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Reclaiming Space: Fostering Inclusivity for Women in Engineering Fields

Shaundra Bryant Daily, Duke University

Shaundra B. Daily is the Cue Family Professor of the Practice in Electrical and Computer Engineering at Duke University. Prior to joining Duke, she was an associate professor with tenure at the University of Florida in the Department of Computer & Information Science & Engineering. She also served as an associate professor and interim co-chair in the School of Computing at Clemson University. Her research focuses on the design, implementation, and evaluation of technologies, programs, and curricula to support diversity, equity, and inclusion in STEM fields. Currently, through this work, she is the Backbone Director for the Alliance for Identity-Inclusive Computing Education as well as Education and Workforce Director for the Athena AI Institute. Having garnered over $40M in funding from public and private sources to support her collaborative research activities, Daily's work has been featured in USA Today, Forbes, National Public Radio, and the Chicago Tribune. Daily earned her B.S. and M.S. in Electrical Engineering from the Florida Agricultural and Mechanical University – Florida State University College of Engineering, and an S.M. and Ph.D. from the MIT Media Lab.

Dr. Jessica Sperling

Dr. Sperling leads the Applied Research, Evaluation, & Engagement area of Duke University's Social Science Research Institute.

Dr. Yerika A Jimenez, Duke University

Dr. Yerika Jimenez is a postdoctoral researcher at Duke University working with the Alliance for Identity-Inclusive Computing Education (AiiCE). Her current research focuses on two primary areas: 1) understanding how to facilitate difficult conversations about diversity, inclusion, and equity (DEI) in computing and 2) understanding how upper elementary students (4th and 5th grades) learn how to debug in block-based programming environments. Specifically, she studies their debugging behaviors, challenges, skills, and ability to articulate their debugging process. She earned her Bachelor's degree in Computer Science at Kean University in 2014 and her Ph.D. in Human-Centered Computing at the University of Florida in 2023. Beyond her research, Dr. Jimenez is dedicated to promoting diversity, inclusion, equity, and mentoring students, especially first-generation college students.

Ms. Amy Arnold

Amy Arnold has been with the Duke Technology Scholars Program since 2017, and currently serves as Executive Director. Before coming to Duke, Amy did management consulting with McKinsey & Company, led a technical product marketing team at Hewlett Pack

Kelly Perri, Duke University

Kelly Perri is a program manager for DTech, the Duke Technology Scholars Program. With 20 years of experience in talent acquisition, technical recruiting, campus relations and project management in the tech sector, she helps students majoring in STEM fiel

Victoria Lee, Duke University
Erin Haseley, Duke University

Work-in-Progress: Reclaiming Space, Fostering Inclusivity for Women in Engineering Fields

Introduction

Engineering's capacity to address society's most urgent challenges depends on fostering learning environments that support and empower diverse perspectives, experiences, and ways of knowing. While the field has long acknowledged the need for greater diversity, traditional approaches focused primarily on increasing numerical representation have proven insufficient for creating lasting change. Instead, meaningful transformation requires fundamentally reconceptualizing how engineering education spaces are structured and how knowledge is created, validated, and shared. This reconceptualization becomes particularly urgent as engineering confronts complex socio-technical challenges that demand innovative solutions drawn from diverse lived experiences and ways of understanding the world.

Despite decades of initiatives, engineering education struggles to create environments that support all students through degree completion. Recent data from the National Center for Education Statistics reveals a stark disparity: while women comprised 29.47% of undergraduate engineering students in 2023, they represent only 17.2% of the professional engineering workforce [1]. This gap points to persistent barriers far beyond initial recruitment, including isolation, stereotype threat, and what researchers have termed the "chilly climate" of engineering classrooms. These challenges are amplified for women from historically marginalized racial and ethnic backgrounds, who must navigate multiple intersecting systems of exclusion [2].

