”I’m Not Like a Human Being”: How the Teaming Experiences of African American Females Reveal the Hidden Epistemologies of Engineering Culture

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Abstract

Engineering culture consists of the knowledge and traditions of the hegemonic, middle-class, white, male majority in the field. The default dominance of whiteness and masculinity can be perceived as unwelcoming to traditionally underrepresented and underserved student populations, like women of color (WOC). As a result, engineering culture may serve as an invisible boundary for WOC to gain positive experiences in the field. This invisible boundary is understood, in this paper, as the hidden epistemologies in engineering: the unspoken but understood rules about knowledge and knowing that influence interactions in engineering spaces. Unacknowledged problematic engineering epistemologies (e.g. hidden curriculum) create an invisible gap in knowledge, specifically for women (and more so for WOC) and their experiences. We utilize the theoretical backing of hidden epistemologies to answer the research question: How do the experiences of WOC on engineering teams reveal the hidden epistemologies embedded in engineering culture?

To answer our research question, we performed a secondary analysis on interview data from a larger study using a phenomenologically informed procedure to identify hidden epistemologies embedded in the participants’ experiences. We used interviews of nine undergraduate engineering students who self-identified as “African American” and “female” on a screening survey and an open coding method. These interviews centered around the participants’ engineering teaming experiences, and within them, we found evidence of the hidden epistemologies of engineering. Specifically, we noted that knowledge is filtered through the majority white, middle-class, male shared identities that form engineering culture, and technical knowledge is valued more than other types of knowledge. The fact that these hidden epistemologies were revealed in data on engineering teams also implies that hidden epistemologies are revealed and reinforced through the social interactions and phenomena of the education process itself.

Implications of this work reveal that some difficulties experienced by WOC in engineering teams have epistemic origins and may serve as barriers to entry into engineering. By addressing and changing these fundamentally problematic epistemologies that drive engineering culture, engineering education researchers help to reform engineering culture so the ways of knowing cultivated in engineering do not oppress the ways of knowing formed from WOC’s experiences.

Introduction

Engineering needs new ideas to keep pace with the increasing demands of infrastructure and technological development in today's world. Diversity of thought, experience, and knowledge are necessary to meet these demands in engineering. Women of color (WOC) are an underrepresented and underserved community [1] in engineering who can offer underutilized intellectual capital. Despite efforts in engineering education, however, WOC remain repressed in engineering as well as most university-level engineering programs in the US [2]. A possible reason for the repression of WOC in engineering may be from the underlying epistemologies of the field itself.

The foundational epistemologies of engineering in the US were established in the mid-19th century through engineering societies in various universities [3]–[7]. Not surprisingly, due to the sociopolitical climate in the US at the time, the only individuals with access to these societies (who therefore shaped their values and cultures) were white, cisgender, heterosexual men [8]. Though we see more diversity in engineering today than when the discipline was first established, the foundations of the field continue to perpetuate problematic practices and beliefs in engineering culture. For example, engineering has been described as a "chilly climate" for women and those with non-centered identities [9]–[12]. Researchers have also shown that women have reduced senses of belonging within the standard engineering culture [13]. Despite numerous efforts to increase women's involvement in engineering [14], [15], the climate in the profession continues to be a barrier.

As further evidence that the foundational culture of the hegemonic, white, male majority plays a role in modern engineering practices, Slaton [16] argues that engineering is just as much about the engineer performing as it is the act of engineering itself. Slaton states that "in science and engineering the validity of findings at the bench derives from the experimenter, not the experiment; [just as] the reliability of a building material or industrial product is determined by the tester, not the test" [16, p. 175]. The process of engineering cannot be separated from the engineer, and the engineer cannot be separated from their identities. As a result, the culture established by the forefathers of engineering (an exclusive group with identity- rather than merit-based qualifiers) influences engineering today. Because of this influence, women enter engineering learning environments and the field at a disadvantage. Simply put, women, and especially WOC, experience systemic repression in the white supremacist, patriarchal, capitalist, and imperialist culture of engineering [17], [18]. The impact of these four ideologies (white supremacy, patriarchy, capitalism, and colonization) are captured in the hidden epistemologies of engineering culture. While we acknowledge that these hidden epistemologies systematically marginalize women and gender-nonbinary people [19], [20], we choose to focus on women within the gender binary in this paper.

