13. "This Is How I Can Fit": Barriers and Facilitating Factors to Gender Inclusion in Makerspace Education

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Abstract: Makerspaces are increasingly seen as a way to draw diverse and interdisciplinary learners together to teach a variety of skills. This qualitative interview study explores the experiences of women in 1 such interdisciplinary makerspace course at a graduate school of education. Drawing on findings from Margolis and Fisher's (2002) study of women in computer science education, we find that this makerspace course was a productive environment to engage women's diverse motivations for making and computing, increasing their confidence across domains. Additionally, we find their learning was tied closely to their identities, which shaped how they experienced the course and instructional support, particularly sexism, the congruence of their thinking and learning with course pedagogy, and collaboration and community. The diversity of experiences these women described provides a challenge for instructors but suggests that gaining an understanding of women's motivations and identities can inform course design and personalized support.

Introduction

Makerspaces are promising learning environments in schools, with the potential to engage diverse groups in interdisciplinary learning opportunities that in other contexts may be reserved for those in science, technology, engineering, and math (STEM) fields. In this way, they offer promising opportunities to draw women into computing recommended by Margolis and Fisher (2002) for "computing with a purpose," by situating STEM learning in an interdisciplinary and social context that women find more motivating (p. 49). Widening participation in makerspaces poses challenges to course designers and instructors, however, as women with varying backgrounds navigate an often unfamiliar learning environment. How to support learners with varied motivations, knowledge, skills, and disciplinary lenses is therefore an important question for fostering belonging when incorporating makerspaces into formal education.

This paper describes an exploratory study of women participating in one such interdisciplinary makerspace course, at a graduate school of education, to teach both digital fabrication tools and pedagogy in maker education. Throughout the semester, six women were interviewed about the course, how their backgrounds and motivations shaped their experiences, and how the teaching team was or was not supporting them. Drawing on findings from Margolis and Fisher's (2002) study of women in computer science (CS) education, we find that this makerspace course was a productive environment to engage women's diverse motivations for making and computing, increasing their confidence across domains. Additionally, we find their learning was tied closely to their identities, which shaped how they experienced the course and instructional support, particularly sexism, the congruence of their thinking and learning with course pedagogy, and collaboration and community. The diversity of experiences these women described provides a challenge for instructors but suggests that gaining an understanding of women's motivations and identities can inform course design and personalized support.

Related Literature

In their study of computer science students at Carnegie Mellon, Margolis and Fisher (2002) found that women's underrepresentation in CS was in part due to the decontextualized way computing was taught, which did not speak to women's motivations for "computing with purpose," and recommended drawing women in by teaching CS in an interdisciplinary and social context. Makerspaces are a promising answer to this call; their "blending of traditional and digital skills, arts and engineering creates a learning environment in which there are multiple entry points to participation and leads to innovative combinations, juxtapositions, and uses of disciplinary knowledge and skill" (Sheridan et al., 2014, p. 526), particularly as university makerspaces aim for broader participation outside of engineering (Hynes & Hynes, 2018).

Despite this, women remain underrepresented and express feelings of exclusion and intimidation in makerspaces (Lewis, 2015; Richard & Giri, 2017; Roldan, Hui, & Gerber, 2018). While some work has pointed to the physical characteristics of these spaces and features of the community that can attract or deter women from participating, there is also a push to critically examine how makerspaces "marginalize certain groups from participating and succeeding" in sustained ways (Roldan et al., 2018, p. 753). In CS education, Margolis and Fisher (2002) found that in addition to different motivations for majoring in CS, women felt less confident in their abilities than men, which through time led to decreased interest in computing. Women's interest in makerspaces is similarly affected by issues of self-efficacy, including how women's work is recognized, how their expertise and ways of working are valued, and overt or subtle sexism faced from male-dominated communities (Buechley, 2013; Faulkner & McClard, 2014; Keune, Peppler, & Wohlwend, 2019). This may be especially true for how women see themselves in relation to making, as women whose skills and identities are more congruent to makerspace culture may not perceive barriers related to their gender (Bean, Farmer, & Kerr, 2015).

