

Belonging and Intercultural Competence as Pathways to Sustainability Learning in Engineering Education

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Abstract

Engineering education increasingly frames sustainability in terms of competencies such as systems thinking, ethical judgment, and collaboration. While these competencies are widely articulated, less attention has been paid to the relational conditions through which students come to enact them in practice. This paper examines how experiences of belonging and intercultural engagement shape pathways toward sustainability learning in undergraduate engineering education.

Drawing on an interpretivist qualitative analysis of student reflections, survey responses, and project narratives from sustainability-oriented engineering coursework, the study investigates how students make sense of sustainability-oriented work in sociotechnical contexts. Using reflexive thematic analysis, the paper focuses on students' descriptions of participation, ethical tension, and responsibility rather than on measures of competency attainment.

Findings identify three relational pathways through which sustainability learning was described: belonging as a condition for ethical and collaborative participation, intercultural friction as a catalyst for values-based reasoning, and relational accountability grounding sustainability practice in responsibility to others. Across these themes, sustainability competencies emerged not as discrete skills, but through participation in uncertain, value-laden decision-making shaped by social interaction and accountability.

By positioning belonging and intercultural engagement as pathways rather than outcomes, this study contributes to LEES conversations on sociotechnical integration and sustainability education. The findings highlight how sustainability learning in engineering is mediated through relational conditions that enable participation and sustain meaningful engagement.

1. Introduction

Sustainability has become a familiar term in engineering education, often accompanied by lists of competencies meant to prepare students for complex sociotechnical challenges. Systems thinking, ethical reasoning, collaboration, and integrated problem solving appear regularly across sustainability frameworks and curricular guidance [1], [2]. In response, engineering programs have expanded project-based learning, community engagement, and design experiences that situate technical work within broader social and environmental contexts.

What remains less clear is how students actually experience sustainability learning in these settings. Much of the existing work emphasizes curricular alignment or the presence of sustainability-related content, with less attention to the conditions under which students engage

in ethical reasoning and navigate value-laden decisions under constraint. In practice, sustainability-oriented engineering work often involves uncertainty, disagreement, and tradeoffs that cannot be resolved through technical reasoning alone [3]. Whether students participate fully in these moments depends on more than instructional design.

The premise of this paper is that sustainability learning is not only a cognitive or curricular matter, but a relational one, shaped by whether students feel able to participate, question, and remain engaged when engineering work becomes ethically or socially complex. Yet relational and affective dimensions of learning are often treated as peripheral outcomes rather than as integral to sustainability learning itself.

This study explores how students describe experiences of belonging and intercultural engagement within sustainability-oriented engineering coursework, and how these experiences shape ethical reasoning, collaboration, and values-based judgment. Rather than evaluating whether students attained specific competencies, the analysis focuses on how students made sense of sustainability-oriented work as they encountered difference, uncertainty, and responsibility. Belonging and intercultural competence are treated not as endpoints, but as pathways through which sustainability competencies became meaningful in practice.

This work is situated within the Liberal Education/Engineering & Society (LEES) tradition, which has long emphasized the inseparability of technical work from social values, power, and responsibility. By foregrounding student experience, this paper contributes an interpretive account of sustainability learning that highlights participation, accountability, and sociotechnical engagement rather than skill acquisition alone.

2. Study Purpose and Research Questions

The purpose of this study is to understand how students' experiences of belonging and intercultural engagement shape their pathways toward sustainability learning in engineering education.

Three research questions guide the analysis:

- How do students describe experiences of belonging within sustainability-oriented engineering coursework?
- How do students interpret intercultural engagement and cultural difference in relation to sustainability-oriented decision-making?
- How do these relational experiences shape students' ethical reasoning, collaboration, and sense of responsibility in sustainability practice?

These questions are intentionally interpretive. The goal is not to assess effectiveness or measure learning outcomes, but to examine how students understand and articulate their learning as it unfolds in sociotechnical contexts.

3. Conceptual Framing

This study sits at the intersection of sustainability education, engineering learning, and relational theories of student development. Rather than treating sustainability competencies as discrete outcomes, this work approaches them as capacities that emerge through participation in complex, value-laden learning environments.

