

Spaces and Practices within University Makerspaces

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Abstract— Academic makerspaces are an increasingly popular venue for informal, opt-in, STEM educational experiences, and many have lauded their potential to increase student access to and engagement with STEM [1, 2]. However, many scholars have critiqued the modern movement as a white, male, middle-class pursuit and have warned against the STEM-oriented, technocentric framing of making activities [3, 4]. These narrow limits on what "counts" as STEM making have the potential to limit both who opts in to participating in these spaces and what types of activities they do there. Following these critiques, there have been calls to broaden student participation, but no examination of why some students choose not to visit these spaces. In this paper, we investigate perceptions of makerspaces amongst STEM undergraduate students using the lenses of Social Boundary Spaces [5, 6], Repertoires of Practice [7], and the Production of Space [8]. Specifically, we ask: (1) How do students view a STEM makerspace? (2) What repertoires of practice do students see as valid within a STEM makerspace? and (3) What is the relationship between students' beliefs about making and their opinions about the physical elements of a STEM makerspace?

To answer our research questions, we interviewed 20 undergraduate students about their impressions of the makerspace, whether they have visited, if they have interest in the space, and what their reasons for participating or not were. We specifically targeted those students who had not ever visited the makerspace or had limited experiences there. Preliminary analyses illustrate divisions between what they conceptualized as making generally, and what they felt counted as making within the context of a STEM makerspace. Implications for alleviating barriers and supporting continued involvement in STEM makerspaces are discussed.

Keywords—makerspaces, equity, STEM

I. INTRODUCTION

Making as an educational activity is on the rise, and with it, facilities designed to support students' making activities, known as makerspaces, have become increasingly prevalent throughout K-16 Science, Technology, Engineering and Mathematics (STEM) education, and especially so in undergraduate engineering education [9].

Makerspaces are described and conceptualized in a variety of ways throughout academic and public discourse, and this narrative is reflective of both the breadth of activities that happen in these spaces and the design of the spaces themselves.

The STEM education community most often defines a makerspace following Sheridan et al.'s (2014) classification as an "informal site for creative production in art, science, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products". They are "physical location(s) that serve as a meeting space for a 'maker community' and house the community's design and manufacturing equipment" [11]. University makerspaces typically include advanced prototyping technology, machining equipment, laser cutters, and a variety of traditional hand tools, but the available equipment and layout of the spaces vary greatly between facilities [9].

In recent years, substantial resources have been invested into makerspaces in the community, K-12 schools, and higher education based on an underlying assumption that their creation will lead to experiences that bolster interest, engagement, and persistence in STEM. Though these claims are largely unsubstantiated, makerspaces are often lauded for their potential to increase access and broaden participation in STEM degree programs and career pathways [1]. Some scholars have qualified this praise with a caveat that making and makerspaces may actually fall prey to the hegemonic, marginalizing norms prevalent in STEM, a domain in which non-dominant populations have been repeatedly denied equitable experiences. Vossoughi et al. (2016) were the first scholars to turn a critical eye towards making, asking what counts as making and who gets to decide in STEM, with an explicit focus on diversity, equity, and inclusion. Following these critiques, there have been calls to broaden student participation, but no examination of why some students choose *not* to visit these spaces.

II. THEORETICAL LENSES

We draw on several theoretical lenses to address our research questions. At the foundation, we recognize that context is important and space is never neutral [8, 12]. Within any community or space, such as a STEM makerspace, there are certain repertoires of practice [7] which are valued and seen as valid, and others which are not. Further, these spaces are surrounded by social boundary spaces [5, 6] that are both barriers to--and spaces with potential for--learning.

Space is never neutral – "it is a product of history, of invisible socio-political factors and it is controlled by the hegemonic class to assert and maintain dominance and control" [8, 12]. Only a few studies have investigated the design of

makerspaces themselves. Hughes and Morrison (2020) are the only researchers thus far to take a critical look at the design of STEM makerspaces, pushing back on the narrative of what STEM makerspaces are supposed to look like using the lenses of Embodied Learning and Materiality, Neuroarchitecture, and Structuralism [8] to discuss “power, inclusion and engagement within a learning space” (p. 1). The authors encourage the reader to “look critically at the current STEM, engineering and maker-related buildings, and spaces and question for whom and by whom these were built” (p. 5), noting that STEM buildings tend to reflect an industrial aesthetic and lack elements from the natural world. STEM facilities then, do not “reflect alternative ways of being and knowing outside the western (male) perspective. If spaces are socially constructed, additional voices and influences need to be part of the conversation to make these places more accessible, inclusive and reflective of those who have historically been excluded. (p. 5)”

