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”A New Way of Seeing”: Engagement With Women’s and Gender Studies Fosters Engineering Identity Formation

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"A New Way of Seeing": Engagement with Women's and Gender Studies Fosters Engineering Identity Formation for Diverse Students

Abstract

Despite widespread appreciation of the importance of diverse participation in engineering, persistent biases and systemic disadvantages continue to impede the flourishing of students with historically excluded identities. We investigate the influence of a STEM-themed Women's and Gender Studies course on the identity formation and sense of belonging of a group of engineering students. Through survey responses and focus group discussions, this study qualitatively investigates how STEM-themed coursework in WGS may influence the attitudes, perspectives, and identity formation of marginalized engineering students. In our interviews, students reported finding WGS coursework to be empowering, liberatory, and strengthening of their STEM confidence and preparedness. Providing students with the critical frameworks, interdisciplinary methods, and conceptual vocabulary associated with WGS can positively influence students' engineering identity formation and support underrepresented students' sense of belonging in engineering. Understanding personal challenges as systemic rather than individual, and recognizing the social construction of engineering knowledge, were so valuable that respondents recommended WGS coursework be required for all engineering students. Our results suggest that the disciplines of gender studies and critical race theory may be powerful avenues to advance the agency and thriving of diverse engineering students.

Introduction

The persistent attrition of diverse students from, and experiences of a hostile climate within, engineering education indicate that while the scholarship on supporting diverse students is varied and robust, it is also incomplete. Important gaps remain. This paper is directed at one of those gaps, specifically, the absence of research on how student engagement with the interdisciplinary, intersectional curricular content offered by Women's and Gender Studies (WGS) programs might support diverse undergraduate engineering populations. In particular, we hypothesize that participation in WGS courses that focus on STEM-related issues—such as critiques of objectivity or the gendered/raced history of scientific and technical knowledge—can have a positive effect on diverse undergraduate populations, especially relative to those populations' formation of engineering identities.

This paper examines how engineering students' engagement with STEM-oriented WGS coursework can support identity development and foster persistence among diverse students. Placing STEM history and cultures directly in the critical frameworks of WGS may help provide these populations with epistemological and personal insights that boost a sense of belonging in engineering and support their persistence.

Numerous studies have addressed aspects of the complex question of student under-representation. The National Academies' *Beyond Bias* investigated the factors contributing to underrepresentation, and determined that biases and structural disadvantages overwhelm talented women and other would-be engineering students. "Women who are interested in science and engineering careers are lost at every education transition," and "the problem is not simply the pipeline" [1].

Concern over the proper metaphor for STEM attrition has long occupied some researchers, and with good reason. At least since Martin's [2] now classic work on conception metaphors in biology textbooks, we have been aware that metaphors can stealthily establish, render "natural," and/or reinforce particular social and cultural assumptions and scripts. Later research has examined how hierarchies of social relations appear in and are bolstered by metaphors deployed in other science literatures [3]. As feminist historian of science Londa Schiebinger notes, "We cannot free ourselves of cultural influence; we cannot think or act outside a culture. Language shapes even as it articulates thought" [4]. These critiques have recently been brought to bear on the "pipeline" metaphor, an image which has long dominated discussions around STEM diversity.

The pipeline metaphor has been the object of critique because it focuses on restricting valves (like math requirements) and on the patching of leaks in order to maintain a "neatly linear march through set academic gatekeepers" [5]. This image not only reduces the complexity of STEM experiences but leaves the "pipeline" itself—that is, the cultures of STEM—unseen and unchallenged. Lacking sociocultural context, it is "an ill-suited frame to understand STEM identity formation, particularly for women and underrepresented minorities" [5], and it does not acknowledge that traditional scientific culture reflects learning styles associated with white men [6],[7]. Since identity is generally understood to be strongly linked to a student's pursuit of, persistence in, and attainment of a STEM education [8],[9], this disconnect is a grave concern.

In place of the pipeline image, the NSF and NSB prefer the metaphor of "pathways," emphasizing the plurality of routes one might take to become a scientist or engineer [10]. Seeking more complexity and nuance, others have proposed that the STEM educational environment be considered a watershed or ecosystem, characterized by diversity and interdependence (e.g. [11]), imagery that reinforces the importance of an overall climate that is welcoming and healthy for all inhabitants. A strength of this metaphor is that it allows for the possibility of doing more than simply passing through a conduit towards an assumed endpoint: within a healthy watershed, all members of the ecosystem grow, develop, and flourish. Rather than merely being "retained" as an individual within a (neutral) pipeline, a member of an ecosystem is part of a group that thrives as an interdependent collective. Metrics for the health of an ecosystem will naturally incorporate intersectionality and complexity beyond traditional recruitment & retention data [12].

However, despite these positive shifts from the limits of the lockstep "pipeline" to the more capacious and humane "ecosystem," metaphors about fostering persistence and thriving are, as a rule, largely confined to the realms of STEM. They invoke STEM classrooms and laboratories, STEM communities and STEM processes (the pipelines of the built environment, the ecosystems of environmental biology). While envisioning different ways of teaching and doing STEM work have been at the center of working for change, it is possible to argue that—as they have sought

ways to be inclusive of all students—STEM fields have also consistently failed to look to all available resources. STEM education has not fully connected with the other educational partners with whom students might productively interact.

