STUDIES IN ENGINEERING EDUCATION

Haverkamp, A., et al. (2021). Calling for a Paradigm Shift in the Study of Gender in Engineering Education. *Studies in Engineering Education*, 1(2), pp. 55–70.

THEORY

Calling for a Paradigm Shift in the Study of Gender in Engineering Education

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Background: Dominant discourse regarding gender in engineering and engineering education relies on simplistic notions of gender as a rigid binary, which obscures the existence of transgender and gender nonconforming (TGNC) people and the gender dynamics they experience.
Purpose: This paper seeks to address the limits of the dominant gender discourse and research paradigm and propose new paths forward. This article calls researchers to intentionally transform their approach and framing of gender to create gender equity for all.
Scope: An examination of existing literature in engineering education is put against prevailing theories of gender and human difference from across academia. The overwhelming majority of literature in the field exists within a reductive gender binary. TGNC students and professionals are largely invisible in engineering education research and theory and this exclusion causes harm to individuals as well as our community as a whole. Such exclusion is not limited to engineering contexts but is found to be a central component of systemic TGNC marginalization in higher education and in the United States.
Discussion: We call for a substantive disciplinary shift towards studying the deep complexity of gender informed by, and accountable to, literature on gender theory, queer studies, and feminist research methodology. We propose interventions for engineering education researchers categorized into three levels: 1) Micro—to recognize gender diversity in engineering education; 2) Meso—to describe and analyze the experiences of TGNC students in research; and 3) Macro—to transform our discipline's conceptualization and theoretical framing of gender.

Keywords: gender; research methods; transgender; feminism; queer theory; trans studies; TGNC

1. Introduction

In September 2017, Scout Schultz—a 21-year-old, White, nonbinary, bisexual campus activist and computer engineering student—was shot and killed by a Georgia Tech police officer. Schultz had a history of depressive events and suicide notes were found in their dorm room. In March 2020, a district attorney decided that the police officer, Tyler Beck, would not face criminal charges (Boone, 2020). Scout Schultz's shooting was a heartbreaking and startling event for the authors of this paper when it occurred. Despite the geographical separation, this was a tragedy in our engineering community where we live and conduct research, and it left us with questions: Is engineering and computer science culture welcoming towards nonbinary students like Schultz, or is it exclusionary? Did cultural and social norms in our field contribute to Schultz's experiences of suicidality and depression? We cannot ask Schultz for their perspective. As researchers, we searched engineering education literature for student voices, lessons, and critiques and ended up with more questions: Does our engineering education system meaningfully support students like Schultz? Where does Schultz, their identity and experience, fit within the current body of gender research? This paper arose from the investigation of those questions and serves as our small memorial to Scout Schultz. Collectively, the authors have formal education and background related to teaching and research in feminism, queer studies, trans studies, and epistemology and are situated within personal and academic queer and trans spaces. From this lens, we assert that reconceptualizing gender and centering TGNC engineering students and professionals is not only of methodological importance, but a matter of ethical and moral concern. Ultimately, it is a matter of life and death.

This paper calls for a paradigm shift in how gender is approached among engineering educators and researchers. We understand the term paradigm as the "ideas nurtured and transmitted from generation to generation" or the model "from

which spring particular coherent traditions of scientific research" (Kuhn, 1962, p. 10; Khuntia & Barik, 2019, p. 1). While the field is shifting in response to calls from engineering education scholars, the reliance on a simplified gender binary continues to marginalize TGNC students and professionals. This shift will require substantial critical thinking by scholars on the nature of how gender operates for themselves and others, and how it operates within other systems of power.

2. Background

2.1. Gender in Engineering Education Research

The engineering education research community has explored gender dynamics and gendered culture for decades. Our purpose here is to highlight and build upon some of this exemplary work, while also illuminating trends that motivate our call for a radical shift in the current research paradigm used to explore gender in engineering.

2.1.1. Gender and Engineering Culture

Institutional change and outreach efforts over the last half-century have sought to increase gender parity between men and women in engineering education with somewhat limited success. These efforts are reviewed and contextualized by Lichtenstein et al. (2014), who summarize, "... in spite of a policy agenda targeted at boosting participation of women and underrepresented minorities in the engineering workforce, progress has been slow" (p. 325–326). National bachelor's degree attainment for women in engineering reached a historic high of 21.9% in 2018, less than a 2% increase from a decade prior (Freehill et al., 2007; Roy, 2019).

Men are demographically overrepresented across most engineering programs, which is an underlying motivation for research on gender experiences in the field. It is not surprising, then, that in addition to being demographically dominated by men, engineering is also *culturally* dominated by men and hegemonic masculinity (Cech, 2007; Godfrey, 2007; Male et al., 2018; Riley, 2008; Riley et al., 2009; Robinson & McIlwee, 1991; Secules, 2019; Silbey, 2016). The enculturation of students to the engineering profession and within the particular culture of masculinity is done through professional socialization, where students eventually adopt the professional values, norms and epistemologies towards the end of forming their professional identity as engineers (Cech, 2014). Importantly, research has identified a *gender filter* comprised of institutional, social, interpersonal, and political layers that acts upon students' formation of engineering identity such that men form the identity earlier and more often (Blickenstaff, 2005). This has significant implications as professional identity formation is correlated positively with desirable student outcomes such as belonging and persistence (Banchefsky et al., 2016; Baxter, 2010; Beasley & Fischer, 2012; Cech, 2007; Chachra et al., 2008; Faulkner, 2011; Hatmaker, 2013; Meyers et al., 2012; Ridgeway, 1997).