3.1 Sustainability Competencies as Lived, Sociotechnical Capacities

Traditional engineering curricula have long prioritized technical skills and content mastery, often at the exclusion of social, political, and cultural contexts. This narrow view has been increasingly challenged by researchers' advocating for a sociotechnical perspective which recognizes that engineering solutions are never value-neutral [4], [5]. Godfrey and Parker [6] critique the dominant engineering model that rewards depersonalized rationality and marginalization of social and justice-oriented dimensions of engineering practice. Some engineering programs, such as humanitarian or global engineering, offer broader curricular spaces where students can explore engineering as a relational practice shaped by social, political, and cultural dimensions.

Sustainability competency frameworks consistently emphasize capacities such as systems thinking, anticipatory reasoning, ethical judgment, collaboration, and integrated problem solving [1], [2]. These competencies reflect the sociotechnical nature of sustainability challenges, in which engineering decisions are embedded in social relationships, institutional constraints, and contested values. Many of these competencies are inherently relational. Ethical reasoning, collaboration, and values-based judgment require interaction with others and engagement with difference and cannot be reduced to individual cognition or content mastery. Sustainability learning therefore depends not only on what students are taught, but on whether learning environments enable participation in uncertainty, disagreement, and shared responsibility. This framing shifts attention away from competency attainment and toward the conditions under which sustainability-oriented reasoning becomes possible.

3.2 Intercultural Engagement in Sustainability-Oriented Engineering

Intercultural competence has received increasing attention in engineering education, particularly in global and community-engaged contexts [7], [8], [9]. It is often framed as preparation for professional work across cultures. While that framing is useful, it does not fully capture how intercultural engagement operates within sustainability-oriented learning.

Sustainability challenges frequently involve navigating cultural norms, power relations, and competing priorities [3]. In these contexts, intercultural engagement can surface ethical tensions

and destabilize assumptions embedded in technical problem framing. Rather than treating intercultural competence as a transferable skill, this study approaches it as a relational learning process shaped by moments of friction, uncertainty, and negotiation.

3.3 Sense of Belonging as a Condition for Participation

Sense of belonging is typically defined as feeling accepted, valued, and legitimate within a learning environment [10], [11]. When students feel seen and valued, they are more likely to take ownership over their learning. In engineering education research, belonging has been strongly linked to participation, identity development, and persistence [11], [12], [13], [14]. This perception is often shaped by cultural norms that favor technical knowledge and competitiveness [15]. Recent work suggests that belonging in engineering is deeply connected with curricular design, institutional norms, and pedagogical practices. Polmear et al. [16] found that peer and faculty interactions, especially those grounded in empathy and responsiveness, significantly affect student sense of belonging. Less often is belonging examined as a condition for engaging in complex learning processes.

From a sociotechnical perspective, belonging matters because sustainability-oriented work often requires students to engage with ambiguity and disagreement. Whether students feel able to speak, challenge ideas, or remain engaged when decisions become uncomfortable is shaped by their sense of legitimacy within a group. In this study, belonging is treated as situational and relational rather than as a stable individual attribute. Thus, belonging and intercultural engagement are positioned as pathways that shape how sustainability competencies are enacted and understood by students.

4. Research Context

The study is situated within undergraduate sustainability-oriented engineering coursework at a large public research university, wherein students worked with open-ended problems that required negotiating technical constraints alongside stakeholder needs, cultural considerations, and ethical tradeoffs. Structured reflection was incorporated alongside technical work, providing space for students to examine assumptions, team dynamics, and responsibility to others.

Enrollment spans multiple disciplines and academic stages, with students bringing varied motivations and prior experiences. Students participate in both sustained project teams and short-lived collaborative groupings, shaping diverse experiences of interaction, recognition, and belonging.

5. Methodology

5.1 Epistemological Stance

This study adopts an interpretivist epistemological stance, viewing students' experiences of belonging, intercultural engagement, and sustainability learning as socially constructed and shaped through context and interaction rather than as fixed or objectively measurable phenomena [17]. Knowledge is understood as partial and relational, produced through participants' sense-making and researcher interpretation [18]. This orientation aligns with the study's interest in how students make meaning of uncertainty and responsibility within sociotechnical contexts. Student narratives and other artifacts are therefore approached not as indicators of competency attainment, but as situated accounts through which participants interpret their learning. Consistent with interpretivist inquiry and reflexive thematic analysis, meaning is treated as co-constructed, and the analysis seeks not universal claims but an analytically grounded understanding of how relational conditions shape sustainability-oriented learning.