We utilize the theoretical backing of hidden epistemologies to answer the research question: How do the experiences of WOC on engineering teams reveal the hidden epistemologies embedded in engineering culture? To answer this research question, we look at the engineering teaming experiences of African American females in a diverse range of engineering disciplines.

Background

Teams are a necessary and vital aspect of the engineering profession, and the process of teaming has been studied widely in engineering education research (EER) and beyond [21]–[26]. The real-world problems engineers face are interdisciplinary and complex, requiring a group of

individuals offering different backgrounds and areas of expertise to solve them. As a result, group projects requiring teams have become a staple in engineering curriculum [21]. Examples of engineering team projects include freshmen design projects to capstone senior design projects, including laboratory projects in the middle years [27]–[29].

Engineering teams offer a mode for interdisciplinarity and task delegation so students can finish large and complicated projects within the span of a course. What is not often taught, however, are the various skills necessary in the social processes that make teaming effective: communication, delegation, and conflict resolution, to name a few [30]–[32]. The social circumstances in which these skills become relevant can reveal hidden epistemologies that guide the teaming process, especially when gender differences and dynamics are considered [21]. Within engineering, these epistemologies are woven into the culture of engineering learning environments and often the engineering field itself [18]. Therefore, we sought data from engineering students' teaming experiences to show engineering's hidden epistemologies.

Theoretical Backing

We employed the theoretical backing of hidden epistemologies to guide the data processing for this paper. To articulate the findings regarding hidden epistemologies properly, we briefly define epistemology and briefly summarize how hidden epistemologies have been studied in EER. Based on theory from the discipline of education, Hofer and Pintrich [33] define epistemology generally as "an area of philosophy concerned with the nature and justification of human knowledge" [33, p. 88]. In the discipline of science education, Topcu [34] defines epistemology as "the study of human knowledge and knowing" [34, p. 1]. In this study, we define epistemologies as "ways of knowing" [36], or individuals' thoughts surrounding knowledge or acquiring and retaining knowledge. With this definition, we define hidden epistemologies as the unspoken, unacknowledged ways of knowing that guide engineering in educational spaces as well as the field. Though this terminology may be less common in EER, hidden epistemologies have been studied in this field as hidden curriculum [37]–[39].

The term "hidden curriculum" was coined by Philip Jackson [40], and it has been operationalized in EER to mean "the unwritten, unofficial, and often unintended lessons, values, and perspectives made by individuals and found in physical spaces within an academic environment" [39, pp. 2–3]. One way researchers have distinguished hidden curriculum from formal curriculum is by delineating context. Formal curriculum is concerned with the "cognitive" or "academic" aspects of learning, while hidden curriculum is concerned with the "social" or "environmental" aspects of learning [41, p. 188]. Though all types of learning are cognitive in nature, the social experience of education in a specific learning environment requires extra skillsets that the purely cognitive practice of knowledge retention, regurgitation, or interpretation (practice of learning) may not require. The skillsets involved in the social practice of learning are what hidden curriculum captures.

In engineering learning environments, hidden curriculum is connected to the underrepresentation and repression of WOC in the field. This is because knowledge and ways of knowing play a role in power dynamics and control such that the hegemonic majority maintains dominance over the cultural narrative [42]–[44]. The hidden curriculum in engineering reflects the epistemic origins of the profession, which assert the values and norms upheld in engineering learning spaces as well as the field. These engineering epistemologies are unspoken and unacknowledged (hidden), which can serve to limit underrepresented and underserved communities in engineering learning

environments. We identify the hidden epistemologies that emerge from the teaming experiences of African American females and recognize their role in impacting these students' experiences as engineers.

Methods

Methodology

We performed secondary analysis on interview data from a larger study using a phenomenologically informed coding procedure. The data were originally collected using a phenomenological methodology. Because phenomenology seeks to highlight "shared experiences" between participants [45, p. 199], we used open structural coding to find the emergent main codes common between the participants, and we followed this with pattern coding. The results highlighted in this paper stem from one main code that emerged from this process: hidden epistemologies, which is defined with two subcodes in Table 2.

Positionality

The context of white supremacy and patriarchy in engineering impacts each of the authors of this paper in unique, nuanced ways due to how the systems of power and oppression interact with our intersectional identities. To provide transparency in how we approach these concepts and to add context to this work, we have provided positionality statements for each author on the research team [46].