While researchers can investigate gendered experiences in engineering broadly or sub-disciplines like mechanical engineering, in practice students and professionals experience engineering in their own specific localized context with particular people. This is apparent in research on how student academic performance, professional engineering identity and program persistence are strongly correlated to measures of students' particular social climate (Godwin et al., 2018; Hatmaker, 2013; Ong et al., 2011; Ross, 2017; Torregosa et al., 2016; Verdín & Godwin, 2018; Walton & Cohen, 2007). The strong influence of social climate suggests that research on gender needs to be based on a clear understanding of systems of power and oppression. As argued by Beddoes (2011), such an approach shifts the discussion from problematizing an underrepresented group (e.g., why don't women persist in engineering education?) to problematizing the systems and structures (e.g., how do engineering education systems control and/or support students?).

Engineering education scholars, recognizing this need to address inequity through recognizing power and social realities, have called for shifts in methods and perspectives such as feminist philosophy and methodology (e.g., Riley et al., 2009). Beddoes and Borrego (2011) surveyed the engineering education research landscape for engagement with feminist theory and found that while most publications approach issues of gender from a broadly liberal viewpoint and refer to aspects of feminist standpoint theory, deep substantive engagement with feminist theories is lacking (Beddoes & Borrego, 2011). Riley, Slaton, and Pawley (2014) have further called for a field-wide reflection about how and why we study inclusion, with a focus on the way our assumptions might be "self-limiting in their impacts" (p. 335). These scholars purport that more authentic and rigorous application of expertise from women, queer, trans, and gender studies is needed to improve the study of gender in engineering education.

2.1.2. TGNC Voices in Engineering Education Research

Despite the body of research on gender in engineering education, transgender and gender nonconforming individuals have been troublingly absent from these discussions. Pawley et al. (2016) conducted a brief review of articles published in the *Journal of Engineering Education* between 1998–2012 that included topics of gender and found no articles mentioned transgender people. They then gave a clear recommendation that the research community should expand the concept of gender beyond the gender conforming binary (Pawley et al., 2016). This call for change seems not to have been broadly answered as

the identified pattern in gender research has largely remained unchanged. While there are certainly exceptions (described below), the overarching conversation builds from a preconceived notion of men and women in a way that renders TGNC students largely invisible.

In a guest editorial in October 2017 to *The Journal of Engineering Education,* Pawley articulated a need to "shift the default" used by engineering researchers surrounding gender theory and gender assumptions in engineering education study participants (Pawley, 2017). To assess the degree which TGNC people were included in research after this editorial, we read all papers and proceedings published in *The Journal of Engineering Education* and in the conference proceedings repository of the *American Society of Engineering Education* (ASEE PEER document repository), released during the 30 months after her October 2017 call, which included the word *gender* in the abstract or title. We identified whether or not these papers considered TGNC students or professionals as a topic of study or discussion. Several papers did include transgender or nonbinary identities in their demographics, but they were not addressed or discussed at all in the paper. We found five papers or proceedings out of 79 that had the word gender that discussed TGNC identities or expansive gender theorizations. Three of the five results were written by authors of this manuscript (Haverkamp, 2018, 2019a, 2019b). The fourth held TGNC students as their subject, a case study centered on experiential learning, inclusive pedagogy, and student empowerment through activism for two transgender students (Boudreau et al., 2019). The fifth paper explored identity navigation of several queer-identified students at a technical university. Within the paper was a nuanced discussion of the matrix of gender and sexuality within the *queer* label, and how trans identities exist within that matrix (Cieminski, 2019). Unfortunately, while three years have passed from Pawley's call to expand gender theories and assumptions, TGNC identities remain largely invisible, and most gender research has continued within a limiting binary framework.

2.2. Overview of TGNC Experiences in Society

The social reality of TGNC individuals in the United States is described as a crisis of marginalization and invisibility, particularly for Black, Indigenous, and people of color in the community (Human Rights Campaign, 2018). The U.S. Transgender Survey (USTS) provides incredible insight into this reality. It is regarded as the most comprehensive numerical study to date on TGNC experiences in the U.S., with a total of 27,715 respondents and over 500 unique gender identifications. The USTS outlines pervasive social and physical violence, relationship mistreatment, and economic hardship for TGNC individuals at rates orders of magnitude higher than those in the general population (James et al., 2016). In addition, there is a clear and disturbing pattern of severe inequity for transgender people of color when compared to White respondents, compounded by anti-trans violence in prison and immigration systems (Spade, 2015; Stanley & Smith, 2015). Further, individuals who identify as neither a woman nor man (such as nonbinary, genderqueer, gender fluid, or androgynous) are more likely to be Black or multiracial, and report lower income compared to binary TGNC individuals (Harrison et al., 2012).

Z Nicolazzo, a transgender higher education researcher, defines three primary forms of everyday obstacles for TGNC students: gender binary discourse, sex segregation, and *gender bashing* (Nicolazzo, 2016; Nicolazzo 2017). Gender binary discourse is "a constellation of words, phrases, actions, rules (written and unwritten), and social realities that regulate 'appropriate' gender identities, expressions, and embodiments on campus" (Nicolazzo, 2017, p. 167). Sex segregation refers to the many ways daily life divides people based on medically defined or perceived sex, such as bathrooms, classroom activities, intramural teams, professional dress, administrative forms, medical access, and on-campus housing options and roommate assignments (Beemyn, 2003; Beemyn et al., 2005; Krum, 2013). Gender bashing entails actions that use gender nonconformity or perception of transgender status as the basis for targeting as a means to enforce cisgender and heterosexual conformity (Namaste, 2000; Nicolazzo, 2017). Ultimately, the confluence of all of these forms of marginalization culminates in the USTS finding that 24% of people perceived as transgender on college campuses were verbally, physically, or sexually assaulted and 16% of TGNC students left higher education due to the harassment that they experienced, with TGNC students of color faring worse than White TGNC students (James et al., 2016).