This work-in-progress study examines how successful support programs foster inclusion and belonging. Through focus groups and interviews with participants in a technology program serving over 400 women, we investigate the specific components that characterize inclusive environments and how these elements challenge traditional power structures while creating spaces where diverse approaches to engineering knowledge and practice can flourish. Our preliminary findings reveal four essential, interrelated components that characterize inclusive environments: being actively invited in, being genuinely welcomed, having people to relate to, and being able to share one's whole self. The findings suggest that surface-level initiatives focused solely on recruitment or representation may be insufficient without deeper attention to how power dynamics, cultural norms, and institutional structures shape students' experiences within engineering spaces.

Literature Review

Research on inclusion in engineering education has historically focused on increasing the numerical representation of underrepresented groups, particularly women and racial/ethnic minorities [3]. The Yale Center for Teaching and Learning established a foundational conceptualization of inclusive learning environments as spaces where every student feels intellectually and academically supported regardless of identity, learning preferences, or educational background [4]. Building on this foundation, Hockings [5] defines inclusive teaching and learning as approaches that make education "meaningful, relevant and accessible to all" while embracing individual differences not as challenges to be overcome but as sources of enrichment for the broader learning community.

However, feminist scholars in engineering education argue that creating inclusive environments requires more than simply increasing numerical representation [3]. While demographic diversity is important, this approach fails to address deeper structural barriers and power dynamics that create hostile environments for marginalized students. Recent work by Rankin et al. [6], [7], [8], [9] reveals how traditional engineering classrooms can become "saturated sites of violence" where multiple forms of oppression converge to create hostile environments, particularly for Black women. These sites include traditional classrooms, predominantly white institutions, and professional spaces like internships - all contexts where seemingly neutral educational practices can perpetuate exclusion through interconnected systems of power.

Riley et al. [2] propose an "ethic of care" framework that emphasizes relationship, responsibility, and attention to power dynamics in engineering education. This approach suggests that inclusive environments must go beyond technical competence to foster caring relationships and acknowledge the full humanity of all participants. Such environments recognize that technical excellence and social justice are not competing priorities but mutually reinforcing goals. Intersectional approaches reveal how multiple forms of marginalization - including gender, race, class, and other identities - shape students' engineering education experiences [7][10]. This theoretical framework suggests that effective inclusion requires addressing systemic barriers while valuing diverse ways of knowing and learning. Traditional approaches that treat "women" or "minorities" as homogeneous groups fail to capture how different aspects of identity intersect to create unique experiences and challenges.

Moore et al. [11] apply self-determination theory to demonstrate how inclusive environments must meet students' needs for belonging and authenticity - allowing them to feel part of the community while maintaining their unique characteristics. This theoretical grounding helps explain why surface-level diversity initiatives often fail to create lasting change. Meanwhile, Friedensen et al. [12] argue for a fundamental reconceptualization of how engineering knowledge is created and validated, suggesting that true inclusion requires challenging traditionally exclusionary epistemological frameworks.

Armstrong [13] presents a comprehensive view of the institutional changes required for meaningful transformation. These changes span multiple domains including admission and enrollment processes, retention strategies, financial assistance, leadership and governance structures, academic curriculum design, teaching methods, and research priorities. The breadth of these considerations suggests that creating inclusive environments requires system-wide transformation rather than isolated interventions. Faculty development emerges as a crucial component of this transformation, with Dewsbury [14] arguing for comprehensive changes to how STEM educators are prepared. Their work emphasizes the need to develop pedagogical competencies and sociocultural awareness, suggesting current faculty preparation may inadequately address the complexities of creating inclusive learning environments.

These strategies are significant in engineering classrooms, where traditional pedagogical approaches sometimes conflict with inclusive practices. As Killpack and Melón [15] emphasize, fostering inclusive excellence in STEM requires explicit recognition of privileges and inequities associated with various social identities, particularly the privilege gaps between different student groups and between students and instructors. While much progress has been made in understanding inclusion in engineering education, significant gaps remain. Current literature reveals the complexity of creating inclusive engineering education environments and the necessity of addressing multiple levels of change - from classroom practices to institutional policies to foundational assumptions about engineering knowledge. This research builds on these insights by examining how successful programs operationalize these principles to create authentically inclusive environments while acknowledging and addressing systemic barriers and power dynamics that impede inclusion.