Author 1: I am a heterosexual, white woman raised by two working-class parents in a double-income household. Both parents are first-generation college graduates from the Midwest, and they raised me and my two siblings in Orange County, California. I graduated from a private, teaching-focused university in Texas with bachelor's and master's degrees in civil engineering with an emphasis on structural engineering. I also worked for three years as a structural engineer before going back to school and pursuing engineering education. My education and career in engineering took place in predominantly white, male settings. Because of the privilege I experience as a white person and the sheltering of experiences that my privilege offers, I have undergone a massive amount of learning to identify systems of oppression embedded in the culture that may limit others in the profession. My goal with my research is to explore norms in engineering to understand and identify systems of oppression embedded in the culture that may limit marginalized communities in the profession.

Author 2: I am a queer, white woman raised by upper middle-class parents in a suburb to a mid sized Southeastern city. I attended a mid-size public high school that was mildly diverse in terms of race and socio-economic status. I attended the same large, research-focused, public land-grant university as my parents and sister to study biomedical engineering. I was not present during data collection to hear the participants' voices or see their facial expressions and can therefore only draw conclusions from their transcribed words. I cannot relate to many of these women's experiences first hand because of my identity as a white woman. Although I do have the marginalizing identity of being a homosexual woman, this is an identity that can be made "invisible" if need be by altering my presentation. I recognize its contrast to a "visible" marginalizing identity such as race. I have investigated teaming experiences in several capacities as well as experiences of women in STEM. I have a strong interest in expanding inclusion efforts in engineering and have participated in several mixed methods projects in engineering education.

Author 3: I am a cis, heterosexual white woman with a strong Catholic identity who has been studying issues of oppression, equity, and inclusion for more than 20 years—including recent work on these issues in engineering education. I am a second-generation American whose grandparents immigrated from Italy and from the Austria-Hungary region in the early 20th century. Growing up in a working-class family embedded in a strong immigrant—predominantly Italian—community just north of New York City, I then moved to a mid-sized city in central Pennsylvania. Neither of my parents attended college, and both worked in factories (as a secretary and machinist). However, while their education marks me as a first-generation college student, both of my parents helped support my siblings through master's and law degrees at Stanford and Cornell, respectively, and education was both a family and a community priority. A persistent concern in my work, intersectionality formed a key component of my doctoral research in the 1990s.

Author 4: I am a Black, female, same-sex loving engineering professor with strong beliefs around spirituality. I am a first-generation PhD in my family and was raised in a racially and economically segregated large city in the Midwest. My research agenda is to broaden participation in engineering. My previous research investigated the experiences of multiple marginalized groups including women of color and members of the LGBTQ spectrum. I typically take an intersectional approach to identity in research and I am passionate about giving voice to those often overlooked in the business of educating engineers in the U.S.

Recruitment and Participants

The interviews used for this study stem from a larger, phenomenologically informed qualitative study. The nine students opted in to be interviewed after a recruitment process that included solicitation to student organizations (National Society of Black Engineers (NSBE), Society of Hispanic Professional Engineers (SHPE), and Society of Women in Engineering (SWE)) as well as events sponsored by the college's academic support center.

Nine self-identified African American female students from the College of Engineering at a large, research-focused university self-selected to be interviewed for this study. We note that because the participants self-identified as female at the time the data were collected, we describe them as such in this paper, though the term "female" is limiting and does not encompass all women or WOC engineering students. All participants were at least eighteen years old at the time of the interviews. Table 1 shows the engineering major of each participant. To protect the participants' anonymity, pseudonyms replaced their names.

Table 1: Participant Self-Reported Engineering Major

Participant Pseudonym	Self-Reported Engineering Major
Carroll	Undeclared (Computer Science project)
Corretta	Computer Science
Danielle	Biosystems Engineering
Diana	Electrical and Computer Engineering
Evelyn	Industrial and Systems Engineering
Flower	Materials Science

Participant Pseudonym	Self-Reported Engineering Major
Kim	Engineering Science and Mechanics
Marjorie	Construction Engineering and Management
Reina	Mining and Materials Engineering

Study Limitations

The limitations of this study include the scope of the study's design and the generalizability of the results. Because this study employed a secondary data analysis on previously collected data, we did not have control or influence over the primary study design the data originated from. Not only does this limit the type of data to be analyzed (what questions were asked in the interviews), but it also limits the type of data analysis used. To stay aligned with the paradigm of the original study, we chose a phenomenologically informed approach to the data analysis.