TGNC scholarship navigates several critical tensions: the first is that some potential study participants are willing to disclose their status and reveal their experiences, but others have meaningful reasons not to. One reason why potential participants of LGBTQ+ studies may not engage or disclose is that some TGNC individuals may not identify as lesbian, gay, bisexual, or queer or form community with other TGNC individuals (James et al., 2016; Prosser, 2006). Many do not give interpersonal or public disclosures of their gender history either, and fear nonconsensual disclosure. In 2017, reality show participant Zeke was "found out" to be transgender by another member of the show several weeks into the program—during his second season on the show. The individual who discovered Zeke's gender history publicly outed this status to cast members and the entire television audience without asking for Zeke's consent. Cisgender peers on the show and fans began to treat and see Zeke differently, often with distrust or hostility**.** Zeke wrote an article for *The Hollywood Reporter* that detailed the harm of nonconsensual outing (Smith, 2017):

> Many gay (cisgender lesbian, gay, bisexual, and queer) people consider coming out a moment of liberation, because sharing their sexual orientation with the world causes them to be seen more authentically. Often, the opposite is true for trans people. When we share our gender history, many see us less authentically—doubting, probing, or denying our gender reality.

In addition to fear of nonconsensual gender history disclosure, the racialization of gender and trans experience produces intracommunity tension regarding TGNC activism's research and political goals. Social assimilation and rights-based approaches predominantly benefit White TGNC individuals and have been the focus of highly visible equality research and political efforts in the United States. Queer and trans activists of color, in contrast, have pushed for liberation from incarceration and police brutality, material changes in living conditions and institutional access, and combatting White domination in society (Spade, 2015; Stanley & Smith, 2015; Stryker et al., 2008). For these reasons, critical trans scholarship remains important—and in tension with itself.

3. Limitations of the Dominant Research Paradigm

It is important to recognize that studies using the man/woman binary as the primary demographic gender identities have been important in building a framework to understand gender dynamics in engineering and to advance gender equity between these two genders. As we move towards a critique of the most common theoretical framings and methodologies used to explore gender in engineering, we take care to not suggest that any individuals are actively promoting harmful conceptions of gender with malintent. Along the same line, studies investigating experiences and perceptions of LGBTQ+ students and professionals in engineering have produced valuable insights. Our call for a paradigm shift is not intended as a condemnation of previous work that has helped elucidate and characterize the research paradigm we are critiquing.

3.1. Gender Binary Framing

Critical research in engineering education continues to advance in terms of reach and scope, but theories of gender that frame research efforts have not yet broadly de-centered or divested from tacit assumptions of cisgender normativity and the gender binary, despite ongoing calls by prominent researchers for the academic community to pivot towards this trajectory (Pawley et al., 2016). This has left important gender dynamics out of investigation or discussion, such as cis-normativity (i.e., norms regarding cisgender assumed status and bodies) and gender normativity (i.e., norms regarding expressions of masculinity, femininity, or deviations from such norms). The authors in their careers have additionally read papers using the term *sex* as the demographic variable and *sex-segregation* as a phenomenon in engineering education research. The use of *sex* language reflects a conflation of sex and gender, and implicitly assumes cisgender status for study participants. We do not wish to call out by naming specific articles, but instead emphasize a need to unravel this language. The implicit assumption of a biological gender binary has significant, palpable consequences for TGNC communities and research.

Riley, Slayton, and Pawley (2014) cautioned that the dominant research paradigm of using numerical demographic methods often combined, subsumed, or excluded identity categories to maintain statistical reliability, thus naturalizing gender and racial categories. This dominant research paradigm has frequently excluded TGNC identities by using two variables for gender. Traxler et al. (2016) describe the prevalent model of gender research in STEM as the *binary gender deficit model,* which simultaneously frames women as deficient or lacking compared to the benchmark of men's success and persistence, while also reinforcing binary notions of gender. This model can reasonably be applied to prior discussions in engineering education regarding implicit deficit framing of women, which has similarly positioned gender as a binary (Volman et al., 1995; Volman & vanEck, 2001). The binary gender deficit model places women's lack of understanding, awareness, or retention in STEM as a flaw inherent to women's gender to be remedied (Gilbert, 2001**;** Phipps, 2007). The gender binary is rooted in an epistemology of Victorian-era biologically defined difference: passive, relational, lacking, and emotional women contrasted to rational, competitive, competent, and technically skilled men (Harding, 1986). Each gender is defined primarily by its contrast to the other. In this framework, TGNC identities—such as nonbinary individuals—are rendered unrecognizable, incoherent, and incongruent with the normative gender order. This is a primary epistemological mechanism by which cisgender normativity marginalizes TGNC individuals systematically (McQueen, 2015). Clearly, the cementation of a rigid gender binary in research undermines its own goals of gender equity.

