program, even if they struggled to articulate its uniqueness externally (Hertz, 2025).

However, as shown in the previous theme, human-centered interventions work only when they are immersive, sustained, and well-scaffolded. Short or surface-level interventions show limited impact, while longer, iterative, participatory experiences produce deeper shifts. In one study, a brief priming intervention not only failed to increase empathy but decreased social consciousness, suggesting that shallow interventions can backfire (Al Kakoun et al., 2021). In another study, modular HCE activities improved process knowledge and collaboration but did not meaningfully shift higher-level HCE understanding or communication skills (Shehab et al., 2022). In comparison, sustained engagement with a real participant over a semester enabled gradual movement toward HCE-aligned values (Okerlund et al., 2022), pointing to how HCE mindsets develop through extended, authentic engagement, not unplanned interventions.

Furthermore, authentic, real-world engagement strengthens students' understanding of user needs and social context. Many papers emphasize direct interaction with users, communities, or stakeholders as essential to meaningful HCE learning. Some examples include: students interview a Habitat for Humanity family and design a sustainable home around their needs (Leffers et al., 2008); Purdue's service-learning program required frequent user interactions and iterative prototyping (Zoltowski et al., 2010); service learning was framed as a powerful way to cultivate social sensitivity and big-picture thinking (Titus et al., 2011); students collaborated with a Haitian school community to design sanitation and water solutions (Huff et al., 2011); and students selected their own user groups and design functioning prototypes around their needs (Jordan & Lande, 2012). Overall, authentic engagement helps students see engineering as a sociotechnical practice grounded in human centered experiences.

3.3 Early and Sustained Exposure to HCE Fosters Deeper Engagement, Broadens Participation and Reshapes Identity

Across multiple studies, students begin with limited, tool-focused, or artifact-centric understandings of human-centered design. Students' reflections overwhelmingly show technology-centered or minimally user-focused conceptions, with almost none demonstrating empathic or stakeholder-integrated perspectives (Sanders et al., 2021). Even after HCE modules, most students shift only from naïve to intermediate understanding; deeper conceptual change remains rare (Shehab et al., 2022). Students in a technical capstone initially prioritized technical tasks and internal-facing goals before gradually adopting more human-centered orientations (Okerlund et al., 2022). Studies show students' default mental models of engineering emphasize technical problem-solving over human needs, requiring intentional disruption. However, multiple studies highlight the importance of early immersion and long-term engagement for developing human-centered mindsets. A one-week HCE summer camp increases pre-college students' awareness of engineering careers and the role of empathy (Tucker & Shehab, 2023). Students with prolonged HCE exposure demonstrated more advanced design reasoning than those without it (Goodman et al., 2024). A redesigned first-year pathway, focused on HCE, aimed to retain students who might otherwise leave engineering (Bonfert-Taylor & May, 2024). Pre-college students showed significant gains in attitudes toward HCE and awareness of its role in engineering, but no improvement in group work skills (Shell et al., 2024). Middle and high school students engaged meaningfully with HCE through real-world app design projects supported by industry partners (Carl et al., 2024). User identity cards helped first-year students practice designing for diverse users, strengthening empathy and user-centered thinking (Jay & Zhou, 2025).

Early HCE interventions effectively built awareness and empathy, but required intentional scaffolding to develop collaboration and more advanced design skills. An example was a first-year disaster-recovery design challenge introduced engineering as a sociotechnical practice from day one (Garnett et al., 2025). It was also shown that teachers participating in HCE research experiences developed intercultural awareness and readiness to teach engineering inclusively (Pinnell, 2025). Teens in accessibility-focused internships gained confidence, agency, and awareness of disability and inclusion (Forsyth et al., 2025). Students with physical disabilities thrived in HCE research environments and developed stronger engineering identities (Golecki et al., 2025). Several papers highlighted the value of first-year or early-stage HCE projects in shaping students' understanding of engineering and improving persistence. A first-year assistive technology project improved student satisfaction and retention while immersing students in authentic user interviews and prototyping (Roszelle, 2025). A 200-level biomedical course (open to non-engineers) uses HCE to help students tackle complex problems and engage community partners (Mueller et al., 2020). A PBL-based geometric design course integrates AV problems to bring a human-centered lens to upper-level civil engineering (Sen & Roesler, 2021). It was shown that early, authentic HCE experiences helped students see engineering as meaningful, relational, and socially grounded, strengthening motivation and persistence.