In comparing the physical spaces of twenty makerspaces, Hughes and Morrison feature three facilities that stood out to them and discuss how the resultant making they observed there is reflective of the facility (e.g., big projects in one “cavernous” facility, and “unplugged” making in a facility with “culturally relevant tools [and] a lot of floor space” (p. 7)). They highlight the potential and affordances of makerspaces to empower “shifts in pedagogy” (p. 2), noting that “inclusion, and a shift in power, due to an inquiry-based teaching and learning approach” (p. 12) were key themes across the three sites. This article brings physical space into discussions of what counts as making and who gets to decide that.

III. METHODS

A. Data Collection

To answer our research questions, we administered a recruitment survey and conducted interviews with undergraduate students. The survey was advertised via flyers in a common engineering space on a college campus, where the university’s engineering makerspace is housed. The flyer contained a QR link to the online survey and advertised a chance to win a gift card for participating. The online survey contained multiple choice and open-ended questions centering around students’ impressions of the makerspace, whether they have visited, if they have interest in the space, and what their reasons for participating or not were. The survey instrument also collected background and demographic information from the students. The survey also included a space for students to indicate if they would be willing to participate in an hour-long, paid interview about making.

A total of 151 students completed the recruitment survey. Then, 20 interviewees were selected from the survey respondents who were interested in the interview opportunity; we specifically targeted those students who indicated they had not ever visited the makerspace or had limited experiences there. These follow-up interviews allowed students to provide greater detail about their perceptions of making, experiences making, view of the makerspace, and how they would like to see the facility change. Students were given the interview questions in advance of the interview and were allowed to choose whether

the interview took place in-person or via Zoom. All interviews were recorded and transcribed via Zoom.

B. Context of this Study

This study was centered on a recently built makerspace that is housed in the main engineering building on campus. While the building (the Engineering Education and Research Center (EER)) houses mostly Electrical and Computer Engineering courses and lab spaces, it also includes the majority of the engineering-specific student services (e.g., the Engineering Study Abroad office), the headquarters for engineering-specific student organizations (e.g., the Women in Engineering Program), the campus’s Engineering Library, and the engineering-specific makerspace, Texas InventionWorks. The building also has a food court and ample seating available, and thus, the space is used as a communal meeting place for students of all engineering departments and some students from other colleges. The EER is also utilized by the college as an event space for career fairs, industry nights, etc. and is a frequent stop on tours of campus.

The EER has a 4-story deep atrium that houses all of the above listed spaces, most of which are enclosed by glass window walls, allowing students to see into the various offerings hosted in the building. The 30,000 square foot makerspace takes up the lower two stories of the 4-story deep atrium, and while it has glass windows that allow students to see into the space, the doors into the facility are tucked away in hallways away from the atrium. This makerspace matches Hughes and Morrison (2020)’s critique of the design of STEM makerspaces - it has a very industrial aesthetic, with exposed pipework, concrete floors, white tables, etc. and lacks any elements from the natural world. This design is consistent throughout the EER building and is the architectural style of all of the new construction on the engineering campus.

The space is not formally restricted to engineering students only, but engineering majors do make up the majority of the visitors. The space includes a variety of tools, equipment, and workspaces, including 3D printers, an embroidery machine, hand tools, laser cutters, vinyl cutters, a sewing machine, and soldering and circuitry equipment. Students can sign up for training appointments on the equipment via the makerspace’s webpage. There is no cost to enter the space, but materials are sold onsite. The majority of the space is devoted to rows of 3D printers and several large laser cutters. Notably, the sewing and embroidery space is missing from the floorplan of the makerspace; these floorplans are the official floorplans posted on the makerspace’s website, and thus, students looking online for information about the space would be unaware of the sewing or embroidery machine.

C. Participants

A total of 20 students completed an hour-long interview. The sample consists of 85% engineering majors and 15% non-engineering majors. The majority of students were enrolled in the Electrical and Computer Engineering department. Most interviewees were undergraduate students and students from every year were fairly equally represented.

D. Analysis

Immediately after conducting each interview, we wrote an analytical memo about the conversation. These memos serve as “written records of analysis which document the analytical and methodological steps taken by the researcher” [13]. Once all interviews were completed, we listened to each of the audio recordings and “pre-coded” the data, meaning we highlighted participant quotes that stood out to me as potentially significant “codeable moments” [14]. We then wrote a second analytic memo; these analytic memos served as a “code- and category-generating method” that allowed me to obtain a broad sense of my participants’ experiences and to begin to draw comparisons across students’ experience [14]. These processes were completed in the Word transcript files, and then we transferred the data to Excel before additional coding cycles.