3.2. Extrapolating TGNC Experiences from Umbrella LGBTQ+ Studies

Research on the lesbian, gay, bisexual, transgender, and queer (LGBTQ+) umbrella in engineering education research will not yield findings necessarily pertinent to TGNC individuals. In practice, relying upon this broad umbrella of sexuality and gender categories will obfuscate the specific experiences and perspectives of TGNC individuals, rather than reveal them. The primary reason is because gender *cuts across* sexuality and many other identities; LGBQ sexualities are not gender exper-

iences or identities by definition (Stryker, 2014). Transgender individuals are a demographic minority within the LGBTQ+ umbrella, consisting of roughly 8.5% of the total LGBTQ+ population (Gates, 2011, thus aggregated data will skew towards the 91.5% of the LGBTQ+ population who are cisgender and binary-identified). Further, there are social tensions and prejudices within the LGBTQ+ community itself in regard to transgender inclusion (Marine & Nicolazzo, 2014; Namaste, 2000; Schilt & Westbrook, 2009; Stryker, 2017; Weiss, 2011). Mainstream LGBTQ+ rights-based nonprofit organizations, and the resulting social narratives they reproduce, were predicated on the ostracization and removal of transgender individuals of color from gay and lesbian communities in the 1970s (Stryker, 2017). Exclusionary political and social dynamics continue to limit the participation of TGNC individuals in mainstream LGBTQ+ activism, especially in regards to trans people of color (Gossett, 2017; Weiss, 2011). Decades of suppression upon TGNC participation in the public sphere results in a tendency for transgender, gender-nonconforming, and nonbinary inclusion framed as new or emerging when compared to lesbian, gay, and bisexual inclusion, or as a recently developed threat to normative gender social relations (Stryker, 2017).

3.3. Intersectionality and Gender

Scholarship about gender has demonstrated a trajectory towards centering the intersectionality of power systems (Cech & Waidzunas, 2019; Gregory, 2015; Mejia, Chen, et al., 2018; Pawley, 2019; Riley, 2008; Riley et al., 2009; Ross, 2017; Verdín & Godwin, 2018). Intersectionality centralizes the multiplicity and interconnectedness of systems of oppression (Crenshaw, 1991). In engineering education, however, cisgender normativity and gender conformity have been left out of the conversation as they intersect with gender identity, race, and other salient identities. In practice, intersectionality theory is sometimes oversimplified into a rote listing of the identities we carry, and not its original intended topic, which is lived experiences of facing multiple sources of oppression simultaneously (specifically, in Crenshaw's formulation, the experiences of Black women). A systems approach to gender research would affirm the intricate nuances of gender to include aspects of cisgender/transgender status and gender conformity as they interlock and interact through institutions, dominant ideologies, and diffuse human interactions (e.g., daily navigation alongside race, culture, indigeneity, sexuality, disability, religious identity).

4. Shifting the Paradigm

For reasons provided above, dominant research theories and practices used for investigating social climates in engineering education and practice are insufficient to capture the nuances of institutional and relational power in regard to expansive understandings of gender in engineering education and practice. To return, then, to the story of Scout Schultz that opens this article, we need a new paradigm of analysis to develop a more complex understanding of the intersecting and complex political systems that gave rise to Schultz's experiences in the world. As an engineering student, Schultz is our responsibility. Individual kindness or action cannot undo our field's complicity in upholding cultures and institutional practices that marginalize TGNC people—whether implicitly or explicitly, intentionally or unintentionally. These structures and ideologies undoubtedly affected Schultz, and can only be changed through theories and practices that work to deeply transform and dismantle interlocking systems of power and control.

We must collectively shift the way gender is approached and engaged to make meaningful and substantial contributions that lift up all engineering students and professionals—not only cisgender, binary identified, and gender conforming individuals. Alongside shifts in gender theory there must be a transformation in our interpretations of gender-based oppression and how it manifests through institutions, social interaction, and cultural navigation across axes of difference, not only in binary gender terms. If this paradigm shift is successful, the study of gender in the coming decades will bring forth substantive advances that can meaningfully impact students' experiences for the better.

4.1. Gender Concepts

Engineering education research as a field must commit to a rigorous and fruitful definition of gender. Gender must be treated as a "complex construct" rather than a "biological inevitability" in order for the discipline to expand its understandings beyond demographics (Riley et al., 2014, p. 349). Gender is the behaviors, roles, stereotypes, expressions, presentations, and actions that are socially constructed to define the boundaries between men and women in our society (Garbacik, 2013). Rather than a natural biological order or a fundamental truth about human life, gender is a unique and constantly evolving social phenomenon found in humans. The assumption of a gender binary and the assumption of two immutable biological sexes are intertwined, interrelated, and irrevocably connected. To operate without one assumption (binary) necessitates rejecting the other (biological foundations of gender). Contemporary research in psychology, neurology, and behavioral science consistently challenge the notion that physical sex characteristics infer inherent or immutable mental ability or social inclination differences (Brigandt & Love, 2017; Iliescu et al., 2016; Joel, 2011; Joel et al., 2014). The assumption of inherent mental, cognitive, or behavioral differences imparted by sex chromosomes is scientifically inaccurate and empirically unfounded as a framework for interpreting gender in human society (Conger, 2017; Fine, 2010). There is a broad spectrum

of human physical, chemical, and genetic characteristics (such as chromosomal variation and physical sex characteristic variation) that complicate any ability to define two distinct human sexes (Ainsworth, 2015).