Methodology

Driving Question and Design

This study addressed the following question: "What factors comprise or enable an inclusive environment, and how can engineering education foster authentically inclusive learning environments?" It used a qualitative approach, specifically a focus group and interview-based design.

Respondents & Data Collection

Data was collected through focus groups and interviews. Participants were recruited from the Duke Technology Scholars Program (DTech), launched in 2016 [16]. This program is designed to support undergraduate women majoring in computer science and electrical/computer engineering through multiple integrated summer and academic-year components. The program provides paid summer internships at tech companies across the United States and shared housing arrangements that create peer living-learning communities. Throughout the year, students receive individualized coaching from program staff who assist with everything from interview preparation to professional development, and guidance from industry mentors. The program also includes networking events, company visits, and professional development activities, including a "DTech Circles" program where students share weekly reflections with their peers. These students were selected to address this driving question as this program was designed to foster an inclusive environment, allowing participants to reflect on this experience in addition to their experience in their university and academic departments.

Recruitment occurred through program newsletters, targeted outreach to DTech students from minoritized groups, and general recruitment emails to all DTech members. Nine students participated in focus groups and interviews, representing a range of academic years (33% sophomores, 33% juniors, 33% seniors) and racial/ethnic backgrounds (33% Black or African American, 33% Asian or Asian American, 11% White, 22% did not disclose). Data was collected via two focus groups and one individual interview, with the individual interview occurring when only one participant attended a scheduled focus group session. Sample questions utilized in data collection events included: What makes an environment feel inclusive? [follow-on: Overall? Within computer science and engineering environments specifically?]; Tell us about a time when you felt included (at Duke, at DTech, etc). [follow-on: What do you think enabled this feeling of inclusivity?] Within a group or setting, who do you think is responsible for creating an inclusive environment? [follow-on: why?]; Do you feel you know how to create an inclusive environment?

[follow-on: What skills are necessary for this? Do you feel you have these skills, or do you feel you are gaining these skills? How?] All sessions were conducted via Zoom and recorded, with focus groups having both a facilitator and notetaker present. Sessions were transcribed using Zoom's automatic transcription feature.

Data Analysis

Qualitative data was analyzed using thematic analysis. In particular, the team utilized rapid qualitative analysis processes to examine data and, via an inductive thematic approach [17], examined how inclusivity was understood, how respondents discussed inclusivity as enabled across varied settings, and reasonings for why and when inclusive environments were valued. This resulted in the initial identification of four key components to inclusive experience, which was validated via member checking [18], where the initial inclusivity framework was sent to all focus group participants for feedback and to affirm whether they viewed the model as reflecting experience and perspectives shared. Seven participants responded, with six indicating no suggested adjustments and one offering a suggestion that was incorporated into the final framework. The combined analysis revealed four key components that characterize inclusive environments in engineering education: being "invited in," being "welcomed in," having people to relate to, and being able to share one's whole self. These findings provide an empirically grounded framework for understanding and implementing inclusivity in STEM spaces.

Study Limitations

The research was conducted at a single institution and with respondents participating in one program, which may limit generalizability across different institutional contexts. Additionally, while our framework acknowledges intersectionality, the primary focus on gender means that other axes of marginalization may require further investigation. The sample size for this qualitative data was relatively small, though it achieved theoretical saturation for our key themes related to components of inclusive environments [19].

Positionality

As the research team, we bring over two decades of collective experience examining equity and inclusion in computing education. Our intersectional identities shape our perspectives, working to transform exclusionary practices and structures in computing. Our research is motivated by personal experiences navigating computing spaces and professional commitments to creating more just and inclusive learning environments. We approach this work with a deep understanding of how power dynamics and systemic barriers impact marginalized students' experiences while remaining reflexive about our positions of privilege within academia. Our interdisciplinary backgrounds spanning computer science, educational psychology, electrical engineering, and education inform our methodological choices and analytical frameworks. We engage in this research not as neutral observers, but as scholar-activists dedicated to institutional transformation and educational justice. While our lived experiences provide valuable insights, we remain open to perspectives that may differ from our assumptions and experiences.