Supporting learners in makerspaces within formal education environments is complex, requiring instructors to employ practices not typical of traditional whole-group or lab instruction (Clapp, Ross, Ryan, & Tishman, 2016). As maker courses are increasingly seen as an inroad to STEM fields for underserved populations, including women, these spaces also challenge instructors to better understand how notions of making and computing interact with individual learners' motivations, identities, and skills (Peppler, Halverson, & Kafai, 2016; Vossoughi, Hooper, & Escudé, 2016).

Research Questions

Part of a broader study to assess the effectiveness of personalizing instruction in a makerspace course, this exploratory study contributes to the growing literature on diverse experiences of women learning in makerspaces to identify ways instructors can better support them and foster a sense of belonging. To do so, we asked (a) what were these disciplinarily diverse women's motivations for learning in an education-focused makerspace course, and (b) what hindered or supported their learning and belonging?

Methods

Sample

This study was conducted in the Spring 2019 course Digital Fabrication and Making in Education. The course was

taught in the Graduate School of Education, aiming to equip teachers and other students interested in implementing "making" in education or designing educational tools with digital fabrication. The class had a total of 22 students from the Graduate School of Education and two students from the Graduate School of Design. The class comprised 16 women and eight men.

The focus on women was emergent based on all students' responses to weekly surveys that aimed to capture their personas and experiences with the instructors (for details see Chng, Zeylikman, & Schneider, 2020). In the first month of the course, women reported more extreme positive and negative responses than men. Because we used a purposive sampling design meant to represent contrasting experiences (e.g., satisfaction and dissatisfaction with instructional support) and personas (e.g., novice and expert), the sample evolved into six women who were interviewed throughout the semester. Two women were interviewed three times (Emily and Lucy), one twice (Erin), and three one time each (Jessica, Sarah, and Maya), for a total of 11 interviews. Figure 1 depicts the final project for each participant.

While the course and also our sample are not representative of typical makerspace courses and users, there is increasing demand for teachers and others in education to possess the skills needed to teach in makerspaces. The class is more diverse in terms of experience with fabrication, motivations, and professional backgrounds than currently found in many makerspaces, and it is more gender balanced (Roldan et al., 2018), but it may represent the more diverse spaces expected in the future.

Methods

Semistructured interviews were conducted by the lead author, a researcher not on the teaching team, using a protocol developed in collaboration with the course instructors. Participation was voluntary and participants granted consent with assurance that responses would not influence grades in the course, and that they could withdraw from the study at any time with no recourse. Interview protocols varied based on the week of the course; for example, in the beginning they focused on students' self-description of their personas' learning in the makerspace, while the middle of the semester focused on their self-reported challenges and assessment of feedback or support received from the teaching team. Interviews conducted after the conclusion of the course focused on participants' learning trajectories and explicitly asked them to discuss how their identities and gender did or did not influence their experience of the course. Interviews lasted approximately 30 minutes (range: 25–41 minutes) and consisted of an open-ended line of questioning and at times a discussion of the weekly surveys to elicit participants' thoughts.

Interviews were transcribed and coded using iterative, hybrid thematic coding that developed codes through both grounded or bottom-up procedures (emic) and drawing on prior literature (etic; Creswell, 2012; Rubin & Rubin, 2011). Initial coding was organized by etic themes identified from the literature and the broader study on personalizing instruction in makerspaces, including collaboration with peers and instructors, competence, and motivation, and emic themes that emerged such as identity and different ways of thinking and learning. Transcripts were independently coded by the lead author and graduate student research assistants to verify the reliability of the coding scheme, and discrepancies were resolved through discussion among the research team. Final themes were identified and transcripts re-coded; this thematic analysis is presented as the results. We aim to provide evidence of validity by using direct quotes that exemplify the findings wherever possible to allow the reader to judge our interpretation and sources of bias (Maxwell, 2010).

Figure 1. Final projects from interview participants. Top: Emily: Pretty Pretty Princess; Erin and Sarah: FrequenC; Maya: Carbon Cruncher. Bottom: Lucy: Plant Craft; Jessica: Sounds of Speech.