Unpacking the fraught biological basis of the gender binary is the foundation of understanding transgender standpoints. Transgender is an adjective which describes an individual whose gender presentation and identification are different than their assigned (often arbitrarily at birth) sex/gender. By contrast, cisgender is an adjective to describe individuals whose gender presentation and identification matches their socially assigned sex/gender (Nicolazzo, 2017). Individuals within the TGNC community include TGNC men and women, nonbinary, agender, genderfluid, and genderqueer people, as well as people with other genders outside of the man/woman binary. Those who identify outside of the binary may not experience society, relate to their body, or outwardly present as either binary gender. Nonbinary is a gender category often used to encompass many genders which are not woman or man. Gender-nonconforming (GNC) individuals may or may not identify as nonbinary, cisgender, or transgender. GNC individuals may not adhere to the social expectations of the gender binary in their behaviors, roles, clothing, desires, relationships, or identity.

The breadth of gender as a social and cultural construction creates many ways to adhere, or not, to dominant gender norms. Gender nonconformity is often depicted as feminine men, masculine women, and androgynous or mixed-gender presenting individuals. However, this conceptualization is still predicated upon binary language and oppositional feminine/masculine heteronormative and cis-normative assumptions. Furthermore, TGNC people must not be framed as universally subversive and radical against a mythical natural binary cisgender social order (Prosser, 2006). Such framing assumes that the dominant social order is a natural and expected result of human's inherent predisposition, rather than a social order predicated upon histories and systems of oppression which erase particular gendered experiences, perspectives, and power. It is not just TGNC people who are oppressed under the dominant social order. Normative binary and cisgender gender individuals are also found to frequently experience significant gender role discomfort—demonstrating a multiplicity and fluidity of gender in all humans (Joel et al., 2014).

4.2. Queer Theory and Trans Studies

Queer theory and trans studies should be integral to future critical research on gender in engineering education, as they critique social categories, institutions, and biopower (state regulation of bodies) which (re)create and regulate difference (Watson, 2005). Scholarship in these closely related fields question the status and administration of gender/sexuality categories and interrogates the boundaries that are created through these categories. These regulations and boundaries—including both literal and figurative policing of gender—simultaneously construct norms of Whiteness, gender, and sexuality. Queer and trans-of-color critiques and women-of-color feminisms specifically elucidate the ways that gender and sexuality are racialized projects within scientific, medical, legal, and political discourses that are built on the regulation (and often torture) of Black, Indigenous, and other people of color for the benefit of White, settler populations.

Because the categories of sex, sexuality, and gender have been built through technologies of enslavement and colonization, understandings of gender and sexuality are inadequate without an analysis of race and colonialism. Heterosexuality, transgender identity, and the gender binary as social organizing systems in the United States are intimately tied to both the gendering of race in relation to chattel slavery and the *gendercide* and attempted forced assimilation of Native American peoples (Miranda, 2010; Morgensen, 2011; Snorton, 2017). Miranda (2010) details the devastating impact on culture, spirituality, and social structure that resulted for Indigenous peoples after Spanish colonizing forces systematically targeted and eliminated individuals perceived as transgressing European gender norms from their tribes. For centuries, Black and Indigenous women, women of color, and feminist theorists have challenged how dominant constructions of *womanhood*—and *the human* more broadly—have been formed through middle and upper-class Whiteness (itself built through anti-Blackness, enslavement, and colonial/imperial violence) (Allen, 1992; Blackwell, 2011; Hull et al., 2015; Pérez, 1999; Royster, 2000; Smith, 2016; Whitebear, 2020; Wynter, 2003). For example, Somerville examines how the "invention of homosexuality" (which historically was constructed as gendered difference) took place through eugenicist projects in social, medical and pyschological sciences, including the 19th-century field of "sexology," to produce evidence of "racial difference through sexual characteristics of the female body" (Somerville, 2000, p. 26). Similarly, Ferguson examines how the field of sociology constructed Black communities as sexually perverse and deficient based on White supremacist, middle class constructions of "proper" heteronormative family formations in order to regulate Black communities (Ferguson, 2004). Snorton (2017) details the work of James Marion Sims, considered the father of gynecology, to build medical discourse and knowledge of *sex* through the torture of and experimentation on enslaved Black women.

Gendered terms and categories (such as masculinity, woman, transgender, nonbinary), then, must be understood through their ongoing racialized and colonial contexts. To unpack these concepts in engineering education is to call into question the role engineering has played, and continues to play, in settler colonialism and White domination, complicating mainstream understandings of TGNC inclusion, oppression, and power. Research in engineering education that seeks to consider the confluence of race and gender through critically queer and trans frameworks must recognize the racial foundations of

the dominant gender system and how these race relations shape TGNC identities. Including TGNC experiences in engineering could become a place where we not only uncover how gender regulates engineering spaces, but also make connections between these broader systems of power.

5. Towards Gender Expansive Engineering Education Research

Intentionally shifting paradigms requires the coordination of acute, concentrated actions and more diffuse, strategic communications. We propose a goal-driven approach to systemic institutional change based on the spectrum of intervention effectiveness proposed by Meadows (1999, 2008). Meadows organizes potential interventions in a hierarchy of leverage. Changes in the goals and culture of an institution have the highest leverage, meaning that changes there are magnified so that even small shifts can have sizeable impacts on the community. Changes in the flow of information (i.e., who knows what, and when) also have a metaphorically long lever arm. Somewhat counterintuitively, direct policy changes and numerical parameters (such as gender demographics) are at the bottom of Meadows' hierarchy because their impact is relatively limited in scope and time.

