

Making space for the women: Exploring female engineering student narratives of engagement in makerspaces

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Makerspaces have the potential to revolutionize engineering education by providing a platform for students to nurture their tacit knowledge. This unique space allows for students to work with advanced prototyping equipment, develop specialized skills and create community. Although makerspaces could become an important dimension of engineering education, it is unclear whether these spaces are inclusive for all engineering students, especially those from underrepresented groups. Specifically, this study aims to understand the experiences of diverse female engineering students in makerspaces. For this study, we analyzed interview transcripts of ten women from multiple U.S. universities housing engineering academic makerspaces—those anchored to and supported by the engineering department/school specifically—and found common themes across their stories. These themes include the perception of gender bias, as well as an intimidating, hostile, and non-inclusive environment. Although the results of this study demonstrate gender bias and marginalization occur in makerspaces, female engineering students still find value in the makerspace through access to resources, opportunities to learn, increased confidence, and female makerspace staff.

Introduction

Engineering has been historically dominated and accepted as a masculine field [1]. This public perception has led women, among other underrepresented groups, to encounter resistance when entering the discipline [2]. Gender bias within the field of engineering has ongoing consequences; namely, women continue to hold a disproportionately low percentage of engineering degrees [3].

University makerspaces represent a unique opportunity to understand how gender bias occurs in engineering through the examination of female engineering student-makers' experiences in the space. Makerspaces provide a platform for engineering students to become competent using advanced prototyping equipment that can be transformative to their engineering experience [4]. A central tenet of makerspaces is providing the opportunity for students to build and improve upon their designs, effectively bridging the gap between their classroom-acquired knowledge and hands-on practice [5]. Additionally, the makerspace is an informal learning environment that aims to be more open and less constraining than a traditional engineering classroom.

In engineering education, gender bias has been uncovered. For example, a study found that female engineers are less likely to be rated as competent than their similar male counterparts by both female and male faculty members [6]. This gender bias has also been found to be associated with less support for female students. Experiencing gender bias highlights otherness-status and increases identity threat among already marginalized populations [7]. The full impact of makerspaces is still underexplored. These spaces aspire to create community, foster a sense of belonging, and in turn, increase retention in STEM fields [8]. Although this is a laudable goal, little research has been conducted on how makerspaces accommodate students from underrepresented groups.

In the current study, we are interested in understanding gender bias within the context of engineering academic makerspaces. With makerspaces being a more recent addition to engineering education programs, makerspaces could be a microcosm of the larger engineering system. However, makerspaces could just as easily represent a shift in culture that moves away from the gender bias that is common to engineering education programs.

Given the increase of university makerspaces and the field of engineering's overarching goal to increase female student retention, it becomes imperative to understand whether makerspaces perpetuate gender bias. Through the analysis of ten female engineering students' narratives, we aim to develop an understanding of makerspaces and how inclusive they are for women navigating these spaces.

Research question

The purpose of this study is to examine the narratives of ten female engineering students and understand gendered nuances in their makerspace experiences. To address our purpose, our work was guided by the following question:

What are female engineering students' perceptions of their engineering academic makerspace?

Methods

Participants

The present work is a subset of a larger study that will compare the experiences of female engineering students in makerspaces with their male counterparts. Participants in the current study were engineering students recruited from seven universities in the United States that house makerspaces. These particular universities were chosen with intentionality to obtain a diverse set of regionally distributed institution types including minority-serving institutions, teaching-focused colleges, and very high research universities. All recruited participants had engaged in their engineering makerspace in some capacity. A \$25 Amazon gift card incentive was offered for completion of this study. The final sample for the present study is presented in the table below.

Table 1. Participant demographics.