Results

Motivation, Interest, and Confidence

Participants described how they found the course motivating, particularly how the interdisciplinarity of the course allowed them to pursue their interests. In addition, we found that the participants described these motivations attached to their identities, but that different types of identities were more central to the experiences of each woman. Here, we describe each participant in turn—the identities, motivations, and learning gains they described.

Emily, an education graduate student, identified first and foremost as an artist, and she was motivated by the opportunity to add "new tools" to her artistry by learning how to use the makerspace. While in the beginning she described herself as a "newbie," "taking baby steps," she drew on the familiarity of the creative process from studio work to feel comfortable with the work. However, she describes the greatest gains she took from the class as increasing her confidence in coding and STEM work, which before the course she thought were "opaque" and unattractive to her when growing up, particularly because she identifies as very feminine and did not see herself in STEM fields. Yet by the end of the class she felt she belonged in the makerspace and was capable of a career in technology, even applying for a job as a makerspace facilitator. At the end of the course, she felt "way more comfortable in what STEM would be. … I think that I didn't realize just how creative coding can be, and how intertwined it could be with an eye for design and with arts … it's way less intimidating now, and that's because of this class."

Erin, also an education student, described herself as a "planner and a huge organizer," that she was "rigid" at the start of the course, and a cognitive scientist interested in understanding hands-on learning. Motivated by better understanding herself and her learning, Erin was up front in her reflections on the course related to her identity, actively thinking about tying her identity to her work, and finding her gender and ethnicity salient in her experience in the course. She described her biggest learning gains as unlearning her notions that "learning isn't fun … but you just have to push through," finding that it was possible to become motivated to learn through a playful and contextualized approach in the makerspace. She said that by the end of the semester, "I was taking more risks, I was trying new things, throwing out ideas. … I did a lot of projects and activities that I thought I could never do at the beginning. Which is really empowering for me."

For Lucy, a design student with a CS background, the ways of thinking and problem solving from her academic and professional work were most salient for her experiences in the course. However, a budding interest in education and designing for children led her to the makerspace in the education school, and the ability to explore those interests are what motivated her in her learning. Her greatest learning came from the ability to apply making skills to educational problems that interest her. She said, "The class has enabled me to pursue projects that I find personally interesting. Whereas if I were in an engineering class, there may be other learning goals that that class has, that is not aligned with my interest." Through this, Lucy also learned that she enjoys working collaboratively with others more than she enjoys working alone, which she had previously thought, and feels comfortable as part of a broader education community.

Maya, an education student, approached her experience in the makerspace with an eye toward how it aligned with her culture, motivated by the promise of using maker education in developing countries. She discussed how the makerspace was an environment that welcomed her way of learning, which she deemed "hard-fun," as she is motivated primarily by tackling difficult challenges. She said, "The way I see the makerspace often is within my own cultural context. … I see [the ocean as] a lot like a makerspace … the terrain of possibilities and I can go anywhere … so I just am curious about those notions, and the idea of a makerspace as culturally relevant." For Maya, her greatest learning in the course came from seeing this approach from her culture applied in formal education, and the confidence that gave her to feel she belonged in her master's program, saying, "Yeah, this is how I can see myself, this is how I can fit."

Sarah, a design student, has a highly interdisciplinary background, and she described herself as a "tourist," taking classes and working across five different schools in the university. She described taking this course in the School of Education because fabrication courses offered by other departments were not suited for beginner-level entry into fabrication. She felt her background gave her a lot of confidence in the making tasks of the course but felt she was "dropping in out of context" on the educational material and struggling to connect to it and other students. But for Sarah, the greatest learning came from recognizing how teaching and learning were in fact important and relevant for her, grounding her passion for making, and feeling an affinity for her classmates, saying, "I could completely see them in my program. … [We are the] same kind of scrappy person. … I think teachers have to be scrappy."

Jessica described herself as a teacher and an experienced maker who was motivated in the class to learn new tools and practices for teaching in makerspaces. For Jessica, working with and helping others motivated her experience, both in her goals for engaging in the class and what she hoped to learn for her future work. She said, "Because I'm like a teacher at heart so if someone needed help and I had free time—or honestly even if I didn't have the free time—I'm going to help them." She also drew on experiences from other makerspaces and enjoyment of the creative process of making that she described as relaxing, helping her enter a state of "flow."