The absence of cross-curricular connections as a strategy is apparent when one looks to the standard toolkit of interventions that has been developed over the last twenty years. Most of these efforts address the under-represented students—who must be helped not to leak out of the pipeline—rather than investigating systemic or "watershed"-type hazards [13]-[15]. Some approaches that aim toward broadening faculty teaching strategies rather than protecting students from them include integrating relevant applications of STEM content; emphasizing the societal context and social justice implications of engineering work [16]; and using project-based learning to engage students in real-world applications and collaborative work [17].

Moreover, engineering's tendency to cling to an idea of itself as "apolitical" and "neutral," rather than acknowledging its social construction and baked-in centering of white masculinity, has been shown to be correlated with the marginalization of under-represented participants in engineering culture [18],[19]. The ideology of depoliticization—"the belief that not only *can* cultural and social concerns be bracketed out of engineering, but they *should* be" [19] perniciously casts engineering practice as neutral and objective, and considerations of access, inequity, or social justice to be threats to the "purity and integrity of the field itself." Depoliticization creates interactional norms with dire consequences for whether under-represented groups feel welcomed and included; in effect, it silences both the marginalized and potential allies.

Interrogations of STEM "objectivity" have roots more than three decades deep. Evelyn Fox Keller identified science's reliance on an "objectivist ideology prematurely proclaiming anonymity, disinterest, and impersonality, and radically excluding the subject" [20]. The (false but strongly-held) belief that STEM fields are objective likely helps explain the gap in STEM diversity initiatives identified above. Asking engineering students to learn about the ways in which gender, race, class, global position and other factors have both formed STEM content and shaped the experiences of those engaged in STEM practice is a direct challenge to the concept of STEM neutrality.

*Re*politicization, then—in the form of acknowledging that the culture of engineering is socially constructed, empowering its citizens to *re*construct it, and incorporating sociocultural context and critique in engineering education—could have the opposite effect. Repoliticizing engineering education could reduce feelings of marginalization, and improve under-represented students' ability to see themselves as belonging in engineering.

A student's development of a robust "engineering identity" is critical to student thriving and flourishing [21]. A strong engineering identity has been shown to contribute to students' academic and personal development [22], persistence in engineering [23]-[24], and professional success [25]. In foundational work, Carlone [26],[27] described the related concept of science identity as having three components: competence; performance; and recognition, as well as being situationally emergent, context dependent, and able to interact with other dimensions of identity such as race, gender, etc. As Godwin [28] notes, students developing engineering identities "must negotiate the roles they play within the community of engineering as a discipline, in groups with their peers, and within the classroom." Tonso [25] describes identity development as

"a complicated process through which campus engineer identities (cultural knowledge learned on campus) provided a lens of meaning through which to "recognize" (or not) performances of engineer selves *as engineers*." Particularly for women and students of color, engineering identity can be very malleable and susceptible to change, with persistence and career plans able to be "strongly swayed" by even small interactions or experiences as undergraduates [29].

Institutions themselves foster engineering identity development through displays of solidarity [30] and by referring to engineering students as "engineers" throughout their education—which, as Chachra et al [31] observe, is unusual: "students of history are never referred to as 'historians'." This linguistic habit is also a reminder that engineering is a pre-professional degree, with both its curriculum and its academic culture explicitly tied to professional practice.

Because engineering workplace cultures value such "masculine" ideals as "a fascination with technology, expertise as a tinkerer, and an aggressive style of self-presentation," McIlwee and Robinson [32] argued that women engineers must both display technical competence and also perform masculine norms of attitude and interaction. Dryburgh [30] found that engineering identity development — despite women's academic achievements — was generally more challenging for women engineers because of the need to portray "at least the appearance of willing adaptation to the masculine culture of engineering." Projecting a confident image was part of the professionalization process delineated by Dryburgh—women "learned, at least in part, to mask anxiety associated with the work hard culture of engineering" [30]. In her interviews and focus groups, Dryburgh found that women engineers developed survival and assimilation strategies such as "defining [sexist] behavior as exceptional, working hard to show their solidarity with male colleagues and coworkers, and accepting uncritically the masculine culture" [30].

While such survival strategies may be effective, we suspect there is greater strength to be found in understanding bias to be not "exceptional" but systemic, and in becoming critical of the socially constructed "masculine culture" of engineering. In fact, for individuals experiencing marginalization, there is a power in naming the oppression and theorizing about it [33]. Such theorizing—the work of naming and understanding one's experience as connected to broader systems of oppression—is central to survival and liberation, as bell hooks [34] has argued. Through individual interviews of women in STEM, Secules et al [35] found that narrative theorizing often echoed the tenets of feminism, and developed students' agency and self-determination.