In addition to the limitations of a secondary data analysis, the study uses a small sample of nine African American females, all from the same university. As a result, the stories of these participants reveal the potential systemic issues from one singular PWI. However, this small sample size indicates the need for more research on WOC since the representation of WOC in engineering remains low. Though the generalizability of the results was not the aim of the study, further research will be useful to fill in this gap and allow for these results to influence other PWIs across the United States.

Data Collection and Analysis

The data were collected through semi-structured interviews that were audio-recorded and transcribed. We employed an open coding method [47], [48] to produce a codebook to answer our research question. Although coding was done independently rather than in a team setting, the lead coder followed the structural coding process defined in MacQueen et al. [47], in conjunction with subsequent pattern coding from Miles, Huberman, & Saldaña [48]. The structural coding pass aided in identifying large sections of the transcripts that mentioned recurring topics or phenomena the participants experienced on their teams. Particularly, the main coder highlighted instances of epistemic metacognition, or comments from the participants regarding the epistemic nature of their experiences. The structural codes formed the preliminary codebook for this dataset. The following interpretive or pattern coding pass allowed the lead coder to group some structural codes together with similar constructs. To refine the codebook, we discussed and agreed upon the code definitions (brief and full), inclusion criteria (when to use the code), exclusion criteria (when not to use the code), and examples of the code in the data. Table 2 shows the main construct and two pattern codes grouped underneath the construct used for this paper.

Participant profiles outlined the basic information of each participant (major, year in program, overall positive or negative experience of team, etc.) as well as any notable takeaways from their interview. The profiles helped to summarize the participants' experiences and capture potential comparisons among structural codes throughout the interviews. To add quality to this study, we kept an audit trail to document the researchers' emotions, reactions, or overall thoughts while going through the analysis process. These analysis tools allowed for the emergence of several results that were unexpected.

Table 2: Codes from codebook development process

Code	Sub-code	Brief Definition	Full Definition	When to use code	When not to use code	Example of Code
Hidden Epistemologies		Unspoken, unacknowledged, but known beliefs and understandings about knowledge in engineering learning spaces	Unspoken, unacknowledged, but known beliefs and understandings about knowledge in engineering learning spaces, including but not limited to the value of different knowledges as well as the social aspect of knowledge sharing	Use code when participant discusses social aspects of knowledge building (including learning, communication, or observing) that involve an implied understanding of the engineering context	Do not use code when participant is discussing a social interaction specific to the particular members of their team (a conflict based on explicit circumstances that do not require implied contextual knowledge to understand)	See examples of sub-codes
	Knowledge filtered through hegemonic majority	Hidden epistemology that implies women have to cater to men to be understood	Hidden epistemology evident in social interactions between women and men in a male-dominated space in which it is obvious the female must cater to males' interests or language to be heard, understood, or communicate effectively.	Use code when participant describes communication issues with the team with underlying dynamics that highlight their unshared identities (gender, race, SES, etc.) with the rest of their team	Do not use code when participant describes specific communication issues based on the explicit personalities or conversations between team members	"I'm still like not used to interacting with my classmates a whole lot because […] just like our wavelengths of thought are different and stuff, and I'm not sure how I would communicate with them and stuff." - Corretta
	Technical knowledge valued most	Hidden epistemology that implies technical knowledge is the most important	Hidden epistemology evident in social interactions that shows how technical knowledge and communication are perceived as more important and prioritized over other types of knowledge (like emotional, procedural, or other skills-based knowledges)	Use code when participant shows a value on technical knowledge, especially if other knowledges used in the team project go unnoticed or under-emphasized	Do not use code when participant does not mention technical knowledge as an important aspect of the engineering team experience	"I felt bad that I didn't know it, but I can't learn and perfect Java in six weeks, so […] I just saw it as 'I need to develop my skills better so I can participate more in any future group projects that I might have.'" - Diana

Results

The data analysis revealed that seven out of nine of the participants described their teaming experiences on a spectrum, including both positive and negative aspects. One participant described her teaming experience as plainly negative (Carroll), and another described her experience on her team as positive (Corretta). The contrasting experiences on their teams offers different perspectives of the hidden epistemologies of engineering that undercut both of their experiences and exemplifies the construct of hidden epistemologies within this dataset. Following Marshall & Case [49], we treat Carroll and Corretta as paradigmatic cases that effectively illustrate the impact of hidden epistemologies on their teaming experiences. These paradigmatic cases show how knowledge is filtered and what knowledge is valued. The comparison between Carroll's and Corretta's experiences sheds light on the engineering practices (or assets) that may help African American females—and more broadly, WOC—to participate in engineering.