Taken together, the experiences of these women in the makerspace course suggest that makerspaces can indeed offer the interdisciplinary, purpose-driven computing opportunities that Margolis and Fisher (2002) recommended to engage women in CS and STEM fields. Participants described myriad goals and interests in the course, as well as a wide variety of self-doubts and struggles, but on the whole their experiences helped them build confidence and interest in a positive way that Margolis and Fisher found lacking in traditional CS education in the 1990s.

However, we also found that women tied these motivations and their own learning closely to their identities. Largely unprompted, participants framed their own experiences and motivations in the course around their identities, whether professional academic such as designer, teacher, artist, but also their gender, culture, and ways of knowing and learning. These identities provided a powerful backdrop for their experiences, particularly which identities each participant chose to discuss, and this suggests that how women see themselves within the makerspace can provide valuable insight into ways of supporting them to build their confidence and motivate them.

Barriers in Makerspace Learning

While the experiences of these women do suggest the success of makerspaces as a formal learning environment that can provide engaging and motivating STEM learning opportunities for diverse groups of learners, they also highlighted barriers to fully participating in maker education. In particular, some of the women described gender bias and sexism, that the pedagogy of the course did not align with their ways of thinking and learning, or that they struggled with the community.

Gender bias and sexism. The women had varying experiences of sexism and gender bias and the role it played in their sense of belonging in the space (see Table 1). Emily discussed how being feminine was an important barrier to working in STEM before taking the course, and that she worried about how her opinions on gender would be received within this community at the university; however, she did not describe sexism or gender as salient in how she experienced this course in the makerspace. For her, the makerspace was a comfortable place to explore STEM through her interest in art without being intimidated by her gender.

However, Erin described her gender identity as a very important barrier, and that she experienced sexism in how her classmates and the teaching team interacted with her. In particular, men were more likely to be thought of as experts, whether or not they worked hard, and women were assumed to need help in coding. She discussed the importance of the male-dominated teaching team, and how she thinks that the only female member of the teaching team was undermined by others. This led her to feel as if she needed to work harder, she had something to prove, and she was careful about how she asked for help. She mentioned that she was not alone in these experiences, and that other women in the class expressed similar concerns to her.

Emily	***Yeah, not at all. [Gender issues] really didn't [play a role]...*** *nah, I felt like there was space for me, and I didn't think it mattered who was there.*
Erin	***I mean like being a woman, and being a woman of color, that's definitely something I thought a lot about, in the space...****sometimes there are these assumptions or bias... and I talked about it often with some of the other females in the class and like, it's definitely a thing that happened to not just me. And it's not-- I think it just says something about maker culture. That it's still very like male-driven, and like white male-driven as well. So yeah, that's something I thought about a lot... [The men were seen as] someone to refer to for questions, even though they didn't do an assignment or didn't really like follow along in class. But for females, we had to kind of prove ourselves and actively answer questions, actively advocating for ourselves.*
	I think that yeah, ***definitely having a more diverse teaching team would be helpful, just because like everyone was white, or there's only one female staff member****. I think that played a big role in the culture of the class...I couldn't really open up about my experiences that much or things like that. I think having a more diverse staff team would be helpful.*

Table 1. Gender bias and sexism.

Ways of thinking and learning. Participants whose ways of thinking and learning did not align with the pedagogical approaches in the makerspace struggled more to feel comfortable and to achieve the mastery levels and increased confidence that are important to motivate sustained work and interest in making (see Table 2). For Erin, accustomed to more traditional learning environments, the open-ended and student-directed nature of the course was overwhelming and discouraging. She described being frustrated by a lack of support and feedback from the teaching team, particularly when she struggled with hardware that did not work and could not bring herself out of it. She pointed to confusion over a lack of structures such as learning goals, rubrics, and organization that made it difficult for her to learn what she wanted. Similarly, Sarah discussed frustration with the pedagogy of the course, desiring more "sage on the stage" from the teaching team and their expertise rather than fully student directed. Jessica also discussed how her philosophy on teaching and learning did not align with how the class was taught, finding frustration in the limited hours of the space and the constraints of the assignments that impeded her from experiencing her own creative process.