Drawing on the work of hooks as well as Patricia Hill Collins [36], we hypothesized that students who engage with critical theorizing around identity, power and practice would feel increased agency from the act of naming systems of power and oppression and would feel empowered to transform such systems, and that this form of empowered agency might strengthen their identity formation and sense of belonging in engineering. We expected that students who rigorously examined the intertwined workings of identity, power and social/knowledge systems would be less inclined to see challenges or struggles in STEM work as the result of individual inadequacy and more inclined to attribute some obstacles to systemic issues beyond their individual abilities.

Carlone [9],[26],[27] has suggested that identity formation offers a valuable way of thinking about teaching and learning; a way to understand the process of enculturation into the community of practice; and a way to make science education more equitable by acknowledging the social construction of science to help students appreciate their own agency. Through narrative theorizing, students may arrive at an alternative framing of their marginalization, appreciating that the engineering system should change rather than asking individuals to transform themselves to be more valued by that system [35].

In this study, we qualitatively investigate the influence of a Women's and Gender Studies coursework on the identity formation and sense of belonging of engineering students. Our hypothesis was that providing students with the critical frameworks, interdisciplinary methods and conceptual vocabulary associated with WGS would positively influence students' engineering identity formation and support underrepresented students' sense of belonging in engineering.

Methods

The goal of our study was to use qualitative data analysis to understand more about the specific ways in which WGS course content might support engineering students' understanding of themselves as participants in the culture of engineering.

Preliminary data gathering included the exit survey in our institution's Mechanical Engineering department, which asks graduating students about which classes have been most valuable to them and why. In the context of our contextual observations—e.g., the limited conceptualizations of STEM attrition, the selective application of "outside" (non-STEM) research, and the problem of objectivity—these data supported our sense of the importance of learning more about if and how WGS coursework may positively influence diverse students' STEM identity development.

Further investigation focused on students who had completed a STEM-focused WGS course developed and offered at Lafayette College, WGS 250: Gender and STEM. WGS 250: Gender and STEM is described in the college catalogue as follows:

> *WGS 250: Gender and STEM* explores the relationship between gender and STEM fields. It examines how stratified social systems— principally organized around gender and gender identity, and also race/ethnicity and sexual identity—intersect with STEM-related areas of inquiry. Using a variety of interdisciplinary perspectives, WGS 250 investigates how STEM fields *both shape and are shaped by* ideas and assumptions about gender and identity. Topics include feminist critiques of science, intersections of gender with technology design/use, gender and the built environment, and links between gender and "doing" STEM.

This course was developed by one author of this study, and was first taught at Lafayette College in 2016. Over the four offerings thus far, it has consistently used the reading list shown in Appendix A.

Students in WGS 250 were asked at the conclusion of the course how it had influenced them and what benefits it might have for continued study in their major discipline. The details of these surveys and results of coding responses are discussed in [37].

In order to explore more deeply the themes arising in students' survey responses, and to better understand their personal and group feelings, perceptions and opinions, we performed focus group interviews with engineering students who had completed WGS 250. Facilitated focus groups have been shown to be effective at offering access to "participants' own language, concepts and concerns" in "social contexts for meaning-making," comprising a feminist methodology appropriate to our research questions and goals [38].

The focus group portion of our study was exempted from requiring approval by our institution's IRB after review in summer 2019. Engineering students who had completed the WGS 250 course in Spring 2018 or 2019 but had not yet graduated ($N = 7$) were invited to one of two focus group sessions held in February, 2020. The invitation included a description of the study and an assurance of confidentiality.

Informed consent was obtained from the study participants in writing before any questions were posed. Discussions were facilitated by one author and a faculty colleague, neither of whom had served as an instructor for any WGS class. Focus group facilitators provided copies of the WGS 250 reading list as a way of reminding participants of past course content and providing reference points for specific reading and authors. In keeping with best practices for focus group interactions, discussions were held in a seminar classroom selected for its comfort, relative privacy, and lack of distractions. With participants' consent, the discussions were audio recorded by the facilitators and the recordings transcribed by a third party service. The transcriptions were reviewed for accuracy by the facilitators.

During the focus group interviews, facilitators posed two primary questions: (1) What effects, if any, did your WGS class have on your personal experience as an engineering major?, and (2) What effects, if any, did your WGS class have on your perspective on your academic field itself?, with follow-up questions as necessary. Participant responses were coded according to their alignment with themes [39] observed in preliminary data [37].

Ten students participated in focus group interviews: five engineers, and five students majoring in other science or math disciplines. All participants identified as women; 3 of the engineering participants also identified as members of a second underrepresented group (LGBTQ+ status, racial and/or ethnic identity, and/or national origin). Due to the small numbers of students involved, to preserve students' anonymity we will not report their ethno-racial breakdown in further detail. Detailed analysis of the course exit survey and focus group data including non-engineering participants is reported in [37]; this paper will focus only on engineering students.