Participant Pseudonym	University Pseudonym	Race/ Ethnicity	Engineering Major	Year
Alyssa	South Central University	Asian	Biomedical	4
Amanda	New England University	Asian	Electrical and Computer Science	2
Ava	Pacific University	Asian	Electrical	1, graduate student

Betty	New England University	Black	Mechanical	4
Melissa	South Atlantic University	Black/Hispanic	Electrical	1
Monica	South Central University	Asian/White	Mechanical	1
Wendy	New England University	White	Mechanical	3
Winnie	Middle-Atlantic University	White	Electrical	4
Winnifred	Gulf University	White	Manufacturing	3
Wynita	Mountain University	White	Robotics	3

Procedure

Four members of the research team followed a standard protocol to conduct narrative interviews with participants. The protocol consisted of asking participants open-ended questions that probed their personal narratives, with specific attention to their experiences as students and makers. Sample interview questions include “What experiences helped steer you to where you are today as an engineering student?”, “Describe a time when you felt like a maker.” and “How does [the makerspace] compare to your classrooms or to labs?” The full interview protocol can be found in Kellam, Cirell, Coley, and Boklage’s 2018 ASEE conference paper [9]. This narrative interview process involved three steps, initially beginning with the participants sharing their story of how they came to be in their current position as a student in the makerspace. The second phase entailed asking follow up questions that were meant to further elaborate on aspects of the students’ stories. The third phase included semi-structured interview questions that were focused on the students’ personal experiences in the makerspace and recommendations to improve the makerspace.

Researchers spent three days at each of the seven universities that were included in this study. During these three days, researchers made observations of the makerspace and interviewed the director or manager of the space as well as at least eight engineering students who used the makerspace. Researchers specifically aimed to include women and individuals from underrepresented groups in the sample. Student participants were recruited via individual requests, mandatory engineering courses and/or were recommended by the makerspace management.

Data analysis

After interviews were conducted, they were transcribed and coded with recommendations from Saldaña [10], which included: 1) utilizing broad codes for the preliminary coding stage, 2) repeating codes to find patterns in the data, 3) developing broader codes and categories, 4) writing analytic memos for insights that occur, and 5) reducing codes through code mapping (i.e., reorganizing and condensing codes to create a clear theme). The research team created a structural coding system that was based upon the research questions. The following are the structural codes that were identified: productive pathways to engineering, road of trials in

engineering, pedagogical experiences that shape identity, cases of stereotype/prejudice/bias, values and skills attained in the makerspace, values and skills attained in the classroom, and recommendations for the makerspace (for more analysis details see [9]).

In the second round of coding, researchers utilized thematic analysis to create more specialized codes to understand the gendered experience of women in university makerspaces. These themes included negative and positive perceptions of culture, which will be the focus of the results in this paper.

Results

Negative perceptions of makerspace culture

Understanding women engineering students' experiences and perceptions of makerspaces could help us better understand how to improve makerspaces. While the participants had a wide range of perceptions, these negative themes point to critical concerns in makerspaces.

One salient negative theme that participants experienced was that male students would often doubt their competency or attempt to dominate their project. While these women may interject and attempt to assert their knowledge, the men would disregard them and sometimes even take over their work.

For instance, Betty, a fourth-year mechanical engineering student, described multiple instances in which different male makers attempted to incorrectly teach her how to use tools or complete tasks. In one instance, despite Betty's attempt to clarify that she was correctly using the equipment, a male peer took the material from her hands and proceeded to "mangle" her work.

So I'm doing this to the steel piece to curve it and I just need a nice smooth curve, I don't want it tight. So I'm doing it little by little and, different guy in this case, starts watching me and he hovers and he's like, "Do you need some help with that?" And I'm like, "No, no I got it, I'm just trying to do it, like a thick curve." And he's like, "Okay." And I keep going and he brings over the shop manager, and he's like, "I don't think she knows how to use this machine."

After multiple instances of negative experiences with male makers, this student asserted that she no longer frequents this specific university makerspace. Her one positive comment about this makerspace was the shop manager, who was a knowledgeable woman that she felt was an ally when male makers would doubt her credibility. However, this one positive aspect was not enough to deter her from avoiding the shop.

Wendy, a third-year mechanical engineering student also shared how others doubted her ability to perform as a maker and an engineer, a gender-biased attitude that she noticed her boyfriend, of the same major and year in school, does not experience:

People are like is this for real? Does she actually know how to use the machine? Is she going to chop her hand off or something? And so I think that definitely still

exists. People don't think you have the capabilities to use certain machineries. So it's kind of a struggle actually.

Despite having had a rich training in woodworking and machinery since she was young, Wendy was often questioned solely because of her gender. Wendy also described that receiving proper training in order to work in the makerspace was a difficult undertaking for students.