Knowledge Filtered through the Hegemonic Majority

Carroll had a notably bad experience on her team, which highlighted multiple hidden epistemologies within the engineering learning environment. Carroll was on a team of six for a first-year computer-science focused team project. She was the only female and only African American on the team. With poor communication practices by everyone on the team and improper division of labor as evidence, Carroll experienced negative aspects of teaming in engineering.

Carroll expressed a need to assimilate into the dominant masculine culture to get along or communicate with her teammates. She states,

> *Working with guys…it takes another type of expertise, where you kind of know how they're going to like click together. Because, like, sometimes they don't click, sometimes they do click together, and when they do, it's like…it's hard because you don't really know what they think of you. You don't know if they're judging you because you're a woman or if like they don't even care. And so that's kind of like the point I'm at right now. I don't know if my team – like the rest of my team – like thinks because I'm a woman, like I'm not cut out to do this, or if they're just like "We don't think that she…I don't think that she wants to be a part of the team because she hasn't been contributing," but in reality I did want to contribute, I just wasn't given the opportunity.*

Carroll mentions a "type of expertise" that is required for communicating with the men on her team to understand where they "click." The type of expertise she refers to is the understanding of the ways in which peers with shared identities operate socially and in a cohesive manner (where they "click"). This is the process of examining the hidden epistemologies that drive the social interactions she has with her team. Because of the historically white male majority in engineering and Carroll's positionality as the only African American female on her team, she acknowledges silently the potential her gender and race play in her exclusion from social interactions with others on her team.

Carroll learns of the necessity of understanding knowledge through the lens of the hegemonic majority to assimilate into her group (a process the men in the group did not undergo to understand her). Even so, after this unacknowledged work to appeal to the ways of knowing of the men in her team, Carroll still must weigh their potential perceptions of her and how her gender may affect them since it sets her apart from the rest of her team. Carroll goes on to describe the metacognitive process of guessing her teams' perceptions of her when stating, "You don't know if they're judging you because you're a woman or if like they don't even care."

Carroll shows the uneasiness of her position as the only female on her team because of not knowing how her team sees her. She recognizes that their perceptions may carry negative connotations based on her gender, which may have a compounding effect when Carroll is perceived as underperforming.

Carroll ends this quote by revealing the impact this hidden epistemology has on the situational unfairness she is put into on the team. The team dynamics did not allow her to contribute as much as she would have liked because of uneven distribution of work. As a result, Carroll feels wronged by the negative perceptions from her team since she wanted to contribute but was not given the chance. Carroll seems to be caught in a place in which she cannot win: either her team does not like her because she is "a woman," or her team does not like her because she did not contribute. Since Carroll was not in charge of delegating tasks, neither reasons for her teams' dislike are in Carroll's control. Carroll's experience fielding her teams' perceptions of her performance shows that even when navigating the hidden epistemology that knowledge is filtered through the hegemonic majority, those outside that majority can still be unfairly judged despite the "expertise" learning to work with guys in the group.

Though Corretta did not have the negative experiences on her team that Carroll had, she still expressed issues with communicating with her teammates as well as her classmates. Corretta was on a team of three for a senior computer science project. When asked if she would continue her friendships with her male teammates, she responded,

> *I'm still like not used to interacting with my classmates a whole lot because I guess like the way that we think is different. I'm just sort of like "Okay, I want to like...", I want to…you know…I don't know, just like our wavelengths of thought are different and stuff, and I'm not sure how I would communicate with them and stuff.*

Corretta surmises that interactions with her classmates may be strained because of differences in "the way that [they] think," which directly alludes to epistemological differences between her and those she is communicating with. She offers the explanation that the "wavelengths of thought" between her and her classmates were not similar enough to know how to communicate with them. Her use of the term "wavelengths" provides imagery for the process of exchanging information in a conversation, and the idea that the wavelengths between her and her classmates are different illustrates the epistemological barrier within that interaction. Since she is referring to her male classmates in this context (based on previous questions asked and the direction of the interview), Corretta's visualization of thought shows how communication issues can occur when the ways of knowing between people differ in such a way that common understanding cannot be met. Similar to Carroll, Corretta understands that to understand her classmates, she would need to tune her wavelength to theirs, or in other words, understand their epistemological background to filter information through it. Therefore, despite completely different teaming experiences, Carroll and Corretta noted the subtle difficulties of communicating with their white male team members, which we interpret as the hidden epistemology of knowledge filtered through the hegemonic majority.