5.2 Data Sources

Participants were undergraduate engineering students enrolled across five courses offered over three academic years, comprising 24 course sections with enrollments ranging from approximately 15 to 45 students. These courses represented four course types, including a travel-based experiential course, a sustainability-themed general education course, an associated experiential application course, and a technical elective focused on water systems. Enrollment was not restricted to a single program or specialization and included students from multiple disciplines who enrolled for general education, technical elective, or study abroad purposes. Participants spanned all academic years, with approximately 50% of enrollees in their second or third year.

All assignment prompts were first reviewed and screened for relevance to the study focus, resulting in 37 prompts identified as analyzable for this paper. Prompts were considered analyzable when they elicited student reflection on participation, interaction, or decision-making under conditions of uncertainty, rather than focusing solely on technical calculation or procedural tasks. From these prompts, a corpus of 230 student artifacts was included in first-cycle analysis. These artifacts consisted primarily of short individual written reflections and group-based project narratives that explicitly engaged belonging, intercultural interaction, ethical reasoning, or sustainability-oriented decision-making. Reflections were typically brief written responses completed multiple times across a course, while project narratives documented team-based design decisions, constraints, stakeholder considerations, and tradeoffs.

Following this initial review, a smaller subset of interaction-rich artifacts was selected for second-cycle analysis based on the presence of explicit participation dynamics, intercultural friction, or articulated sustainability reasoning. Interaction-rich moments were defined as

instances where students described active negotiation of ideas, disagreement, responsibility, or cultural difference during collaborative work. Additional course materials were screened but excluded when they focused solely on technical calculation or procedural tasks without engagement in relational or ethical dimensions of engineering work.

All materials analyzed were produced as routine components of coursework rather than solely for research purposes. This study was reviewed and determined to be exempt under Category 4 by The Ohio State University Institutional Review Board.

5.3 Analytic Approach

Data were analyzed using reflexive thematic analysis [19], [20]. Analysis was iterative and interpretive. We began with repeated readings of the dataset to develop familiarity, followed by inductive coding focused on moments where students described belonging, interpersonal dynamics, cultural difference, ethical reasoning, or values-based judgment.

After initial patterns were identified during first-cycle analysis of 230 artifacts drawn from ten assignments, 179 artifacts were selected for focused second-cycle analysis based on the presence of explicit participation dynamics, intercultural tension, or articulated reasoning about responsibility. Exemplar quotes were then selected from this subset where these dynamics were clearly expressed within interaction-rich moments.

Codes were refined across analytic cycles and grouped into broader patterns of meaning. Theme development prioritized coherence and interpretive usefulness rather than frequency or consensus. Variation and unresolved tension were retained as analytically meaningful rather than treated as anomalies. Consistent with a reflexive approach, themes are presented as analytic constructions grounded in sustained engagement with student materials rather than as exhaustive or definitive representations.

6. Findings

This analysis identifies three relational pathways through which students described developing sustainability-related competencies within engineering coursework. Students often framed sustainability learning not as the acquisition of technical knowledge alone, but as a process shaped by participation, relational engagement, and responsibility to others as they navigated uncertainty and difference. The findings are organized around three themes that capture these processes of meaning-making:

- Belonging as a Precondition for Ethical and Collaborative Engagement
- Intercultural Friction as a Catalyst for Values-Based Reasoning
- Relational Accountability and Sustainability Practice.

6.1 Belonging as a Precondition for Ethical and Collaborative Engagement

Students described belonging as shaping whether and how they engaged in sustainability-oriented engineering work. It was not presented as the outcome of effective collaboration, but as a condition that made meaningful participation possible. When students felt recognized as legitimate contributors, they were more inclined to question assumptions, voice uncertainty, and remain present in collective decision-making, especially when disagreement or ambiguity emerged.

At the same time, participation was not evenly available. One reflection noted, “Not being able to talk about our pictures meant that the pictures we could not understand were not used. This excluded some of the people from the process because all of their drawings were confusing to us.” In this instance, exclusion did not stem from interpersonal conflict but from communicative constraints that determined whose ideas could enter deliberation. Participation depended not only on contribution, but on intelligibility within the group’s norms. Belonging, therefore, was tied to legitimacy and access rather than comfort alone.