This is in contrast to the experiences described by Emily, who found her artistic creative process supported her experiences in the space, Maya, whose culture aligned with learning in the class, and Lucy, whose professional and academic background were congruent with the pedagogical approach.

Erin	*[Projects are] very open-ended. Or like,* ***they don't have specific times we need this draft in by this time… There aren't really any rubrics in this class either so I don't know how they're grading… Because it's all student-driven****, and like all the presentations that we have in class, or any discussion about the readings are all led by students. So I don't know if that's like the best approach to like teaching concepts.* ***So I'm struggling with that.***
	The teaching team doesn't give as much feedback as I thought they would be*. Which is interesting. And I thought that would be a bigger part, them reaching out to us and giving us feedback or helping us…They do have office hours, drop-in hours, but they're usually in the evenings, so I can't make them all the time... I think that part, we probably need more facilitation…*
Sarah	*I almost wish there was more structure around, be* ***like a little bit more "sage on the stage."***

Table 2. Ways of thinking and learning.

Community and collaboration. All the women discussed the community of the class and collaboration as important for their sense of belonging and their learning in the makerspace (see Table 3). Negative interactions and lacking a sense of community were barriers for Jessica's experience in the makerspace. To her, the space was competitive, and others' competition for materials and time with the machines was disengaging. Early in the semester her assignment was broken by another student, and she felt that a member of the teaching team discouraged her from helping another student. These interactions discouraged her and impeded her learning and sense of belonging. Erin also points to a lack of community as late as the fifth week of the semester as a barrier to her tying her identity into her work or feeling comfortable taking risks, and her negative experiences related to sexism in the course made her wary of how she asked questions or responded to others (see Table 4). Despite the positive interactions that motivated Sarah, Lucy, and Emily, for example, the community and social environment was perceived as hostile and unwelcoming for a number of women.

Jessica	*Honestly I was more willing [to help others] in the beginning... But then there were a couple of instances where I felt like, "Why you gotta act like that?" Not out loud but like in my head. Like* ***why you gotta be so aggressive, you don't need to act like that****. Or when I helped someone in that earlier class and someone was like "don't like try to help, make that person do it." And I was like okay, that's weird…because I'm like a teacher at heart so if someone needed help and I had free time- or honestly even if I didn't have the free time- I'm going to help them.* ***I guess it's more like disengagement. From the class. Or being in the space.***
Erin	*Because* ***we don't have that community yet... And do I want to share my personal experiences with the people in this class? I don't know yet****. So I think maybe, I don't know, doing activities or things that kind of form the community and help foster this community, might be more important before diving into projects.*

Table 3. Community and collaboration.

Discussion

That women's experiences varied in how they responded to the course is not surprising, as women do not represent a monolithic group, but rather represent diverse identities and varied experiences. However, the relation of these barriers to the types of identities that participants discussed as most salient to their motivations, interests, and learning within the course may provide valuable insight for instructors who aim to not only attract women into makerspaces and STEM learning opportunities, but who also support their sustained engagement in them. The women who identified with the ways of thinking and learning employed by the pedagogy of the course, for example, did not need the same level of

instructional support. Women who feel their gender identity is central to their experience of the course may be more likely to perceive subtle forms of sexism and bias, highlighting the need for instructors to gain a deeper understanding of when students feel marginalized.

While the teaching team measured students' personas in terms of their feelings of competency and some of their learning preferences (e.g., collaborative or independent), our findings suggest personalizing learning requires going beyond this. Instructors should aim to more deeply understand each learner's professional, ethnic, and gender identities, their motivations, and how they relate to maker culture to better support students. Additionally, instructors should prioritize understanding individuals' ways of thinking and knowing relative to makerspace pedagogy to better anticipate the level of support needed. In our context, the challenges and successes related to these issues appeared to be more extreme for women in the course than for men. Further work is needed to understand whether this is true in other makerspaces as well.