We then examined and descriptively coded each interview transcript; “descriptive coding summarizes in a word or short phrase ... the basic topic of a passage of qualitative data” [14]. Next, we used “focused coding” to categorize the data according to the Repertoires of Practice framework [7, 14]. Here, we both deductively coded the data using *a priori* codes from the Repertoires of Practice framework and inductively coded the data for emergent themes. Focused codes enabled the us to identify specific conceptualizations of making practices, divisions within students’ thinking, and whether they felt certain practices were appropriate within the context of a STEM makerspace [7, 14]. Following these analyses we used “focused coding” to categorize the data from a spatial lens [8, 14]. Focused codes enabled us to identify specific perceptions of the makerspace, the physical or visual elements they discussed while forming those perceptions, the relationships students saw between space and activities, and how they would like to see the makerspace change. We categorized students based on their conceptualization of which practices count as making, and in which contexts, and categorized students based on their opinions of the makerspace. We present two vignettes, one student each with a positive and negative view of the space.

IV. FINDINGS

We categorized students based on their conceptualization of which practices count as making, in which contexts, and their opinions of the makerspace. We present two vignettes, one student each with a positive and negative view of the space.

A. Theo

Theo is a 3rd year Chemical Engineering major who sees making as inherent in human nature, picturing a concept map with “the bubble of making [at the center], and then there’s branches out into all these other things. So, you have engineering and cooking and art and whatever else you can possibly see.” Unlike other students, Theo does not exclusively link making with STEM or engineering or constrain it to only physical forms of making. Theo has a broad definition of making and a positive view of Texas InventionWorks. Despite having never visited the space, Theo really likes the makerspace; he thinks “all the technologies that they have down there” seem “really cool,” and when he looks into the space he

sees “young engineers and problem solvers, young people making new things ... that’s how we change the world, right?” Theo described the space as a “laboratory,” a “think tank,” and a “man cave,” because “when I think of a man cave I think of some place where you’re at a friend’s house, and they just have a bunch of gaming stuff, a lot of fun things to do. I feel like when you go down [to the makerspace], there’s always something fun you can either create or do there.” But Theo “just hasn’t had the time to visit the space.”

His ideal makerspace would be similar to Texas InventionWorks, and would look, “laboratory-esque,” “futuristic,” and “efficient” with 3D printers on one side and laser cutters on the other side – the two types of equipment he “knows about.” Because he “doesn’t really like sewing,” he would not include any sewing or embroidery equipment in his makerspace, but said it would be “cool to have a little cooking place... but I feel like that’s a little bit different, because [a makerspace] is more laboratory like, making things for engineering stuff, and then that’s kind of separate.” He thinks including culinary practices in TIW would be “distracting.”

When he pictures students in his ideal makerspace they are doing “engineering activities, you know, just innovation itself. It’s going to represent what the makerspace looks like. But I’m not gonna... I want them to do whatever they want to do.” In reflecting on this statement, he said “actually no, it should be the other way around – the space they’re in reflects the activities they’re doing” and his makerspace “is going to be very techy. I’d assume people are going to be doing technological innovations, whether it’s making a component for their projects or making some kind of simulation.” He concluded by saying the relationship between the space and the activities students do there “can be inverted as well, it’s an equilibrium type of thing.”

He recognizes that some practices, “like cooking and sewing are looked down upon” and thinks that’s a “real shame because I don’t see making like that. But in this space, I’m not sure, because the EER is an Electrical Engineering building. I’m not sure if you want to incorporate these ideas into this space specifically or make up other makerspaces in their own departments.” He doesn’t think a Culinary Arts major would want to “walk all the way to this building” because “this isn’t really the center of campus. It’s like a pretty decent walk from everywhere. But it’s where engineers are and they are going to be more inclined to come here for their own engineering interests.” Theo reflected: “I feel like engineering and sewing are different. I can see why they could be considered the same. But I don’t know. They both have the same goal because they’re kind of trying to complete something. But engineering, I just have tied more to technology and sewing more to clothing.”