Students often linked their willingness to remain engaged to how they navigated ethical or value tensions. Perceived risk and uncertainty shaped whether students intervened, with participation often delayed or suppressed under conditions of ambiguity or constraint. As one student reflected, “Working silently made it hard to communicate ideas effectively, so if someone had a better idea, it was hard for them to voice their opinion.”

When students engaged, they were more likely to surface tradeoffs and consider responsibility beyond technical correctness. Belonging also shaped how students framed accountability. Those who described stronger peer connections emphasized shared responsibility for decisions and outcomes. Design choices were justified through reference to collective agreement, mutual obligation, and attentiveness to others’ perspectives rather than individual optimization. Harmony was not a prerequisite. Several students described belonging emerging through sustained disagreement, suggesting that being taken seriously mattered more than interpersonal ease.

Students further observed how informal positioning influenced whose voices carried weight. One reflection stated, “I definitely think that the people who stepped up first and were closer to the board took charge and influenced the initial decisions.” Authority here arose from proximity and timing rather than formal designation. Access to shared artifacts shaped the direction of collective reasoning. In this sense, belonging involved access to decision-making processes, not simply inclusion within the group. These accounts show that belonging shaped access to participation, influence, and responsibility. It functioned as a condition for ethical engagement rather than as a secondary outcome of teamwork.

6.2 Intercultural Friction as a Catalyst for Values-Based Reasoning

In this study, intercultural friction refers not only to cross-national or demographic difference, but to moments when differing norms, value frameworks, professional logics, or role-based expectations became visible in interaction. These differences may arise within classrooms and design teams, as well as in institutional or community contexts. Students described such moments as consequential for how they understood sustainability-oriented decision-making.

Students frequently framed intercultural engagement through tension or misalignment rather than seamless collaboration. One reflection explicitly acknowledged “the role of western partners and the power dynamics at play,” signaling recognition that engineering work was embedded in asymmetrical relational structures rather than neutral technical exchange. In this moment, intercultural friction surfaced the positional dimensions of engagement.

Across reflections and project narratives, students described encountering differing expectations and priorities that disrupted purely technical reasoning. As one student noted, “Some of us thought of those who would use the utilities, while others thought of the utility client itself.” These moments surfaced differences in how responsibility and appropriate action were understood, requiring students to interpret competing perspectives rather than resolve them outright.

Importantly, students did not consistently describe these tensions as fully resolved. Several emphasized ongoing uncertainty, particularly in situations where cultural difference or institutional hierarchy could not be reconciled neatly. Learning was often articulated as proceeding with caution and attentiveness rather than confidence in technical authority. Intercultural engagement thus functioned less as a transferable skill and more as a catalyst that surfaced values, power relations, and ethical judgment central to sustainability practice.

6.3 Relational Accountability and Sustainability Practice

Students described sustainability learning as grounded in responsibility to others rather than in abstract principle alone. As one student reflected, “Compatibility with community and adoption of the design/technology was consistently brought up as our responsibility... if the community is not receptive and eventually abandons the technology, then the design is a failure.” Sustainability-oriented decision-making was framed as answerability to peers, communities, and project partners.

Accountability emerged through relationships and shaped how students approached uncertainty and ethical judgment. In one team discussion, students debated who their design was truly accountable to. As one reflection noted, “people didn’t all agree on who the design was really accountable to,” with some emphasizing regulatory compliance and others prioritizing “the operators and the people using the water.” Through deliberation, the group shifted toward

centering those who would bear the consequences of the system's performance. Here, sustainability was not simply a matter of meeting standards but of negotiating responsibility in context.

Reflections frequently justified design decisions in relational terms, emphasizing anticipated impact and responsiveness rather than technical optimization alone. Students articulated sustainability as something they were answerable for. This framing influenced how they evaluated imperfect solutions, particularly when tradeoffs carried social consequences.

Students also emphasized that relational accountability complicated practice rather than simplifying it. One reflection described the weight of decision-making under uncertainty, noting that "even if we thought our solution was technically sound, it still felt heavy knowing other people would live with the consequences." Responsibility to others made tradeoffs more visible and more difficult to resolve. Accountability was closely tied to collaborative practice. Sustained teamwork shaped expectations around follow-through and ethical conduct, while even brief collaborative exchanges influenced how decisions were justified. Sustainability, in these accounts, was described as an ongoing practice of attentiveness and care rather than the application of predefined solutions.