Several papers examined how students understand, interpret, and internalize HCE, revealing developmental patterns. Seven categories of HCE experience were developed, ranging from technology-centered to empathic design (Zoltowski et al., 2011). In one study, students' post-course conceptions approached expert perspectives, though differences remain (e.g., research-led vs. solution-led design) (Oehlberg & Agogino, 2011), showing variation in depth of human-centeredness (Jordan & Lande, 2012). Students at different educational levels demonstrated natural tendencies toward user- and context-focused thinking, though race and gender influence how they balance human and technical considerations. High school students showed spontaneous HCD thinking; African American males emphasized context and users, while White males focused more on technical constraints (LeSure et al., 2014). Human-centered success criteria (e.g., user satisfaction) emerged only when students engaged with real clients (Bitetti & Danahy, 2018). Overall, students progress through recognizable stages of HCE understanding, and instruction can intentionally support movement toward more empathic, contextualized design; learners bring diverse perspectives to design, and identity shapes how they interpret human-centeredness.

3.4 Power, Ethics, and Social Justice Are Essential Dimensions of HCE

In the papers, HCE is framed as an ethical discipline that must grapple with power dynamics, institutional inequities, and community impact. Ethical engagement and awareness of power are core competencies, not peripheral concerns, in human-centered engineering. In a study, explicitly teaching social and institutional power helped students recognize how engineering decisions can reinforce or challenge inequity (Schimpf et al., 2023). In another study, HCE literacies helped students center marginalized community voices and disrupt top-down design norms (Morales & Rainey, 2024). Math and engineering pathways were reimagined to counter systemic biases that disproportionately exclude underserved students (Bonfert-Taylor & May, 2024). However, introducing social awareness, inclusivity, and empathy required intentional, evidence-based pedagogy. Students could recognize user diversity and social context, but only when guided through structured activities. Priming alone could not overcome dominant engineering values that suppressed empathic engagement (Al Kakoun et al., 2021). A compatibility survey combined with reflection helped students question assumptions about "universal users" and recognize cultural, educational, and experiential differences (Hammond et al., 2022). Participatory design with a real prosthetics user foregrounded interaction-based values and ethical considerations (Okerlund et al., 2022), pointing to how socially aware HCE requires purposeful, scaffolded experiences that help students interrogate assumptions and engage with real users.

Human-centered approaches can diagnose and redesign institutional systems, not just products. HCE was applied not only to artifacts but also to program structures, advising systems, and educational ecosystems. For example, HCE was used as a framework to identify curricular gaps and guide organizational change (Tucker et al., 2023). HCE and data analytics were applied to redesign a pre-engineering program, addressing economic and institutional barriers (Pawar & Smith, 2023). HCE was also used to rebuild foundational math pathways using HCE principles to improve retention and belonging (Bonfert-Taylor & May, 2024). Treating educational systems as design problems revealed structural inequities and enables targeted redesign. Several papers highlight a shift toward embedding human rights, distributive justice, intercultural competence, and ethical responsibility into engineering curricula. A graduate course redesign integrated sustainable transportation with human rights principles, emphasizing distributive justice, accountability, and socio-technical analysis (Santos & Chacon-Hurtado, 2024). Multi-year global HCE initiatives improved students' intercultural competence and highlighted the importance of managing power dynamics and avoiding unintended harm (Jayakumar et al., 2024). Boston College's HCE program foregrounded societal implications, character development, and interdisciplinary learning (Hertz, 2025). Students working with Latin American mining communities developed richer understanding of cultural, social, and communication complexities (Smith et al., 2018). Global challenge–focused summer programs led students to apply design skills in their home communities (Chalah et al., 2019). Underrepresented doctoral students in the HCCS program showed increased career self-efficacy, scholarly productivity, and persistence, supported by mentorship and community (Waisome et al., 2019). High school and undergraduate participants gained confidence and applied skills beyond the program (Chalah et al., 2019). Overall, HCE is evolving into a justice-oriented, ethically grounded approach that prepares engineers to navigate complex social and institutional contexts.