Results

Our analysis of interviews with participants revealed four key findings about the nature and impact of inclusive environments in engineering education spaces.

Finding 1: Core Components of Inclusive Environments
Participants identified four essential characteristics that define inclusive environments in engineering education. First, students emphasized the importance of being "actively invited in" - not just being allowed to participate but receiving explicit invitations to join groups and take on leadership roles. This active invitation was significant in flattening power dynamics and helping students overcome initial self-doubt:

> "I'm just sitting in the back on the verge of tears like this is the worst ever. I have no idea what's going on. I don't know anyone in this class... Then, one girl introduced me to 6 other girls in the class... that genuinely got me through the class... I felt a sense of community. She was in a position of power of like having the connections that I didn't have - I would never have said hi to her."

Second, participants distinguished between being invited and being genuinely welcomed, noting that true welcome involves positive body language, receptive facial expressions, and thoughtful language choices. As one student explained: "Even if it's all people who you identify with, you might still feel uncomfortable if people's body language is like closed off, or people seem to be looking at you with judgmental faces." Participants were particularly sensitive to language choices, with one student highlighting how a professor's decision to use "leader and follower" rather than "master and slave" terminology in class significantly impacted their sense of belonging.

Third, participants emphasized the importance of having people they could relate to within the environment. While demographic representation, particularly gender in technology spaces, was important, participants noted that shared values and experiences were equally crucial for creating connection:

> "[In CS] it is such a higher volume of men than women, so even just seeing someone who's female identifying can help so much, even if they're not like the same as my racial background... even just having someone who isn't a man can make me feel like I can share or be more vulnerable or ask for help."

Finally, participants identified the ability to share one's "whole self" as a crucial feature of inclusive environments. This included feeling safe to show vulnerability and make mistakes without judgment:

> "In some more technical environments... you don't really talk about mistakes, or establish the fact that it's okay for you to make mistakes and that you're not going to get in trouble... I think that makes a space a lot more inclusive and comfortable because I feel definitely more willing to share things and speak my mind."

Finding 2: Impact on Student Success
Participants reported that inclusive environments directly enhanced both their confidence and productivity. Students described how feeling included provided critical support during challenging periods:

> "I think it provides like support and room for people to feel like they can succeed... when things get difficult, and you think 'maybe this isn't for me?'... If you feel included in the environment, then you're a lot more likely to feel like 'oh yeah, I think I can do it.'"

Beyond individual confidence, participants observed that inclusive environments fostered greater productivity and creativity through enhanced collaboration:

> "On a purely economic productivity level, things often work more smoothly if it's inclusive, because then you feel comfortable asking for help or offering advice... rather than being worried that people are going to judge you or reject your advice because of who you are."

Finding 3: Importance of Systemic Institutional Commitment
While department inclusivity often depended on individual faculty initiative, DTech demonstrated systematic commitment to inclusion through all four key components. One student articulated this difference clearly:

> "I think inherently the Computer Science Department [inclusivity] right now is very much an individual priority, where if an individual professor, or TA, or person takes it upon themselves to be inclusive, then it would be fine, but it doesn't feel like a departmental priority."

Participants consistently identified stark contrasts between broader engineering departments, where prioritization was seen as promoted primarily at the level of individual faculty, and DTech, which they viewed as more fully supporting inclusivity at the full-program level. This form of program-level support, not based on specific individuals, was seen as valuable and reflects a focus on the importance of systemic or institutional versus individual commitments.

Finding 4: Skills for Fostering Inclusion
While participants valued inclusive environments, many expressed uncertainties about their ability to create such spaces, particularly in formal work settings. Students identified specific skill gaps, including managing group dynamics, facilitating inclusive meetings, and handling conflicts. As one participant noted:

> "I feel like I have an idea of how to foster an inclusive environment via talking and communication, but in terms of like an actual work environment... you might have to help resolve a conflict... I tend to be a little bit of a pushover. So, I don't know if I could really do a good job."