7. Discussion

This study examined how students described belonging and intercultural engagement within sustainability-oriented engineering coursework, and how these relational experiences shaped ethical reasoning, collaboration, and values-based judgment in sustainability practice. Taken together, the findings respond to the study's guiding questions by showing that belonging shaped students' participation in sustainability-oriented reasoning, intercultural engagement often surfaced tensions embedded in design practice, and relational accountability grounded students' understanding of responsibility to others. Viewed collectively, these themes suggest that belonging and intercultural engagement operated not as ancillary outcomes of engineering education, but as relational pathways through which sustainability learning became meaningful in practice. These relational processes shaped how students interpreted responsibility, negotiated tradeoffs, and made decisions under conditions characteristic of sustainability challenges.

7.1 Relational Pathways to Sustainability Competencies

Sustainability competency frameworks commonly emphasize capacities such as systems thinking, normative reasoning, collaboration, and integrated problem solving [1], [2]. Much of the engineering education literature has focused on defining these competencies or aligning pedagogical structures to support their development. Less attention has been paid to the relational conditions under which these competencies are enacted by students.

The findings suggest that sustainability competencies developed through relational pathways rather than through isolated skill acquisition. Belonging shaped students' willingness to participate and engage in ethical deliberation, intercultural engagement surfaced values and power relations, and relational accountability grounded sustainability reasoning in responsibility to others. These processes align with sociotechnical perspectives that treat engineering practice as inseparable from social interaction, negotiation, and context [3], [21].

Viewed through this lens, competencies such as collaboration and normative reasoning are not merely cognitive capacities, but practices that emerge through participation in sociotechnical learning environments. This framing complements existing sustainability competency models by shifting analytic attention from what competencies are to how they develop in practice.

The findings also suggest that these relational processes are shaped by dynamics of influence and access. Participation was not evenly distributed, nor was authority neutral. Students' reflections illustrated how communicative norms, spatial positioning, institutional hierarchies, and global partnership structures shaped whose ideas entered deliberation and whose perspectives carried weight. Sustainability reasoning unfolded within these conditions rather than outside them. Recognizing this does not reposition sustainability education as primarily a critique of power, but clarifies that relational learning environments are structured by patterns of influence that shape ethical engagement and decision-making.

7.2 Belonging as a Condition for Sociotechnical Participation

Research on sense of belonging in engineering education has consistently linked belonging to persistence, identity development, and participation, particularly for students from historically marginalized groups [14]. In this literature, belonging is often treated as a psychosocial outcome or contextual support rather than as a learning mechanism.

The findings here extend this work by positioning belonging as a condition for sustainability learning itself. Students described belonging as enabling participation in uncertainty, disagreement, and ethical reasoning. Feeling legitimate within a group supported engagement with value-laden decision-making and collaborative sense-making, both of which are central to sustainability-oriented engineering practice.

Importantly, belonging was not contingent on comfort or consensus. Students described belonging emerging through being regarded seriously, even amid disagreement or tension. This suggests that belonging in sociotechnical learning environments may be situational and relational rather than stable or affective alone. Such moments of recognition appear to shape whether students engage fully with sustainability-related reasoning or withdraw from participation.

7.3 Intercultural Engagement and Ethical Reasoning

Intercultural competence is often framed in engineering education as preparation for global work or professional effectiveness across cultures [7], [8]. While valuable, this framing can position intercultural learning as adjacent to core technical or sustainability learning.

In contrast, the findings indicate that intercultural engagement functioned as a catalyst for sustainability-oriented reasoning. Students described moments of cultural friction that disrupted assumptions and rendered technical solutions insufficient. These encounters prompted explicit engagement with values, power, and responsibility, aligning with scholarship that emphasizes sustainability as inherently normative and context-dependent [22], [23].

Rather than resolving uncertainty, students often described learning to remain attentive, cautious, and humble in the face of difference. This aligns with sociotechnical approaches that emphasize engineering judgment under conditions of ambiguity rather than technical certainty [3]. Intercultural engagement, in this sense, was not a transferable skill layered onto sustainability learning, but a relational process through which ethical reasoning was activated.