Technical Knowledge is Valued Above Other Knowledges

In addition to the unspoken understanding that knowledge is filtered through the white male majority culture to be understood, Carroll also experienced the prioritization of technical knowledge above all other forms of intellect, sometimes to the extent of dehumanizing people. On a team of six, two male team members took on the hardware and software tasks of building an autonomous vehicle, leaving the rest of the team with little to nothing to do. Then, because of

Carroll's lack of contribution, she felt scrutiny from other team members. When asked if she thought her team liked her, Carroll responds,

> *I don't know, they just don't seem to…care…maybe would be like a better term. They just like…like "She's only valuable if she's working on something," that sort of thing. And so other than that, I'm not like a human being.*

Carroll uses the word "care" specifically to describe what her team lacked in their regards to her. This implies and is supported in her next sentence that Carroll's personhood was unimportant compared to her technical contribution to the team. The lack of care from her team describes a picture of indifference toward Carroll unless she can prove herself "valuable" by "working on something." In the context of Carroll's team project, "working on something" implied some type of technical labor that brought the team closer to completing the project. Carroll ends by mentioning that if this criterion of value was not met, she is perceived as "not like a human being." The reception Carroll got from her team, in which she is only valued as a human being based on her work output, may have played a role in her engineering identity. When asked if she sees herself as an engineer, Carroll answers with the desire to gain more knowledge before truly owning that identity. She states,

> *I guess I want to take initiative and learn more. Like over the summer I've been doing more projects by myself and just kind of like expanding my knowledge. So when I come back and I get to work on teams again, like maybe I'll be able to offer more valuable expertise in like an area.*

Carroll mentions "expanding [her] knowledge" so she can offer more "valuable expertise" when she is on another engineering team in the future. This teaming experience taught her that her value is based on output, and because Carroll did not have the opportunity to contribute technically in the way she wanted to, she could only contribute limited output (and therefore have limited value) to the team. Her team taught her the hidden engineering epistemology that technical knowledge can grant a level of "expertise" that gives her work more value. The prioritization of technical knowledge in engineering limits Carroll's view of what work can be considered valuable, especially in a project that involves many non-technical aspects (like project management, developing deliverables, and making meaning from the technical pieces of the project) necessary for its completion.

Corretta's experiences are a direct contrast to Carroll's in the way of valuing technical knowledge. When asked how the process of dividing up the tasks for the project went, Corretta answered,

> *Yeah, it was good because sometimes I can feel like kind of weird or… "Can I do this if I'm just given a random role?" It's like "Oh, I have to make sure I do this so I don't let my group mates down." But if it's like something where I'm specifically…like they notice I wasn't good at it or something during that…or like I was throwing out specific ideas and it's like I'm knowledgeable in that, then I feel more comfortable working on that. Because it's like "Oh, I know this. I don't have to like try and come up with something just to make sure my group mates don't yell at me."*

Corretta mentions that her team was willing to work with her strengths and her weaknesses, noticing if she "wasn't good at it" or if she was "knowledgeable in that." Corretta does not feel pressure to know more than she does or "try to come up with something" to avoid conflict with her team because she is confident in her contributions to the project. If she does not know something, she is still able to contribute in other ways. This contrasts with Carroll's experiences in which she felt she needed to be technically proficient in her next team interaction. The difference between Carroll's and Corretta's interactions lies in the alignment of their projects to

their skillsets. Carroll's team chose a project that utilized a coding skillset she did not possess, and so from the beginning, she felt behind and unable to contribute. When examining Carroll and Corretta jointly with the other seven participants, we identified reasons for their contrasting experiences (discussed in the following section) in the form of assets that can potentially combat barriers to participation in engineering.

Discussion

The phenomenological approach to this data set revealed comparisons between the participants' teaming experiences that may help to identify potential barriers to entry and participation for WOC in engineering. The contrasting experiences between Carroll, Corretta, and the other participants showed the following assets within a team that cater to positive outcomes:

- Lack of isolation or familiarity with group members
- Appropriate project expectations based on skillsets of students
- Equitable task division and delegation
- Respectful communication

In the case of Carroll, she was the only female and African American on her team, and she did not know any of her team members prior to the beginning of the project. She met the criteria for the course she enrolled in, but the project in the course required skills beyond her skillset. This left her set apart from other members of her group who did have the extra skills for the project, creating a clear social divide, to which Carroll did not receive the opportunity to contribute. Tasks were not assigned to her, and she was unsure of her place on the team. This feeling was bolstered by the disrespectful communication she received from other team members. The four assets listed above, when not met, work in concert to bring forth negative outcomes for Carroll. Within the cracks of her broken experiences emerged the hidden epistemologies in engineering that can serve as barriers for marginalized groups like WOC. At the time of her interview, she was unsure if she would continue in engineering, in part because of her experiences on this project.