Additionally, based on how these women described their experiences, our findings do point to a number of areas that instructors bringing makerspaces to environments such as schools of education can consider to make the space welcoming and productive for all women. For one, even having one woman feel discriminated against cannot be ignored, despite others' finding the space to be gender neutral. Simply having a larger female-male ratio of students did not hide the masculinity of maker culture for Erin, or the gendered lens of STEM on the periphery for Emily. Instructors may be able to mitigate this by having a diverse and representative teaching team, as well as being explicit in identifying instances of sexism and bias by providing anonymous reporting opportunities. Second, the ways student-directed pedagogy and open-ended, hands-on learning environments were welcoming or challenging for different learners highlights the need for certain supports in order not to alienate those who prefer more structure. Based on the experiences of these students, it appears instructors can mitigate these challenges by having office hours accessible for everyone and providing feedback and explicit expectations early in the course when students feel particularly overwhelmed. Finally, because collaboration is at the heart of learning in makerspaces, the class community is crucial. Instructors should prioritize building community in the start of a makerspace course to help advance students' learning by allowing them to feel comfortable with each other and overcome intimidation they may feel if they perceive themselves as outsiders.

References

Bean, V., Farmer, N. M., & Kerr, B. A. (2015). An exploration of women's engagement in Makerspaces. *Gifted and Talented International*, 30(1–2), 61–67.

Buechley, L. (2013, October). *Thinking about making.* Presented at the FabLearn Conference, Stanford University, CA.

Chng, E., Zeylikman, S., & Schneider, B. (2020). The double-edged sword of automating personalized interventions in makerspaces: An exploratory study of potential benefits and drawbacks. In *Proceedings of the International Conference on Artificial Intelligence in Education* (pp. 64–68). Switzerland: Springer International.

Clapp, E. P., Ross, J., Ryan, J. O., & Tishman, S. (2016). *Maker-centered learning: Empowering young people to shape their worlds.* San Francisco, CA: John Wiley & Sons.

Creswell, R. (2012). *Qualitative inquiry and research design.* Thousand Oaks, CA: Sage.

Faulkner, S., & McClard, A. (2014). Making change: Can ethnographic research about women makers change the future of computing? In *Ethnographic Praxis in Industry Conference Proceedings*, 2014 (pp. 187–198). doi:10.1111/1559-8918.01026

Hynes, M. M., & Hynes, W. J. (2018). If you build it, will they come? Student preferences for makerspace environments in higher education. *International Journal of Technology and Design Education*, 28(3), 867–883.

Keune, A., Peppler, K. A., & Wohlwend, K. E. (2019). Recognition in makerspaces: Supporting opportunities for women to "make" a STEM career. *Computers in Human Behavior*, 99, 368–380.

Lewis, J. (2015). Bar*riers to women's involvement in hackspaces and makerspaces.* Retrieved from

http://eprints.whiterose.ac.uk/144264/
Margolis, J., & Fisher, A. (2002). *Unlocking the clubhouse: Women in computing* (Rev. ed.). Cambridge, MA: The MIT Press.
Maxwell, J. A. (2010). Validity: How might you be wrong? In W. Luttrell (Ed.), *Qualitative educational research: Readings in reflexive methodology and transformative practice* (pp. 279–287). New York, NY: Routledge.
Peppler, K., Halverson, E. R., & Kafai, Y. B. (Eds.) (2016). *Makeology: Makers as learners* (Vol. 2). New York, NY: Routledge.
Richard, G., & Giri, S. (2017). Inclusive collaborative learning with multi-interface design: Implications for diverse and equitable makerspace education. In *Proceedings of the 12th International Conference on Computer Supported Collaborative Learning (CSCL) 2017* (Vol. 1; pp. 415–422). Philadelphia, PA: International Society of the Learning Sciences.
Roldan, W., Hui, J. S., & Gerber, E. M. (2018). University makerspaces: Opportunities to support equitable participation for women in engineering. *International Journal of Engineering Education*, 34(2), 751–768.
Rubin, H. J., & Rubin, I. S. (2011). *Qualitative interviewing: The art of hearing data* (3rd ed.). Thousand Oaks, CA: Sage.
Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. *Harvard Educational Review*, 84(4), 505–531.
Vossoughi, S., Hooper, P. K., & Escudé, M. (2016). Making through the lens of culture and power: Toward transformative visions for educational equity. *Harvard Educational Review*, 86(2), 206–232.

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