Results

Mechanical Engineering Exit Survey: Graduating seniors in mechanical engineering at Lafayette College annually complete an exit survey in which they identify their most valuable classes both within and outside their major. 4 of the 62 members of the class of 2018, as well as 6 of the 50

members of the class of 2019, reported their most valuable non-engineering class was a Women's and Gender Studies course (either WGS 101, the introduction to this field, or WGS 250, Gender and STEM). Data from our Office of Institutional Research (OIR) indicates that a WGS class had been taken by 5 of the 62 members of the mechanical engineering class of 2018, and 9 of the 50 members of the mechanical engineering class of 2019. Thus a high fraction report WGS classes to be the "most valuable" of the 20 non-STEM classes they took at our institution: on average, **70% of those who had taken a WGS course as one of their 20 non-engineering courses found it to be the most valuable.**

We noted an overall increase in participation, as well: 8% of mechanical engineering students completed WGS courses 2018 while 18% and 16% did so in 2019 and 2020; in all other majors across the college, an average of approximately 14-16% of all students take WGS. This increase may indicate the strong positive reputation WGS courses have within Mechanical Engineering.

Mechanical engineering students are also asked *why* the specific course they identified was valuable. Respondents who took WGS courses ($N = 23$) noted that WGS coursework "made me a more aware, conscious, active member of society," was "eye-opening;" "help[ed] me understand what was happening around and to me," and recommended WGS "should be mandatory for all students." Even this small number of responses reveals STEM identity-related developmental patterns that can be coded [39] into two primary themes:

- **AWARENESS OF SOCIAL SYSTEMS** Acquiring an awareness of systemic privilege/oppression based on identity groups, and shifting from the individual experiences to systemic processes. Learning to identify challenging personal experiences as understandable social phenomena.
- **INCREASED CONFIDENCE AND AGENCY** Gaining new feelings of preparedness for the future in STEM, including readiness for STEM career, and Gaining an increased sense of agency and control of through "knowledge tools" and related data (understanding implicit bias, etc)

A demographic breakdown of these students is shown in Table 1. From these data we observe that while the overall percentage of ME students who completed some WGS coursework was 8, 18, and 16% respectively in the classes of 2018, 2019, and 2020, the percentage was significantly higher for students from historically marginalized or "underrepresented" backgrounds: 28%, 50%, and 60% of women in the classes of 2018, 2019, and 2020 chose to pursue WGS coursework; 25%, 33%, and 60% of students from "domestic under-represented groups" did so. While the relatively small numbers of students involved is a limitation of these findings, the numbers suggest that this coursework is particularly relevant for and sought out by these students. This supports further investigation of the influence WGS coursework may have on attitudes and beliefs, particularly for students experiencing marginalization in STEM.

Table 1. Demographic data for mechanical engineering students who did or did not take a course in Women's and Gender Studies. Demographic categories are those used by Lafayette College's Office of Institutional Research.

	ME BS Class of 2018 N = 62		ME BS Class of 2019 N = 50		ME BS Class of 2020 N = 57	
	Did not take WGS	Took WGS	Did not take WGS	Took WGS	Did not take WGS	Took WGS
Domestic caucasian	43	2	30	6	40	6
Domestic URG	8	2	6	2	5	3
International	6	1	5	1	3	0
Female	7	2	10	5	10	6
Male	50	3	31	4	38	3

Focus Groups: Focus group discussions reinforced students' sense that WGS coursework had been clarifying or expanding, particularly in revealing systemic issues and providing a vocabulary that liberated students from the sense that negative experiences had been due to individual inadequacies or mistakes.

In the course of discussion, focus group participants had the opportunity to articulate how their WGS course had contributed to their "fit" in their major, and thus to their engineering identity. Two representative statements follow:

- "When I first decided on [disciplinary] engineering, I didn't second guess my decision because I grew up with strong female presences in my education. But, after several semesters of seeing many women and people of color drop the major while my internships were in heavily white/male environments and the curriculum focusing on white/male accomplishments I began to seriously question my place. After taking WGS 250, it's easier to do something about it and like possibly change your surroundings or talk to someone about it or just like—I don't know—just take it less personally, I guess, and understand that this is, like—things are structured in a way to make you feel like you don't belong, it's not that you don't belong."
- "On an intellectual level I fit very well into my field of study. However, it is noticeable that I am often one of the only women in the room and the vast majority of my professors have been male. I also do not fit society's norm for what an engineer should look like. In meetings with lab technicians and stakeholders for my final year project, they are surprised to find out I'm an

> engineer and not an art student helping out. I think [the WGS class] just made me a lot more aware of possible biases that people would be experiencing and, kind of, experiencing that power that goes along with putting names to things where maybe you had had a bit of a feeling like, 'Oh, maybe that's just me that I'm not feeling confident in this' or, 'I feel like I have to do x, y, z' to compensate. But actually putting a name to it and realizing that a lot of these experiences are shared or is a shared experience with women in STEM was empowering and it was—yeah, so you're able to actually put words to feelings."

In these comments we observe students' articulation of their conversion from an individual to a systemic understanding of structural biases: "things are structured in a way to make you feel like you don't belong," permitting them to "take it less personally" and feel less inclined to "question" their "place" in engineering. They also felt more capable of changing those structures: feeling "power" from their knowledge, and stating "It's easier to do something about it." Gaining the vocabulary and knowledge tools of WGS — "putting a name to...these experiences," and gaining the understanding that "these experiences are shared...with women in STEM," was empowering, confidence-building, and liberatory. Students mentioned particular phenomena that, once understood as systemic and commonly experienced, felt less obstructive: "There were some other females that I knew in the class, and a lot of us had conversations about that outside of lecture on how we all really identified with that term of imposter syndrome and how there [hadn't been] a word to go along with it beforehand, but once we learned about this term, it really clicked."