We have adapted Meadows' hierarchy into three categories at the macro-, meso-, and micro-scales. **Table 1** presents our proposed interventions for engineering education researchers who study gender ranging from micro-level interventions with less leverage to shift the discipline to macro-level interventions requiring a sizable cultural and spiritual shift in disciplinary approach. The three scales correspond to three intervention objectives: 1) to affirm gender diversity in engineering education research and practice; 2) to describe and analyze the experiences of TGNC students, faculty, and practitioners; and 3) to transform our discipline's conceptualization and theoretical framing of gender.

Table 1: Proposed levels for gender expansive engineering education research shifts.

Micro (Parameters, policies)	Meso (Information flow)	Macro (Goals, culture)
affirm gender diversity in engineering education research and practice	describe and analyze the experiences of TGNC students, faculty, and practitioners	transform our discipline's conceptualization and theoretical framing of gender
Demographics and surveys	Narrative and community methods	Queer theory, trans studies

5.1. Micro-level interventions

The engineering education research community must begin to recognize the greater diversity of gender. In recording gender demographics in surveys and forms, researchers can make gender a multivariable categorical instead of a binary, dichotomous variable (Fernandez et al., 2016). The Human Rights Campaign issued guidance in a document titled "Collecting Transgender Inclusive Gender Data in the Workplace and Other Surveys" (2016), which proposed gender as a two-part question (see **Figure 1**). The first question asks for gender instead of sex and provides multiple options, allowing for the respondent to self-describe. The second question begins with a preface explaining the term transgender and asks whether the respondent identifies as transgender. This question allows for opting out of answering. For contexts that do not center the transgender population, the first question in **Figure 1**, "What is your gender?" should suffice. If a research project does not explicitly focus on transgender experiences and perspectives then there should not be a reason to separate individuals on basis of transgender status, as it may appear invalidating (i.e., separating transgender men from cisgender men without an intentional research purpose).

Q1. What is your gender?
❑ Woman
❑ Man
❑ Non-binary/third gender
❑ Prefer to self-describe _____
❑ Prefer not to say

Q2. Transgender is an umbrella term that refers to people whose gender identity, expression, or behavior is different from those typically associated with their assigned sex at birth. Other identities considered to fall under this agenda include non-binary, gender fluid, and genderqueer—as well as many more.

Do you identify as transgender?
❑ Yes
❑ No
❑ Prefer not to say

Figure 1: Human Rights campaign guidance on gender demographics in surveys (Human Rights Campaign, 2016b, adapted).

Educators and researchers should demonstrate awareness of gender diversity and gender difference in a variety of direct personal ways. In the classroom it can take place through asking for pronouns, using gender neutral language in class examples, and ensuring that students have an opportunity to provide their names in case they differ from those on the course roster (Harbin, 2016). There are many ways to obtain pronouns, and there is no clear consensus on a best practice. The instructor can confidentially obtain pronouns at the beginning of the term through an online survey or introduction worksheet, request pronouns verbally, ask that students add them to a name sign on their desk, or add them to institutional student data. The last option—having pronouns as a part of student institutional data—is not available on all campuses and may require a campus-wide effort, which engineering departments could champion.

Beyond demographics and classroom interactions, faculty should become personally well educated in gender and eliminate the assumption that biological characteristics have any determination on individuals' gender or expression (Case et al., 2009). Educational resources abound on the internet where nonbinary and trans advocates are able to freely offer their thoughts and suggestions. Z Nicolazzo created a "Trans* Studies in Higher Education Syllabus" online document with sixteen weeks of articles for academics to read to address this precise need, with the document prefacing a hope that cisgender academics will cease asking rudimentary questions to TGNC academics (which is a "manifestation of cisgender privilege") and instead become engaged in the existing literature (Nicolazzo, 2020). Articles such as "100 Ways to Make the World Better for Non-Binary People" by AC Dumlao also contain dozens of ways we, as a community, can inwardly dismantle binary, cisgender assumptions and outwardly change the ways we interact with others (Dumlao, 2018).

5.2. Meso-level interventions

We argue that the primary way engineering education researchers can change the flow of information around gender is to consider the ways the TGNC engineering community is treated as a source, audience, and collaborator in research. The design of future research with the TGNC community should include a number of methodological shifts to ensure that the findings are comprehensive and do not reinforce harm.

5.2.1. Narrative and Community-based Methods

Research investigating gender dynamics for TGNC students, faculty and professionals should involve and incorporate these TGNC subject communities throughout the research process, from project conception to publication. Histories of straight and cisgender researchers producing harmful or inaccurate narratives about the lives of LGBTQ+ people can inform us of the potential dangers of a community of non-TGNC identified researchers formulating papers, theories, and descriptions of TGNC lives. Research methods which engage or partner with subject communities on the research process are more likely to create beneficial outcomes which are by and for the community, instead of by and for the researchers. Narrative methods, autoethnography, participatory methods, community-centered methods, collaborative methods, and research justice approaches center the subject community's involvement, and some in the engineering education research community have begun using these methods (Case & Light, 2011; Creese & Frisby 2011; Faber et al., 2016; Foor, 2007; Gregory, 2015; Haverkamp, 2019b; Hesse-Biber, 2014; Martin & Garza, 2020; Pawley, 2013; Pawley, 2019; Secules et al., 2018; Walther et al., 2017). Narrative-based and autoethnographic methods allow direct quotes, low sample size, and/or individuals to substantially inform findings for marginalized underrepresented communities.

Even with interpretivist approaches there is a risk for researchers outside the community to overgeneralize or essentialize communities based on individual narratives. This emphasizes the importance of involving the participants' community. Participatory and community-centered research emphasizes knowledge as being constructed socially and culturally within a community. The subject community leads the process of identifying topics to be investigated or addressed with participation of the community in the question formation, data collection, and analysis. Community collaborative research methods similarly center the community being studied at every step of the research process. Such collaborative methodologies seek input from and create active roles for the population being researched, creating relationships which shape the meaning-making process start to finish (Nicolazzo, 2016).