These findings suggest that while students can clearly articulate the characteristics and benefits of inclusive environments, they may need additional support to develop the skills necessary to create such spaces themselves.

Discussion

Our findings reveal the complex interplay between individual experiences and institutional structures in creating inclusive engineering education environments. The four components we identified - being actively invited in, being genuinely welcomed, having people to relate to, and being able to share one's whole self - both affirm and extend existing frameworks for understanding inclusion in STEM education. The importance of active invitation aligns with previous work on belonging in engineering education (Riley et al., 2009). However, our findings highlight how this must go beyond passive acceptance to intentional inclusion. Participants' experiences demonstrate that power dynamics inherent in engineering spaces can create barriers that require deliberate intervention to overcome. This extends Armstrong's (2011) work on structural transformation by illustrating specific mechanisms through which institutional practices can reinforce or challenge existing power structures.

Our finding regarding genuine welcome versus mere invitation reveals the subtle but important distinction between formal and authentic inclusion. This resonates with Rankin et al.'s (2021) concept of "saturated sites of violence," where seemingly neutral educational spaces can become hostile through interconnected systems of power. The participants' sensitivity to body language, facial expressions, and language choices demonstrates how microaggressions and subtle forms of exclusion operate in engineering spaces.

The emphasis on relational connection adds nuance to traditional approaches focused primarily on demographic representation. While participants valued seeing people who shared their gender or racial identity, they emphasized that shared values and experiences were equally important for creating genuine inclusion. The ability to share one's "whole self" emerged as particularly significant and represents a novel contribution to engineering education literature. This finding challenges the traditional separation between technical and personal aspects of engineering education, suggesting that true inclusion requires space for vulnerability, mistakes, and authentic self-expression. This aligns with feminist critiques of engineering culture while offering concrete insight into how more humanizing environments might be created.

Importantly, our finding that students desire but feel unprepared to create inclusive environments suggests a crucial gap in engineering education. While programs like DTech can model inclusive practices, students need explicit support in developing skills to foster inclusion. This points to opportunities for expanding engineering education to include training in group dynamics, conflict resolution, and inclusive leadership.

Conclusions & Future Work

This work-in-progress study makes three key contributions to engineering education research. First, it provides an empirically grounded framework for understanding the components of inclusive environments, moving beyond abstract concepts to specific, actionable elements. Second, it reveals how systematic institutional commitment, rather than individual initiative alone, is crucial for creating sustained inclusive environments. Third, it identifies a specific skill gap in engineering education around preparing students to create and maintain inclusive environments. The findings suggest that meaningful transformation of engineering education requires attention to both interpersonal dynamics and institutional structures. Surface-level diversity initiatives are insufficient without a deeper examination of how power operates in engineering spaces and how it can be redistributed to create more equitable environments. The experiences of participants in this study demonstrate both the possibility and the necessity of creating engineering education spaces that support students' full humanity while maintaining technical excellence.

Several promising directions emerge from this initial study. First, while our framework acknowledges intersectionality, future work should more deeply examine how different axes of marginalization interact to shape students' experiences. This could involve expanding the participant pool to include more diverse voices and applying sequential interviewing methods to gather richer data about intersectional experiences. Second, Finding 4 regarding students' desire for inclusion-fostering skills merits further investigation. Future studies could identify specific competencies needed for creating inclusive environments, develop and evaluate training interventions to build these skills, examine how these skills translate from educational to professional contexts, and/or study how power dynamics influence skill development and application. Third, comparative studies across different institutional contexts could help understand how local cultures and structures influence the implementation of inclusive practices. This could include examining the differences between predominantly white institutions and historically black colleges/universities, variations across engineering disciplines, or the impact of different institutional policies and practices.

As the field continues tackling complex socio-technical challenges, fostering environments where students can fully participate and contribute their perspectives becomes an ethical imperative and a practical necessity for advancing engineering innovation and excellence. The path forward requires sustained commitment at individual and institutional levels, guided by empirical research that centers student experiences and acknowledges the full complexity of creating inclusive educational spaces.

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