... to use a makerspace you have to get training. If you want to get trained on something like a band saw, you really want to know the ins and outs of it. You can't get it done in like an hour. It has to be a longer process. But people don't have time for that so training ends up getting cut short. But if you don't feel super confident with the machine you're going to be less likely to go in and use the makerspace. I think there's a weird barrier to entry for makerspaces that it's really hard for people to overcome.

Winnie, a fourth-year electrical engineering student, also spoke about how the makerspace can be intimidating. She explains, "Oh yeah, so like the barrier to entry. I've noticed from a couple other women in the space, that they feel pressure to do it right the first time, and that's not how the world works." As a transgender woman, Winnie noted explicit attitudes of bias from other makers in the space that made her feel unwelcome. She also shared that she felt the pressure to not present as "inexperienced" while working in the space. She described that it took "a while" for her to gain confidence being in the makerspace altogether.

Overall, from these narratives, there appeared to be a few salient themes. Gender bias appeared to exist from other male peers who doubted these participants' abilities to properly use machinery and complete their projects. There also was a perception of a hostile and non-inclusive environment. Lastly, participants noted that the makerspace was intimidating and that the infrastructure of the space often keeps students from participating and feeling welcome.

Positive perceptions of the makerspace

While participants shared negative experiences in the makerspace, they also shared positive experiences, which again, highlight the importance of the makerspace as an environment to create change and help counteract gender bias experienced in engineering.

A predominant theme was the importance of female role models for the participants, which helped them acclimate to the makerspace culture. For instance, various participants noted how female makerspace managers were very knowledgeable and approachable. They also served as allies from male peers who would doubt their skillsets. Alyssa, a fourth-year biomedical engineering student, described how a female makerspace staff member helped ease the intimidation she felt in the makerspace:

She's one of the people who knows the ins and outs of the sewing machine, but not only [that]... she also teaches the classes how to use different 3D printers or resin printers. That's been really helpful, and she also has a really welcoming personality.

Multiple participants noted that female staff in the makerspace were knowledgeable, helpful, and positive to their overall experience. Knowing how important it is to have a skilled mentor in the makerspace, Wendy took on the role of teaching other students, effectively promoting her confidence as a maker:

I was helping people with some of the machinery... I'm just overseeing to make sure that you don't chop your hand off and stuff. I definitely felt cool helping people with using the drill and stuff. And people would ask me for advice.

Furthermore, various participants shared that the makerspace allowed for more meaningful engineering experiences than those of the classroom. They appreciated the opportunity to access such diverse resources. Having the autonomy to create and utilize the skills that these students have learned thus far not only helped foster confidence in their engineering identity but also helped solidify their future career plans. Melissa, a first-year electrical engineering student, described how her university makerspace has helped her conceptualize her future. "The makerspace really lets you get a taste of what it really could be like in the workforce. It's a good way to make sure you know what you want to do."

The makerspace also allowed for students to take ownership of their projects and see their work as a reflection of themselves. For example, Wynita, a third-year robotics engineering student, described how the makerspace allows her to create.

In the makerspace environment, I don't feel like I'm being pushed to do something. I'm working on this. I'm going to do it my way. No ifs, ands, or buts about it. This is going to be me. This is going to be my own work.

It appeared that more time in the makerspace for these participants to create their own projects fostered more autonomy and confidence. The makerspace also represented an environment where there was some flexibility for trial and error. Although Winnie noted that female makers, including herself, felt self-imposed pressure to maintain perfection, she also acknowledged that the makerspace presented a unique opportunity to learn: "...you're expected to fail in a good way." Winnie appeared to hold conflicting perceptions of the makerspace as both a place to "tinker," yet not appear "inexperienced" at the same time.

Several participants noted that they were appreciative that the makerspace allowed them to access resources and tools. Monica, a first-year mechanical engineering student, described her university makerspace with admiration, "I came in and looked, and just wow'd by all the machinery and the spiral staircase, and all the beautiful building design."

Ava, a first-year electrical engineering graduate student, also shared that she finds comfort in the makerspace, even calling it a second home. This showed that the space not only served as an effective learning environment, but also a space for safety and ease for certain female engineering students.

It's really starting to feel like another home because we're just there so often and I brought in bins for all of our parts because we have accumulated so much stuff.

Every Friday we clean up. it's just like another home to us now I guess. We spend so much time in there, like even on the weekends we're there.