Student comments also resonate with engineering identity models and measures. Carlone and Johnson [9] proposed that the strength of one's STEM identity depends on their competence, performance in public settings, and recognition for their competence and performance. "Typicality" is one measure of identity — "I am similar to the other people in my discipline in ways that make me feel like a typical representative." These students notice their atypicality, but after the WGS course they feel recognized for the way they "break the mold," "disprove the doubters," and that their atypical identity contributes to their competence and value.

The experience of the WGS course was a positive factor in these students' persistence in engineering, and in their development of a sense that, as one participant put it, "if people don't think I fit, that's on them." Their comments in the focus group discussions reflected increased STEM confidence and agency: "I compete more with men to prove stereotypes wrong," and "I feel well equipped to address implicit bias." Somewhat surprisingly, despite being offered across campus in a non-STEM discipline, the course also had a positive impact on their sense of belonging in STEM: "This class [WGS] has made me feel more at home in the STEM field than any of the 15+ STEM classes I've taken."

Multiple participants used the language of clarifying vision or revelation for their WGS experience: glasses, lenses, and veil-lifting were all common metaphors. Follow-up questions surfaced the source of this revelation: being exposed to the critique of scientific objectivity/neutrality and developing an understanding that STEM products and practices reflect cultural context and social construction. In the words of one student, "looking at how the biases of the person who's making that program can reach into an algorithm was very interesting. And there was a lot on the design process in engineering. That's something that I feel like will be

directly affecting me in the workplace later in thinking about who's on the design team… Is this 'the average person on the design team' or 'the average person' that we're looking at?" In dialogue, students discussed the effect that these new visions had on them:

> Subject 5: This class made me see so much — so many things in STEM that are gendered, without anyone questioning that they are. And the whole concept of stereotype threat, I had no idea about before I got to this class. And it made me see everything in [the engineering building] as like... Oh, wow. You walk in and you see this like timeline of important people in engineering and they're all white men.
>
> Subject 4: There's definitely subtle clues to where students are welcome and not welcome.

The students in our study identified this issue, and described feeling empowered to apply their WGS knowledge in support of other students experiencing marginalization. Examples of the opposite impulse had been discussed in WGS 250: "The people who make it through, [who] are able to finish despite all of the adversities that they face and all the extra loopholes that they have to go through being a woman in STEM, [we talked about] how there can be a tendency to kind of pull the ladder up after you. So it's like I had to suffer through all of this, so you've got to suffer through it too. And, I felt the opposite: you're supposed to try and make it easier for the people that come after you. So that made me want to be better about making it easier for those that come after me."

Relatedly, students in the focus groups described sharing ideas from WGS 250 or even persuading others to take the class because of its empowering and liberating effects on themselves. The following dialogue is representative of this theme:

> Subject 1: I really liked [the main text for the course, *Gender and Science*] because it had very "hard science" experiments proving why you would be feeling certain ways or why certain biases existed. And for me that was very reaffirming and so I knew that's something [my friend] would appreciate as well and so I gave her the book.
>
> Subject 2: How I convinced my friend to take [WGS 250] was, [I explained that] it really put things more in context. And like, I guess, everyone knows that gender biases or biases exist but not really knowing the science behind it or like how real it is and how implicit bias can be a big thing. And just in general how it helps you think more critically of stuff.
>
> Subject 3: Yes, I've convinced two of my friends to take this class this semester. They're both [science] majors, but yeah, I feel like when I was explaining it to them since I know that they both want to get into research, I was saying, "It really makes you critical of the research that you're doing,and it just gives you a broader spectrum in which to look at a problem."

> Subject 4: I don't stop talking about this class, to people that'll listen to me. I'd never shut up about it.

Focus group interviewers then asked the participants who the ideal audience for the class would be, and at what point in a student's education they would be most receptive and responsive to the material.

> Subject 4: I think it's good for everyone. Because you're either in the position where this is affecting you and you need that, sort of, affirmation that like "I'm not the only on experiencing this," or you're the one that's not experiencing this and you need to realize that like —not, "I have it easy," but "I can help this issue."
>
> Subject 3: Yeah.
>
> Subject 5: And then it's also like you get women in STEM who —or other, I guess, minorities—who sort of just over time will learn this information, just through firsthand experiences. But then you get the typical white male, cis, straight people, that just... Like if you don't ever know that this is going on, because you're never experiencing it, then you can't be an ally to anyone.
>
> Subject 1: [WGS offers something] even male students say that they're missing in terms of criticizing a design process.
>
> Interviewer: So, when is the ideal *time* to take the class?
>
> Subject 3: Either having it late in the curriculum, where people are looking back on their time and like possibly having regret — or you risk doing it early and people are not ready for it and they don't take it seriously, which I know happens.
>
> Subject 4: I just so wish that I had taken this class earlier, that I think it should be earlier rather than later. But I do agree that freshman year might be too soon.
>
> Subject 3: And just thinking about like my own experiences of freshman year, if I had taken this class like my first or second semester, I would have just been so depressed, like so deeply depressed, and not gotten as much as I could out of it, and not channeled that into anger, as I did while taking it (laughter) at the time that I did. I just didn't have the confidence in my environment to be able to use this class, as a freshman.
>
> Subject 2: But you want to take it early enough to allow the class to impact how you interpret things and possibly your own behavior as well.