3.5 Assessment of HCE Learning Requires Various Forms of Evidence

Validated tools and literacies are emerging to measure and support human-centered engineering learning. Different papers collectively advance assessment instruments, conceptual frameworks, and design literacies that help educators understand and cultivate HCE competencies. For example, Pagano and colleagues (2024) developed a validated HCE self-assessment survey revealing five factors, including stakeholder interaction as a distinct dimension. Morales & Rainey (2024) identified a taxonomy of HCE literacies that students used to frame problems and engage with community partners, and Tucker and colleagues (2023) provided a framework that visualizes learning trajectories and supports competency mapping. The field is building the measurement and literacy infrastructure needed for evidence-based HCE education. Reflection and qualitative evidence are powerful windows into students' design thinking, but, currently, underutilized. Their diagnostic power depends on structure and developmental readiness. Open-ended reflections successfully mapped students' HCE experiences using a phenomenographic framework, though brevity and prompting limited depth in reflecting (Sanders et al., 2021). Reflective writing helps students articulate awareness of user diversity and biases, showing early capacity for social interpretation (Okerlund et al., 2022).

These papers collectively argued that qualitative, experiential, and contextual evidence are essential for understanding impact and equity. Critiques narrowed definitions of rigor and argues for qualitative criteria such as transparency and actionability (Strickland, 2025), and validated surveys and observations were used to track HCE competencies across a program (Parks et al., 2025). Mixed-methods interviews revealed structural barriers and student experiences invisible to quantitative metrics (Pawar & Smith, 2025). Rubrics explicitly valued qualitative data and trained students to integrate it with quantitative anthropometric data (Saleem et al., 2025). Generative AI was used to create realistic qualitative transcripts, making user-centered data more accessible for instruction (Isoghie et al., 2025). As it is common in HCE projects for students to conducted real interviews with community members to identify pain points and design assistive technologies (Roszelle, 2025), HCE pushes engineering education toward broader, more human-centered notions of rigor and assessment. Overall, qualitative and user-centered data are gaining legitimacy as essential components of engineering design education. The papers emphasize the importance of qualitative data, empathy work, and user narratives in engineering learning and assessment.

4. Discussion

4.1 Human-Centered Engineering Is Emerging as a Distinct Disciplinary Identity

Several papers articulate HCE as more than a teaching method; it is a discipline with its own values, literacies, and epistemologies. The papers describe, in various ways, HCE's shared values, ethical commitments, and ways of knowing, distinguishing it from traditional engineering design (Craft et al., 2025). Figure 2 shows the increasing number of papers published in the ASEE conference proceedings with the phrase "human centered" in the title. As an emerging discipline, the papers show how early exposure to sociotechnical design shapes students' professional identity (Garnett et al., 2025), and how lived experience analysis and need-finding enrich HCE learning environments (Golecki et al., 2025). HCE is coalescing into a discipline that blends technical rigor with human experience, ethics, and societal impact. Across these papers, HCE is treated as a core competency that should be intentionally developed, assessed, and scaffolded across entire programs. Learning progressions make empathy, iteration, communication, and implementation explicit program-level outcomes aligned with ABET (Parks et al., 2025). As HCE is increasingly becoming a program-level priority, not an add-on, coordinated "design spine" aligns HCE learning objectives across multiple mechanical engineering courses (Lande & Lalley, 2025). Conceptual frameworks are being created to define shared values and ways of knowing for HCE as an emerging discipline (Craft et al., 2025). The findings suggest that institutions are moving from isolated HCE activities to systematic, vertically integrated HCE curricula.

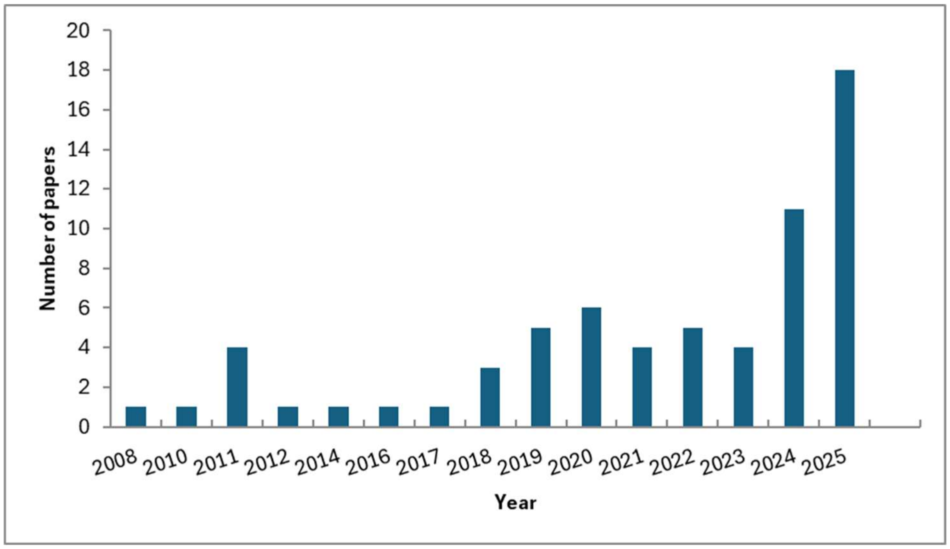

Figure 2. The increase over the years in the number of published ASEE conference papers with "human centered" in the title.