B. Callie

Callie is also a 4th year Electrical and Computer Engineering major and loves to bake and to make her own clothes from thrifted finds. She has a negative view of Texas InventionWorks and a nuanced view of making, that is divided into “traditional and nontraditional making.” She thinks of “traditional making” as a straightforward activity, where you have a vision of an end product and follow through on making it. Callie was required to take a tour of Texas InventionWorks

and completed training on the 3D printers and laser cutters as a part of a first-year design course; she described her first visit as “a really great start to being introduced to the maker space” but never came back because “once that opportunity to be with somebody who, you know helps me out in the makerspace was done, it was scarier to go back.” She thinks this is partially due to “all the windows, like people can see any mistake that you make if you make mistakes, or if you don't know what you're doing. And I guess, there's a high risk, and I wouldn't like feeling like I could break something very expensive or mess up something very expensive by not knowing what I'm doing.”

She calls the activities happening Texas InventionWorks “traditional making,” which involve a tangible result. For Callie, traditional making “constitutes building, so anything that involves something that belongs to a toolkit, like a hammer, a drill, that type of thing.” She associates making with physicality but, after some hesitation, decided to include software in her definition of making because “the end product... it exists, but it's a little bit less tangible. It's a software. It's something that you know it still functions. But you can't touch it.”

She's visited the makerspace in one of the Fine Arts buildings on campus, called The Foundry, and was drawn in by the “really cool sewing machine,” not knowing that the makerspace in the EER also has a sewing and embroidery machine. She's frustrated by the divisions she sees in what counts as making, even in her own thoughts on what counts, reflecting that “artwork feels like a different realm than making, which is, when I take a second to think about that, I don't agree with myself on that. I wouldn't like it to be this way, but I think to me, making feels like a STEM endeavor, whereas creating feels like a Liberal Arts endeavor.”

Because of the types of activities she wants to do while making, she prefers the Fine Arts makerspace over Texas InventionWorks – “they don't have as many like 3D printers or laser cutters, but they do have this really cool sewing machine, which I thought was like novel, but like it's definitely - I don't know. I think it's a comfier layout than the EER one, its more approachable. I think that it's because 1) it's a little bit more in the corner - there's a little bit more privacy and 2) the lighting – like there's not concrete floors, it doesn't feel like a lab. It feels like a space for not just making, but creating um, which I think we talked about a little bit feels different to me. And it's just it feels warmer, I guess. Like the lighting, the colors, the decor.”

Overall, she thinks the Fine Arts’ “environment feels comfortable. It feels more fun, and it feels less like, ‘Oh, man, I gotta go create this project for a class,’ and it feels more like, ‘Oh, I get to create this cool thing that I want to make.’”

V. DISCUSSION

Following Vossoughi, Hooper and Escudé's (2016) call to question what “counts as making” and building upon prior work aiming to expand dominant conceptions of making and to support inclusivity in STEM makerspaces (see Andrews & Boklage, 2023 for a review), we examined the relationship between makerspace design and students' conceptualizations of which practices count as making, and in which contexts.

A. Students' Conceptualizations of Making

Overall, students' responses showed divisions between what they conceptualized as making generally, and what they felt counted as making within the context of a STEM makerspace. Some students equated the makerspace with “engineering making” for an academic purpose and thus, did not intend to visit unless they were required to for a class; only one or two students felt making was a “fundamental human practice” or acknowledged the inherent value of self-expression through making [16]. Most students did not see space for the types of making activities they did as personal hobbies, with family members, or in other student organizations as appropriate for or relevant to the engineering makerspace on campus. Few students included “everyday practices that have been the historical domain of women” [3] like crafting and sewing in their definitions of making, differentiating between practices they see as “more technical” and more “artsy craftsy,” positioning the latter as lesser than or not appropriate in STEM makerspaces. The hierarchy of project complexity that creates a division between more “academic” and “personal” pursuits may contribute to students' sense that some of their prior making experiences don't really count as making, and subsequently, keep students out of the makerspace.

B. Relationships between Makerspace Design and Conceptualizations of Making

The engineering building, the makerspace, and the equipment within the space reinforce this hierarchy. “There is an important relationship between physical space and learning” and “space is never neutral,” it is “a social construction—it is a product of history, of invisible socio-political factors and it is controlled by the hegemonic class to assert and maintain dominance and control” [12]. The imagery of a hard, industrial, laboratory like workplace communicates to students that this space is a space for mass and mandatory productivity, exclusively for academic and so-called entrepreneurial endeavors that align with the values of capitalism.