These methods' approaches are relational in nature. Forming interpersonal relationships, trust, understanding, and buy-in is a form of labor in and of itself by participants (Foley & Valenzuela, 2008). Marginalized communities further provide data and research participation, and this labor is often unpaid or underpaid. Research justice is an academic movement to upend the unequal cost and benefit of research conducted on marginalized communities, and to redress inequity through a restructuring of the research process (Jolivette, 2015). Surveys, interviews, and focus groups create great benefit for the institution and its research team (in forms of grant funding, tenure, graduate degrees, among others) with little to no benefit for the subject community (which may or may not even receive compensation). Fair financial compensation which matches or exceeds the per-hour wages of the researcher, summer internships, paid research positions, and paper authorship are a few ways to strive for equal benefit for TGNC subject populations from a research justice perspective.

Including TGNC voices in engineering education research necessitates active mentorship, recruitment, and development of TGNC engineering education scholars. As Julia Serano writes in *Whipping Girl* (2007):

> If cisgender academics truly believe that transgender and intersex people can add new perspectives to existing dialogues about gender, then they should stop reinterpreting our experiences and instead support transgender and intersex intellectual endeavors and works of art. Instead of exploiting our experiences to further their own careers, they should insist that their universities make a point of hiring transgender and intersex faculty, and that their publishers put out books by gender-variant authors. And they should finally acknowledge the fact that they have no legitimate claim to use transgender and intersex identities, struggles, and histories for their own purposes (p. 212).

Those who have identity-specific experiences under oppression are best suited epistemologically to understand, explain, and analyze that oppression. Feminist research praxis is predicated upon the idea that those being researched have greater understanding and knowledge about their life than the researcher (Walsh, 2015). Put together, community- and narrative-based methods give research agency to the TGNC population.

5.2.2. Resiliency frameworks

There is a tendency for research on underrepresented groups to record data primarily surrounding negative experiences, which produce narratives that their lives are *inherently* damaged, deficient, or one-dimensionally defined through harm. Research that replicates and amplifies *only* information on discrimination regarding the TGNC community runs the risk of reinforcing a harmful narrative. Deficit-based framings have been recognized as harmful in the engineering education literature (e.g., Long & Mejia, 2016; Mejia, Revelo, et al., 2018; Vanasupa, 2020). Examples include surveys or narratives solely focused on discrimination or marginalization. Researchers have described deficit-based approaches as depicting the subject population as inherently underachieved and in need of help, repair, or assistance (Kim & Hargrove, 2013). Similarly, Tuck (2009, p. 143) identified damage-centered research as a "pathologizing approach in which the oppression singularly defines a community."

We propose emerging engineering education research to include a substantive focus on TGNC student resiliency, which has been established as an effective research approach in trans studies, identifying relational support networks, skillsets, and strategies for student success (Haverkamp, 2019b; Nicolazzo, 2016; Nicolazzo, 2017; Stolzenberg & Hughes, 2017). A resiliency framework centers TGNC agency—asserting that "transgender [people] are not a problem to be solved" (Marine, 2011, p. 1182). Resilience is "not considered to be an individual personality trait" or a set of unique abilities marginalized individuals have (Kim & Hargrove 2013, p. 306). In line with the social theory of resilience described by Bottrell, it is a collective experience of social navigation shared by the community, including their friends, families, and community agencies (Bottrell, 2009). Resilience can also be defined as the force within an individual which allows them to re-align their lives after disturbance from society to "pursue wisdom, self-actualization, and altruism" (Richardson, 2002, p. 3009). Through interpreting the paths TGNC students use to navigate a binary gendered, statistically hostile social climate, their support structures can be identified and strengthened effectively (Wilkes, 2002). Exploring resiliency overturns one-dimensional narratives to allow a more complex personhood to emerge—depictions of individuals whose lives include joy, success, and meaning outside their identity, not only stereotypes, discrimination, and oppression related to their identity (Guishard, 2009).

5.3. Macro-level interventions

We labeled this section *macro-level* because changing generations of engineering students' and professionals' conceptualizations of gender cannot be accomplished within even a few years. As an engineering education research community that investigates inclusion and equity, we must dedicate ourselves to holistic disciplinary transformation regarding our approach to gender. This ambition is tricky to summarize concretely and concisely, because we collectively need to spend significant time asking what gender is, how gender operates, and what we are hoping to achieve through our study of gender in engineering. It requires us all—the authors of this paper included—to foster a sense of humility regarding our understanding of gender.

No one person, paper, or year can shift our entire disciplinary culture and trajectory. Individuals, despite our best intentions, likely cannot shift their own internal gender paradigm overnight. The authors of this paper have spent collective decades in higher education and engineering and can attest to the long-term internal, spiritual, and relational work required to de-center biological binary gender essentialism and binary gender deficit models.