In the case of Corretta, she was the only female on her team, and she did not know her team members prior to the project. However, she noted that she felt competent to finish the tasks she had on the project, her team had an equitable division of tasks, and members made sure they were all on the same page of the project throughout its duration. The last three assets allowed Corretta to have a positive teaming experience, but her isolation as the only female on a team of unfamiliar people allowed her to experience the hidden epistemology of knowledge filtered through the hegemonic majority. Corretta shows that a combination of the assets listed above can yield positive results despite the hidden epistemologies of engineering culture that can be unfriendly to African American females and, in worse cases, be a deterrent.

Grimson and Murphy [50] establish an "epistemological basis of engineering," and visualize a hierarchy of epistemologies as a pyramid [50, p. 161]. The bottom level is "foundational knowledge" [50, p. 164], such as math or science principles. The second level is "engineering domain knowledge" [50, p. 166], which is specific to any particular engineering profession. The top level is "knowledge about knowledge" [50, p. 170], or understanding how and when to use the knowledge of the other two levels. Within the middle level of this model, which concerned domain-specific knowledge, Grimson and Murphy included "transferrable skills" including effective communication and the ability to work on a team [50, p. 169]. As a fundamental skill embedded in the epistemologies of engineering, students should be able to practice these skills in

teams during their engineering education. The data on African American females' teaming experiences show how these skills are acquired differently for each participant based on team dynamics and conflict resolution (or lack thereof). Within this process of learning these skills, the epistemologies that underpin their learning processes are exposed. For some like Carroll, the hidden epistemologies of engineering appear and can be a deterrent to participation in engineering. For others like Corretta, the epistemologies that the field aims to achieve (like transferrable skills and teaming abilities) light a path forward toward participation and achievement even amid the hidden epistemologies of engineering culture. Coretta's experience shows how positive teaming can combat the "culture of disengagement" [51, p. 47] in engineering that ignores the need for equity based on the concept of "meritocracy" [51, p. 49] and devalues non-technical or "social competencies" [51, p. 48]. By focusing on the assets that connect to positive teaming experiences, engineering educators can guide the culture of engineering toward epistemic equity and inclusivity and thereby fulfill the epistemological basis of engineering [50] for all students.

Riley, Slaton, and Pawley [18] offer an explanation of the persistence of hidden epistemologies in students' experiences, and it lies in the historical construction of the modern classroom, in which "difference [between students] is nonproblematic: not meaningless, but not requiring address" [18, p. 342]. As we are addressing the experiences of African American females, we have not reached the goal that difference is nonproblematic, and this will continue if the hidden epistemologies in engineering are not acknowledged and dismantled through conscious social change. This study shows that the teaming experiences for African American females shed light on the embedded epistemologies that guide the engineering culture. Social factors from the other team members and the expectations of the course help dictate which epistemologies rise to the surface.

Conclusion

In this paper, we sought to understand African American females' experiences on engineering teams. We performed a secondary phenomenological data analysis on qualitative data from a larger study, and we developed a preliminary codebook examining hidden epistemologies in engineering culture brought to the surface of the participants' testimonies. Results from the data analysis show that Carroll and Corretta, through contrasting teaming experiences, revealed the hidden epistemologies that knowledge is filtered through the hegemonic white male majority and technical knowledge is valued above other knowledge types. These findings suggest that the hidden epistemologies in engineering may provide obstacles to participation in engineering, and certain assets in the teaming process may protect WOC from these obstacles. The evidence of the participants' positive teaming experiences reveals that the hidden epistemologies of engineering that can deter WOC from engaging with the field are also in league with the engineering epistemologies that foster healthy teaming practices and camaraderie between team members, as teaming is an integral part of the engineering experience. By supporting the assets in the teaming process, engineering educators can negate the effects of harmful hidden epistemologies and potentially change them to foster equity and inclusivity within engineering knowledge and ways of knowing.

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