Our focus group participants identified sophomore year as a "sweet spot" in which WGS knowledge would be welcome and applicable without being demotivating, suggesting that having experienced some of the challenges of the first year, students would recognize their own experiences (it's not just *me*!) without becoming overwhelmed and demoralized by the systemic biases within the culture of STEM (it's *not* just me). They agreed that while the perspectives and methods offered by WGS were particularly relevant for those experiencing marginalization,

those in the majority would also become more effective allies and collaborators once "armed" (or in the words of one student, "weaponized") with WGS knowledge. Students expressed concern that some peers would resist the systemic, socially-constructed-not-objective view, and that by reacting poorly might reduce the positive impact on others.

An additional method of visualizing the focus group findings is through a word cloud in which words are sized according to the frequency with which participants used them in discussion [40]. In line with best practices [41], the transcripts of recorded discussions were used to generate the word cloud shown in Figure 1. The preeminent sizes of Critical, Lens, and View in this image are consistent with the dominant themes observed.

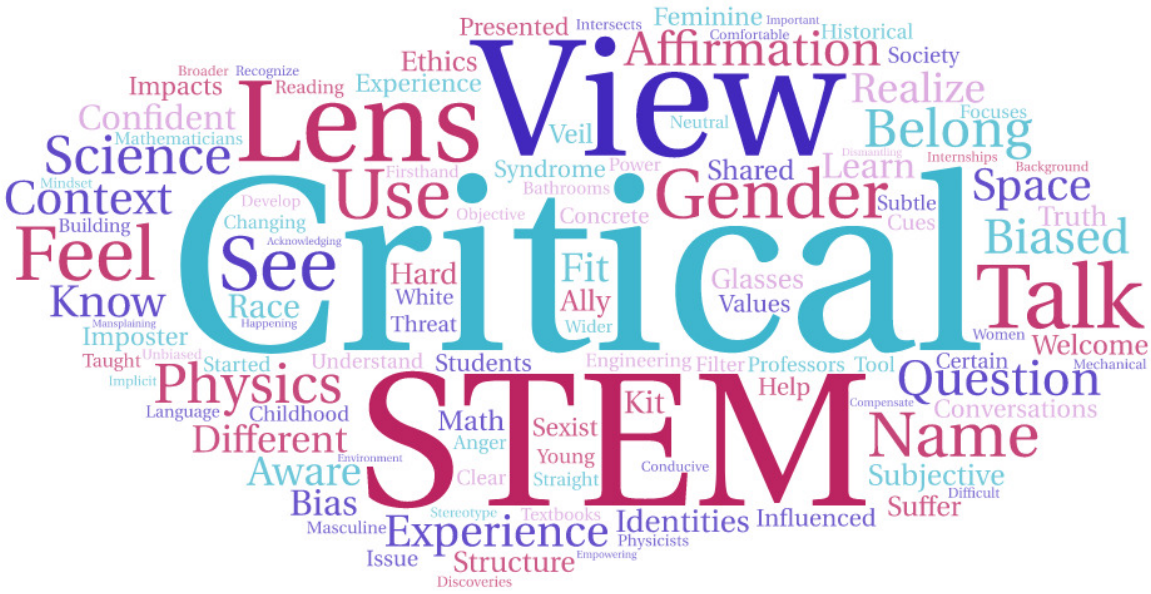

Figure 1. Word cloud generated from interview subjects' responses on focus group transcripts.

Discussion

Significantly, the same three themes arose powerfully in both of our qualitative instruments. These were: (1) a shift in students' understanding of their STEM experiences from the individual to the systemic; (2) increased agency and confidence through knowledge tools; and, (3) a critique of STEM objectivity. These three themes align with our hypothesis that diverse engineering students would be empowered by engaging in WGS' use of a critical lens to examine patterns of identity and dis/advantage in STEM.

Engineering students who engaged with critical theorizing around identity felt increased agency from the act of naming systems of power and oppression and, as a result, felt empowered to act in opposition to such systems. As we hypothesized, this form of empowered agency strengthened their identity formation and sense of belonging in engineering. To quote one focus group

participant, “it’s not that you don’t belong,” it’s that “things are structured in a way to make you feel like you don’t belong.”

In both surveys and focus groups participants described their WGS experience as clarifying vision or revelation: glasses, lenses, and veil-lifting were common themes. Our subjects perceived themselves as having been unknowingly constrained by an uncritical view of STEM, and felt empowered — *and made better engineers* — by a more contextualized one: “WGS provided a really useful lens through which to look at STEM critically. It made me think more critically about the studies I read, my own biases, and how I can design better,“ said one engineering student. This is consistent with the work of Cech [19] and Pawley [42] and with Evelyn Fox Keller’s notion that the myth of STEM objectivity perpetuates exclusion and marginalization. Our findings suggest that an understanding of STEM’s non-neutrality is empowering and liberatory for some underrepresented students in engineering, and correlates with their sense of belonging and engineering identity development.