Queer theory and trans studies hold the potential to not only build new frameworks regarding gender in engineering, but to question the epistemological basis of historical and ongoing diversity and inclusion efforts as well. A line of engineering education research on gender and sexuality that incorporates queer theory and trans studies might resist the tendency to

relegate identity into strict confines of pre-determined categories and instead move towards analyzing the historical, racial, and colonial logics that predicate this line of gender research to begin with. A queer theorist's investigation of gender in engineering might interrogate the commodification of difference reproduced through gender research pathways and programs, or ways which our gender discourse solidifies or disrupts power structures beyond demographic representation, for example (Ferguson, 2012). Viewing gender as regulated, policed, and administered by various social systems will allow for nuanced investigations of gender conformity, gender binary stereotyping, and the gendering of ideologies or physical spaces. This could potentially move the conversation in new directions, upending traditional notions of what equity looks like for the profession, or even that equity can be achieved in a discipline without large-scale changes in the surrounding global society.

In the coming years and decades, we should strive towards interdisciplinary collaboration in gender research, particularly with fields already highly engaged in queer and trans theory such as queer studies, women and gender studies, and transgender studies. Methodologies enacted through direct co-investigation with researchers in ethnic studies, critical anthropology, and justice-oriented sociology will also provide expertise and cross-disciplinary sharing of information. We need to make space in our research and in our funding mechanisms to engage and partner with scholars in fields with expertise and experience with transgender and gender nonconforming lives, bodies, and identities. Long-term research agendas may seek to transform the political and material realities for TGNC individuals throughout the United States, as experiences throughout society overlay student experiences in engineering education.

Finally, resisting binary categorization of gender and other identity aggregation necessitates deep reflection on our own discipline. The borders we construct around our academic work and professional identities as engineers and engineering education researchers should be interrupted. Interdisciplinary work, as a concept, is predicated upon an epistemology of necessitated knowledge segregation within academia (Pawley, 2012; Robinson, 2008). "Undisciplined" work comparatively understands that "knowledge is not bound by a single academic discipline" and a refusal to "comply or conform to the rules of category" (deSouza & Purpura, 2012, p. 167). A broad paradigm shift in engineering education research towards this end would, in turn, acculturate new generations of engineering professionals into such a paradigm, and directly address Riley, Slaton, and Pawley's consideration of "how the profession serves structures of power" in regards to gender (Riley et al., 2014, p. 338).

6. Conclusion

We hold the memory of Scout Schultz as one of countless lives of TGNC people taken through both interpersonal and state violence, while placing it in a larger context of anti-trans violence that trans women of color, particularly Black trans women, experience. Schultz's story should remind us as faculty and administrators that TGNC lives are real—not a theoretical—and that we have a responsibility to ensure that the frameworks and practices within our programs center affirmation, recognition, and an informed understanding of gender difference, at the least, to support TGNC students.

In the final section of the paper, we proposed paths forward to help uncover TGNC narratives and stories. The proposed theoretical and methodological shifts are imperative should engineering educators take up the task of digging deeper into these nuanced gendered experiences. We have a responsibility to Scout Schultz's memory and to all of our TGNC students. These interventions could foster the creation of engineering gender research literature that not only documents the successes, perspectives, desires, and experiences of TGNC students, faculty, and practitioners, but actively works to develop an engineering education culture where individuals are able to express gender freely and safely in the classroom and beyond.

Acknowledgements

This paper and the pursuant research endeavors are in acknowledgement to the life, activism, and memory of Scout Schultz. We also honor the lives of the TGNC people known to be killed in the United States and Puerto Rico during the writing of this article: Yampi Méndez Arocho, Bree Black, Monika Diamond, Dominique "Rem'mie" Fells, Selena Reyes-Hernandez, Lexi, Merci Mack, Tony McDade, Johanna Metzger, Riah Milton, Helle Jae O'Regan, Dustin Parker, Shaki Peters, Nina Pop, Penélope Díaz Ramírez, Serena Angelique Velázquez Ramos, Neulisa Luciano Ruiz, Layla Pelaez Sánchez, Brayla Stone, Summer Taylor, and Jayne Thompson, We are grateful to funding from the NSF under grant EEC-1764103. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

We are grateful to the anonymous reviewers and editors for their comprehensive and constructive feedback that provided us sound guidance for revision.

Oregon State University in Corvallis, Oregon, is located within the traditional homelands of the Mary's River or Ampinefu Band of Kalapuya. Following the Willamette Valley Treaty of 1855, Kalapuya people were forcibly removed to reservations in Western Oregon. Today, living descendants of these people are a part of the Confederated Tribes of Grand Ronde Community of Oregon (grandronde.org) and the Confederated Tribes of the Siletz Indians (ctsi.nsn.us).

Competing Interests

This work is supported by an NSF grant EEC-1764103. The authors have received funds from this grant to cover tuition, fees, insurance and costs of living. Our proposed work is centered on three objectives (quoted from the proposal).

The research project has three objectives: (i) to infuse critical theory and methodologies into engineering education research; (ii) to record, examine, and share how undergraduate engineering students of different genders find belonging and success; and (iii) to collaborate with research participants to generate recommendations toward transforming engineering programs into more inclusive and just spaces.

Authors Contributions

In-line with ICMJE recommendations, all authors:

- made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work;
- contributed to the drafting the work, or revising it critically for important intellectual content;
- provided final approval of the version to be published;
- agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; and
- agreed to be named on the author list, and approved of the full author list.

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How to cite this article: Haverkamp, A., Bothwell, M., Montfort, D., & Driskill, Q.-L. (2021). Calling for a Paradigm Shift in the Study of Gender in Engineering Education. *Studies in Engineering Education*, 1(2), pp. 55–70.

Submitted: 16 January 2020 **Accepted:** 10 December 2020 **Published:** 11 February 2021

VIRGINIA TECH | VT Publishing

Studies in Engineering Education is a peer-reviewed open access journal published by VT Publishing.

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