Theo explicitly discussed the relationships he saw between the design of the makerspace and the types of making that students would do in the space, calling the relationship an “equilibrium type thing,” where both the activities influence the space, and the space influences the activities. He was attracted to the makerspace because of the “laboratory-esque,” “futuristic,” and “efficient” technology that reminded him of a “man cave” in his friend's basement. Despite having a very broad definition of what constitutes making, Theo did not include cooking or sewing in his ideal version of a makerspace because those practices are fundamentally “different” due to his association of engineering making and technology. During our conversation, he wrestled with his own sexist views of different industries, but ultimately was not able to expand his conceptualizations of what fits in a STEM makerspace to match his broad conceptualization of making. Interestingly, this wrestling did not prompt Theo to question or criticize the makerspace; at the end of the interview, Theo still romanticized the space and wanted to change very little about it. This could perhaps be because his own conceptualizations of making have

been directly formed by or reinforced by the makerspace, the equipment within the space, and the engineering building itself.

Callie saw so-called “traditional making” as a straightforward process with a clear product determined by consumer constraints (“a STEM endeavor”), and more “creative making” as a freeform, hobbyist activity that relied more on aesthetic and personal preferences (“a Liberal Arts endeavor”). Callie thinks the floor-to-ceiling windows that surround the STEM makerspace make the facility a high-risk space to be in, because everyone “can see any mistake you make.” She prefers the makerspace facility in the Fine Arts building because of its “warmer” and “more colorful” aesthetic, which makes that space “more approachable” for her. In the Fine Arts building, Callie feels comfortable “to create,” rather than simply “make.” The differences between The Foundry (the Fine Arts makerspace) and Texas InventionWorks likely has reinforced Callie’s own partitioning of “traditional making” and “creative making,” but she wants to see this change. She pushed back against her own conceptualization of making throughout the interview and wanted to see a makerspace where students could feel comfortable with any making practice, and with “not just making, but creating.”

In all, students face many barriers before opting in to participating in a STEM makerspace. But beyond factors like time or interest, beyond prior making experience or not feeling like they have a reason to visit the space, beyond questions about training on the equipment or fears of the perceived technical skillset of the students already in the spaces, the makerspace itself is a place that holds a very specific meaning for students. There is a dominant narrative of what STEM makerspaces are supposed to look like and be and their designs reflect what is valued by the dominant community, and subsequently shape the forms of making that can occur there [12]. To truly support inclusivity in makerspaces, we must “look critically at the current STEM, engineering and maker-related buildings, and spaces and question for whom and by whom these were built;” STEM buildings tend to reflect an industrial aesthetic and lack elements from the natural world, and then, do not “reflect alternative ways of being and knowing outside the western (male) perspective. If spaces are socially constructed, additional voices and influences need to be part of the conversation to make these places more accessible, inclusive and reflective of those who have historically been excluded [12].

Those looking to establish or run a makerspace must think critically about what the makerspace itself will communicate to learners about who and what is valued there. Space is never neutral, and design choices reflect what is valued by the dominant community, and subsequently shape the forms of making that can occur there. Hughes and Morrison (2020) recommend makerspace founders: “(1) think big, start small, but start; (2) take risks to shift pedagogies, and (3) create a makerspace that reflects its community of users” (p. 15). Makerspace leaders can offer learners opportunities to engage with a wider variety of projects, such as crafting and sewing,

and should place relevant materials and equipment prominently within the space.

VI. CONCLUSIONS

We examined the ways students conceptualize which practices count as making, and in which contexts. We found that students differentiated between what they conceptualize as making generally, and what they felt counted as making within the context of a STEM makerspace. Most students’ definitions of making fall in line with the dominant, STEM-oriented, techno-centric framing of the modern making movement, rather than embracing “experiences that support makers in deepening and applying science and engineering knowledge” or their own “other powerful forms of knowledge and practice” [16, 17].

The building, the makerspace, and the equipment within the space reinforce this hierarchy, communicating to students what and who is welcome there. Industrial design choices communicate to students that they must be industrious in a space. An emphasis on machinery (especially on 3D printers) shows students that 3D printing is not only a priority, but that it is the accepted and encouraged practice in that space. A makerspace with one sewing machine will not reflect a community of users that are interested in sewing and having so few compared to the number of 3D printers (a more technical, and therefore more valued practice in STEM spaces), marginalizes not only that practice in that space, but also those students who are interested in sewing or embroidering. STEM makerspaces must reflect upon their design and equipment choices and consciously choose to make changes that will support inclusivity in these spaces, or the same practices (and people) that are valued in STEM will continue to hold power.

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