This finding also resonates with the work of Bielefeldt [43] on the role of empathy and the ethics of care in engineering projects, which she found were particularly important to historically marginalized students: “If students feel that engineering can help others but the general culture of engineering does not embrace this identity, students may feel that they don’t “fit” within engineering. This feeling could result if students don’t see social context in their core engineering courses.” Greater contextualization of engineering knowledge and more appreciation of the impact culture has on engineering makes students more likely to see the social impact they can have as engineers, and thus to feel that their desire to “care” is a good fit with engineering culture, and a valuable part of their own engineering identity.

A STEM identity enables people to “think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science” [44]. The related concept of engineering identity has been shown to have a significant role in educational success [22], persistence [23-24], and career trajectories) [21]. Students’ sense of engineering identity has been understood as comprised of (1) individual interest, desire and curiosity about engineering; (2) individually perceived performance and competence in engineering; and (3) recognition from others as an engineer [28]. Our focus group participants found themselves more interested in a contextualized, socially constructed sense of “engineering,” and found their confidence in engineering enhanced, after exposure to their WGS coursework.

Karen Tonso has demonstrated that “engineering identity” may be usefully understood as culturally produced and contextualized, and that measures of “typicality” obscure “enculturated, complicated, profession- and site-specific ways to belong that encode ideologies of privilege” [25]. The methodologies of WGS, including critical theorizing around identity, power, privilege, and practice, are well-suited to provide students knowledge tools with which to construct and understand such engineering identities. Indeed, the participants in our study reported feeling increased confidence and belonging in their engineering classes and projects, and recognized the distinct value they contributed to the engineering community and profession as women (among other marginalized identities).

Liechtenstein et al’s [29] study of engineering students’ career decision making yielded several insights, including one about the potentially large impact of small actions: “[D]uring the span of

students' tenure as undergraduates, their thoughts about career options were strongly swayed—we could even say disproportionately swayed—by a single experience, such as an internship, interaction with faculty or even staff, or advice from a mentor." The large impact of small variables observed in [29] support the current study's implication that a semester-long WGS experience could have a game-changing effect, especially in the context of how highly mutable, and even fragile, early engineering identities can be.

Within STEM classrooms, STEM faculty can develop marginalized students' sense of a "legacy of competence" by highlighting the historical contributions of diverse scientists and engineers [45]. Dasgupta and Stout [46] have found that a "stereotype inoculation model" enables women to develop stronger implicit STEM identities through exposure to positive cues in their surroundings. The current study suggests that this valuable work within STEM may be valuably supplemented by students' experience in other disciplines. The WGS framework and scholarship gave the students in our study a different, wider-lens view of engineering itself, and enhanced their sense of STEM identity.

Pawley [42] argues that "feminist science studies are particularly relevant to engineering and engineering education, namely, for scrutinizing what 'counts' as engineering content and why." Our participants felt strongly that all students should be exposed to the theory and methods of WGS. They identified ways in which this knowledge was helpful to those experiencing marginalization within engineering, and also ways in which it would help members of the dominant culture be more effective allies and collaborators themselves. This harmonizes with Karen Tonso's finding that "Identity is not merely something that people express about themselves, or shape in the presence of other forces; it is also and simultaneously something that learning communities make of people." [25] If more members of the learning community have access to an understanding of systemic oppression and feel empowered to reconstruct their culture, they may enlarge their own sense of "who does engineering" and thus make strong engineering identity more widely available. This is consistent with the notion that "feminist critiques of science are crucial to improving scientific theory and practice" for all participants [42]. Engineering education for all students is deepened and strengthened by its "re-politicization;" in WGS terms, "feminist critiques of objectivity, and the struggles to theorize concepts like voice, authority, identity, ways of knowing and positionality" may be as influential in engineering as they have been in the social sciences [42].

We caution that if a WGS or similar class is integrated into an engineering program, it should not provide an occasion for engineering departments to abdicate responsibility for facilitating their own, distinct conversations. Rather, it should be a moment for intentional partnerships. Exposure to and engagement with WGS concepts and methods is important for supporting diverse engineering students—it may even, as some of our study participants suggested, be necessary—but it is not sufficient. Adding this innovative and possibly transformative approach to the "toolbox" does not exempt engineering cultures from continuing to actively engage in inclusive transformation. Our results suggest it will be particularly valuable for engineering students to dismantle the myth of "neutrality" and "objectivity" within the culture of engineering: acknowledging that the culture of engineering is socially constructed, empowering its citizens to *re*construct it, and incorporating sociocultural context and critique in engineering education. For example, the feminist frameworks offered by Riley et al [47] offer a range of questions

engineering educators could address with their students in order to make visible the gendered and racialized history and culture of engineering.