7.4 Relational Accountability and Sustainability Practice

A notable contribution of this study is the articulation of relational accountability as a dimension of sustainability learning. Students framed sustainability not as adherence to abstract principles, but as responsibility to people affected by engineering decisions. This aligns with calls in LEES scholarship to foreground accountability, public values, and ethical responsibility in engineering education [23], [24].

Relational accountability complicated sustainability practice rather than simplifying it. Students described heightened awareness of tradeoffs, uncertainty, and the limits of technical authority when decisions carried social consequences. This framing positions sustainability competencies as ongoing practices of care and attentiveness rather than as discrete achievements.

The findings suggest that sustainability learning in engineering education is shaped by relational conditions that enable participation, surface values, and ground responsibility. Belonging, intercultural engagement, and accountability operate as sociotechnical mechanisms through which sustainability competencies become meaningful in practice.

8. Conclusion

This study examined how students described experiences of belonging and intercultural engagement within sustainability-oriented engineering coursework, and how these relational experiences shaped ethical reasoning, collaboration, and responsibility in practice. Rather than treating sustainability competencies as outcomes achieved through technical instruction alone,

the analysis foregrounded the relational conditions under which such competencies became meaningful.

Across the analysis, sustainability learning emerged through participation, friction, and negotiated responsibility rather than through discrete skill acquisition. These relational pathways illuminate how competencies such as collaboration and normative reasoning take form within sociotechnical engagement rather than apart from it.

8.1 Implications for Engineering Education and Sustainability Pedagogy

The findings contribute to ongoing LEES conversations on sociotechnical integration by demonstrating how sustainability learning is mediated through relational conditions. Sustainability competency frameworks commonly emphasize capacities such as collaboration, normative reasoning, and ethical judgment [1], [2], yet these capacities are often discussed as cognitive or curricular targets. This study shows how such competencies are enacted through participation, interaction, and accountability rather than acquired as discrete skills.

For engineering education, this suggests that attention to belonging and intercultural engagement is not ancillary to sustainability learning. These dimensions shape whether students engage in uncertainty, participate in ethical deliberation, and remain accountable in complex decision-making. Pedagogical structures that create space for recognition and relational responsibility may therefore play a central role in supporting sustainability-oriented practice, even when sustainability is not explicitly foregrounded. This may include structured reflection prompts, facilitation strategies that redistribute voice, and design activities that explicitly surface competing accountability frameworks.

Within sustainability pedagogy, the findings highlight the value of examining learning processes rather than only outcomes. Intercultural engagement functioned as a catalyst for values-based reasoning, making visible the normative and contextual dimensions of engineering work [22], [23]. Belonging influenced participation in these processes, suggesting that sociotechnical learning depends on relational legitimacy as much as on instructional design.

8.2 Limitations and Positioning

The claims advanced here are interpretive and situated. The analysis draws on student reflections, survey responses, and project narratives from sustainability-oriented engineering coursework within a single institutional context. These data capture students' meaning-making rather than direct measures of competency attainment. The study does not claim generalizability or assess learning effectiveness.

Consistent with an interpretivist stance, themes are treated as analytic constructions developed through sustained engagement with the data rather than as objective features awaiting discovery

[20]. The analysis prioritizes coherence and interpretive plausibility over saturation or consensus. Variation and unresolved tension are retained as analytically informative.

8.3 Closing

By positioning belonging and intercultural competence as pathways rather than outcomes, this study advances a relational account of sustainability learning in engineering education. It responds to LEES calls to dissolve artificial boundaries between the social and the technical by showing how ethical reasoning, collaboration, and responsibility emerge through lived participation. This framing offers a grounded contribution to understanding how sustainability competencies become meaningful to students, while leaving open important questions for future work on pedagogy, assessment, and institutional design.