4.2 Human-Centered Approaches Are Being Embedded Into Technical and Domain-Specific Engineering Contexts

The findings from analyzing the selected papers point to how HCE is no longer confined to general design courses; it is being integrated into specialized engineering domains, like materials science (Goodman et al., 2025), biomedical engineering (Mueller et al., 2020), and civil engineering (Sen & Roesler, 2021). Current HCE approaches are proving adaptable and valuable across technical subfields, enriching domain-specific engineering practice. Across these papers, HCD appears in introductory (Toney et al., 2024), upper-level (Trachtman et al., 1999; Jordan & Lande, 2012), capstone (Leffers et al., 2008; Huff et al., 2011), and service-learning environments, showing its growing relevance across the curriculum. HCE is no longer peripheral; it is becoming a foundational approach across engineering education. In addition, as shown in the previous section HCE is being used to build new interdisciplinary programs and pathways. In other words, HCE is not just shaping courses, it is driving the creation of new majors and interdisciplinary structures. For example, a new interdisciplinary major (Product Design and Entrepreneurship) is developed through an iterative, stakeholder-informed process, aligning HCD, engineering, and entrepreneurship (Dziallas et al., 2025). A flexible, non-linear HCE curriculum uses mapping tools to ensure students still meet competency requirements (Parks et al., 2025). HCE is becoming a bridge between engineering concepts and Sustainable Development Goals, attracting non-engineering majors (Mueller et al., 2020). HCE is acting as a foundation for new academic structures that blend engineering with entrepreneurship, sustainability, and social impact. Furthermore, Human-centered design can be applied to educational systems, not just products. Several papers treat programs, pathways, and institutional structures as systems that can be designed and that should be shaped around stakeholder needs (Pawar & Smith, 2025; Strickland, 2025; Lande & Lalley, 2025), showing how HCE principles are increasingly used to redesign educational ecosystems, improving access, persistence, and equity.

4.3 Human-Centered Design Supports Broader Educational Goals, Including Identity Development and Professional Readiness

The content analysis of papers shows that HCE contributes to student motivation, retention, and professional formation. Students report strong engagement with business and value-proposition elements, though judges note gaps in realism—highlighting the need for integrated professional skills (Toney et al., 2024). Students feel more comfortable with HCE topics and report broadened worldviews (Trachtman et al., 1999). As noted across themes, service learning builds socially sensitive engineers prepared for modern practice (Titus et al., 2011), as HCE projects support real-world context, differentiated instruction, and lifelong learning skills (Huff et al., 2011). HCE enriches engineering education by connecting technical work to human impact, strengthening students' sense of purpose and professional identity. Furthermore, HCE frameworks support program-level coherence and competency development. Several papers used structured HCE frameworks to scaffold learning across courses, programs, and faculty development (Shell et al., 2024; Parks et al., 2024; Young-Brice et al., 2025). The findings suggest that HCE frameworks help institutions map competencies, track growth, and align learning experiences across multiple levels of the curriculum.

Conclusion and Future Work

Human-Centered Engineering is emerging as a discipline that blends technical rigor with empathy, ethics, and societal impact. The literature shows rapid growth in HCE programs, diverse pedagogical approaches, and increasing attention to power, justice, and authentic community engagement. Yet the field still faces challenges in defining its scope, developing assessment frameworks, and aligning with accreditation systems. Analyzing published work in ASEE conference proceedings reveals common themes and points to HCE being taken seriously across assessment, curriculum, research, and institutional design. Rather than appearing as a single pedagogy or framework, HCE shows up in many forms, shaped by context and audience. Together, these papers show how centering people, context, and impact can coexist with the technical expectations of engineering programs. Establishing HCE as a discipline requires clearer articulation of methods, deeper historical grounding, and more evidence on effectiveness. Establishing HCE as a discipline within the engineering education community will depend on building robust communities of practice that support shared learning, interdisciplinary collaboration, and theory-building. Together, these developments highlight significant potential to reshape engineering and instructional design toward more human-responsive, socially attuned practices.

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