This study is limited by the self-selection of students choosing to enroll in WGS 250, which could indicate a pre-participation bias in terms of personal interest or knowledge around social justice, anti-racist or feminist issues. Similarly, focus group participants are self-selected, which could also limit the generalizability of our results. Focus group data on changes in student perspective are self-reported and could therefore be affected by social desirability bias and/or confirmation bias, as well as by demand characteristics within the study.

Conclusions

Through survey responses and focus group interviews, this work found that students' experience in a STEM-focused WGS course was empowering and liberatory. Engineering students with historically marginalized identities who engaged with critical theorizing around identity, power and practice felt increased agency from the act of naming systems of power and oppression and, as a result, felt empowered to act in opposition to such systems. As we hypothesized, this form of empowered agency strengthened their identity formation and sense of belonging in engineering. Courses like WGS 250 can help shape an understanding of science and engineering for all students — particularly valuable at an institution like ours where the divide between engineering and "everyone else" is significant.

Our subjects felt so strongly about the positive impacts of these courses that "they ought to be required." Along with WGS, fields such as Ethnic Studies, Queer Studies and Indigenous/Native Studies (for example) may offer or develop courses focused on STEM-oriented topics that also directly connect engineering students with knowledge of systems of systemic disadvantage in the STEM cultures and bias in STEM practicies.

Our qualitative research addressing the question of how WGS coursework influenced the attitudes of engineering students found that students felt empowered, provided with increased agency and a strengthened, expansive sense of their own engineering identity. The movement from a sense that challenges were individual to an understanding of systemic bias and power structures was linked to an increase in STEM self-esteem and confidence.

Participants repeatedly described their WGS experience with language of clarifying vision or revelation. Our findings suggest that an understanding of STEM's non-neutrality is empowering and liberatory for some underrepresented students in engineering, and correlates with their sense of belonging and engineering identity development. In addition to the clear benefits we observed for students from historically marginalized and excluded identities, courses like WGS 250 can help shape what counts as engineering for all students, and thus contribute to the transformation of the culture and biases of engineering.

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Appendix A: Reading list for WGS 250: Gender and STEM

WGS 250: Gender & STEM Reading List

Objectivity and Feminist Science Studies: Gender and Race
Simone de Beauvoir, Excerpts from The Second Sex
Evelyn Fox Keller, "Gender and Science"
Sandra Harding, "Thinking about Race and Science" and "With Both Eyes Open" (from Science and Social Inequality: Feminism and Postcolonial Issues)

Life Sciences: Nature, Nurture, No Thanks?
Londa Schiebinger "Biology"
Emily Martin "The Egg and the Sperm"
Upchurch and Fojtova "Women in the Brain: A History of Glial Cell Metaphors"
Anne Fausto-Sterling "The Bare Bones of Sex, Part I: Sex and Gender"
Cordelia Fine, Delusions of Gender: How our Minds, Society and Neurosexism Create Difference (pp xv-117)
Cordelia Fine, Delusions of Gender (pp 118-239)

Human Genome Project
Barbara Katz Rothman, "For Whom the Bell Curves, "Rates and Races," "The Human Genome Diversity Project"

The "Science" of Homosexuality
Jennifer Terry, "Anxious Slippages Between 'Us' and 'Them:' A Brief History of the Scientific Search for Homosexual Bodies"
Roger Lancaster, "Familiar Patterns, Dangerous Liaisons"
FILM: Changing Our Minds: The Story of Dr. Evelyn Hooker, dir. Richard Schmiechen

Sexual Selection
Sarah Hrdy, "Empathy, Polyandry and the Myth of the Coy Female"
Joan Roughgarden, "The Theory of Evolution"

Physics and Math
Londa Schiebinger "Physics and Math"
Barbara Whitten, "(Baby) Steps Towards Feminist Physics"

Tech/Computer Science
Judy Wajcman, "Feminist Theories of Technology"
Bardzell, "Feminist Human Computer Interaction (HCI)"
Elizabeth Churchill "Gender and Design"
Jane Margolis "Normalizing the Racial Divide" and "Claimed Spaces"
Carol Cain Miller "When Algorithms Discriminate"
T.L. Taylor, "Becoming a Player: Networks, Structures and Imagined Futures"
Nick Yee, "Maps of Digital Desires: Exploring the Topography of Gender and Play in Online Games"

Engineering and Design
Judy Wajcman, "The Built Environment: Women's Place, Gendered Space"
Patricia Hill Collins, “Toward a New Vision: Gender, Race and Class”
Koskela and Pain, “Revisiting Fear and Place: Women’s fear of attack and the built environment”
Foor and Walden, “‘Imaginary Engineering’ or ‘Re-Imagined Engineering’: Negotiating Gendered Identities in the Borderlands of a College of Engineering”

Gender and “Doing STEM”
Virginia Valian “Gender Schemas at Work” and “Effects on the Self”
Margolis et al “Geek Mythology” and “Living among the Programming Gods”
Moss-Racusin et al, “Science faculty’s subtle gender biases favor male students”
Molly Dingle, “Gendered Experiences in the Science Classroom”
Melanie Tannenbaum, “The Problem when Sexism Just Sounds so Friendly”
Rebecca Solnit, “Men Explain Things to Me”
Gendered Innovations (Londa Schiebinger, Stanford University)