Wendy noted that although she felt that there was gender bias within engineering on the whole, her university makerspace had managed to create a culture where she did not have these experiences. Being in the makerspace served as a reminder that she is strong and is skilled in her craft.

I definitely feel like at [New England University] it's cool because I don't feel like a minority. I don't feel like I have opportunities to do things because I'm a woman. I don't feel like I have less opportunity to go in and make something cool in the makerspace. Obviously because I do that. I do think that there's something about the kind of work that I do is that I really like woodworking. You have to be strong. You have to be able to clamp down wood, hold a drill, control all the machines.

Female makerspace staff, access to resources, room to learn, and increased confidence were all benefits that the participants shared about the makerspace. Despite experiencing gender bias in the makerspace, it seems that overall, the participants benefited from being able to access different resources and create their projects showing the true worth of makerspaces.

Discussion

From these participants' narratives, it is clear that while makerspaces have room to improve, they are also an important facet of these students' learning. With certain adjustments, there could be a significant positive shift in women engineering students' overall experience in university makerspaces.

Female engineering students face gender bias in makerspaces. From other makers doubting their ability to unfair expectations of perfection that some women self-impose, women face gender-specific difficulties. These women's narratives suggest that there is tension in the perception of the makerspace experience. On one hand, having access to resources and the freedom to create is liberating and confidence-building; on the other hand, women are still experiencing threats, both subtle and explicit, to their engineering competence and ability. While it appears that many of the study's participants benefitted from engaging in the space, there are also genuine concerns. Researchers have found that the primary cause of gender bias difficulties within engineering education were caused by singling out female engineering students with the intention of helping them [11]. Indeed, one of our study's participants began to avoid her university makerspace after male peers inappropriately and forcibly provided her with advice. Given that makerspaces aspire to be communities of inclusion and creation; this outcome is unacceptable.

Our study also found that participants described positive makerspace experiences. Participants noted that makerspace staff tended to be exceptional, especially the women, who they could count as allies when gender bias was occurring. These results are similar to the findings of Roldan, Hui, and Gerber [12] who found that women engineering students appreciated diverse female leaders working in makerspaces. Another study found that women engineers with women

peer mentors had increased belonging, motivation, confidence, and retention in their engineering majors [13]. Similarly, makerspaces could hire female students as staff to increase female representation, peer mentorship, and support.

Additionally, participants noted that the ability to work with different materials and tools increased their confidence, which correlates with previous findings [8]. Given the pivotal role that makerspaces may have in increasing confidence in engineering skills, ensuring that makerspaces are inclusive is critical.

A possible method of promoting inclusivity in makerspaces is to implement inclusivity training modules into the standard safety training that is required to work in the makerspace. Several students noted that in order to work in the makerspace, you have to acquire a solid foundation of knowledge regarding the machinery safety protocol. Similarly, students may also be required to be trained in proper inclusive practices to ensure that the makerspace environment remains protected from other threatening experiences, such as gender bias and discrimination. Shop managers and staff may also consider taking a more active role to ensure that the students who use the makerspace are also helping to create an inclusive culture. This may help curtail future gendered experiences for participants and others engaging in the makerspaces.

Future Directions

Although creating an inclusivity training protocol for makerspaces may take time and resources to develop, it is a valuable and necessary step to address gender bias. Future research can work to develop and tailor inclusivity training programs specific to university makerspaces.

Additionally, while the current study recommends to increase female staff representation in makerspaces, this poses a challenge considering the disproportionately low amount of women in both student and faculty roles in engineering [14]. In order to address this disparity, research has recommended targeting women when advertising for STEM positions to increase the number of female applicants, as well as prioritizing diversity initiatives through hiring practices [15]. University makerspaces may look to adopt these recommendations when hiring makerspace staff to increase female representation and, in turn, improve the experiences of female students in makerspaces.

Conclusion

This work articulates the perceptions of makerspaces held for a small sample of female engineering students. To further elucidate the uniqueness of gender in experiencing the makerspace, it will be necessary to also investigate the experiences that the gender majority group has in the makerspace. Future work will focus on comparing the experiences and perceptions of female and male engineering students in the makerspace, which will support a more complex understanding of the role of gender in makerspaces.

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