References

- [1] K. Brundiers *et al.*, “Key competencies in sustainability in higher education—toward an agreed-upon reference framework,” *Sustain. Sci.*, vol. 16, no. 1, pp. 13–29, 2021.
- [2] A. Wiek, L. Withycombe, and C. L. Redman, “Key competencies in sustainability: a reference framework for academic program development,” *Sustain. Sci.*, vol. 6, pp. 203–218, 2011, doi: 10.1007/s11625-011-0132-6.
- [3] D. Nieuwsma and D. Riley, “Designs on development: engineering, globalization, and social justice,” *Eng. Stud.*, vol. 2, no. 1, pp. 29–59, 2010.
- [4] W. Faulkner, “Nuts and Bolts and People’ Gender-Troubled Engineering Identities,” *Soc. Stud. Sci.*, vol. 37, no. 3, pp. 331–356, 2007.
- [5] J. A. Leydens and J. C. Lucena, *Engineering justice: Transforming engineering education and practice*. John Wiley & Sons, 2017.
- [6] E. Godfrey and L. Parker, “Mapping the cultural landscape in engineering education,” *J. Eng. Educ.*, vol. 99, no. 1, pp. 5–22, 2010.
- [7] K. A. Davis and D. B. Knight, “Exploring how personal and program characteristics inform engineering students’ IC development,” *J. Eng. Educ.*, vol. 114, no. 3, 2025, doi: 10.1002/jee.20625.
- [8] D. K. Deardorff, “Identification and assessment of intercultural competence,” *J. Stud. Int. Educ.*, vol. 10, no. 3, pp. 241–266, 2006, doi: 10.1177/1028315306287002.
- [9] T. D. Drayton, C. Vance, and A. D. Christy, “Belonging and Intercultural Growth in A Humanitarian Engineering Makerspace,” in *9th International Symposium on Academic Makerspaces (ISAM)*, 2025, p. Paper No. 101.
- [10] J. Lynch-Sauer, K. L. Patusky, M. Bouwsema, and P. Collier, “Sense of belonging: a vital mental health concept,” *Arch. Psychiatr. Nurs.*, vol. 6, no. 3, pp. 172–177, 1992, doi: 10.1016/0883-9417(92)90028-H.
- [11] T. L. Strayhorn, *College students’ sense of belonging: A key to educational success for all students*. Routledge, 2018.
- [12] A. Patrick, C. Riegle-Crumb, M. R. Kendall, J. Bachman, and V. Subbian, “Sense of belonging in engineering and identity centrality among undergraduates at HSIs,” *J. Eng. Educ.*, vol. 112, no. 4, pp. 735–739, 2023, doi: 10.1002/jee.20510.
- [13] A. M. Rainey, J. M. Smith, and D. Verdin, “Classroom practices that support minoritized engineering students’ sense of belonging,” in *ASEE virtual annual conference content*

access, 2021.

- [14] Verdín, Dina, “The power of interest: Minoritized women’s interest & identity foster belonging and persistence in engineering,” *Int. J. STEM Educ.*, vol. 8, p. 76, 2021, doi: 10.1186/s40594-021-00292-1.
- [15] K. L. Tonso, *On the outskirts of engineering: Learning identity, gender, and power via engineering practice*, vol. 6. Brill, 2007.
- [16] M. Polmear, “Engineering Identity Development Among International Students in UK Foundation Year,” in *ASEE Annual Conference & Exposition*, 2024.
- [17] S. R. Jones, V. Torres, and J. Arminio, *Negotiating the complexities of qualitative research in higher education: Fundamental elements and issues*. Routledge, 2013.
- [18] J. W. Creswell and C. N. Poth, *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications, 2016.
- [19] V. Braun and V. Clarke, “Using thematic analysis in psychology,” *Qual. Res. Psychol.*, vol. 3, no. 2, pp. 77–101, 2006.
- [20] V. Braun and V. Clarke, “One size fits all? What counts as quality practice in (reflexive) thematic analysis?,” *Qual. Res. Psychol.*, vol. 18, no. 3, pp. 328–352, 2021.
- [21] E. A. Reddy, M. S. Kleine, M. Parsons, and D. Nieuwsma, “Sociotechnical integration: what is it? Why do We need it? How do We do it?,” in *ASEE Annual Conference & Exposition*, 2023.
- [22] R. Lozano, M. Y. Merrill, K. Sammalisto, K. Ceulemans, and F. J. Lozano, “Connecting competences and pedagogical approaches for sustainable development in higher education: A literature review and framework proposal,” *Sustainability*, vol. 9, no. 10, p. 1889, 2017.
- [23] A. Pawley, “Opinion: Asking questions, we walk: How should engineering education address equity, the climate crisis, and its own moral infrastructure,” *Adv. Eng. Educ.*, vol. 25, p. 450, 2019.
- [24] A. E. Slaton and S. Vakil, “Engineering Education in Times of War, Upheaval, and Revolution,” in *ASEE Annual Conference & Exposition*, 2024.