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ORIGINAL PAPER

Vibe Check: A 360-degree Enumeration of the Common Features of a University Makerspace

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Abstract

To better grasp the issue of underrepresentation in makerspaces, it's crucial to closely examine the environment where these problems arise. A spatial enumeration of a makerspace, which is a complete listing of items within a collection or environment, extends such an evaluation. By responding to this overarching research question, "why do students from underrepresented communities turn away at the threshold of a makerspace," this article provides findings from the first phase of a five-year, qualitative research program. Specifically, this paper presents the sensory features (sight, sound, smell) that comprise a university makerspace. The process and findings from enumerating a makerspace offer vital insights into how STEM-focused environments convey inclusivity. Seventeen makerspace leaders from a university network were asked to discern what a typical makerspace looks, sounds, and smells like. The findings from this study provide information professionals with entry points to analyze their makerspace from a DEI standpoint.

Keywords Makerspaces · Equity and inclusion · Grounded theory

What are the key characteristics that define a makerspace? This article outlines both the tangible and intangible aspects that constitute a makerspace, which are informal, collaborative, and STEM-focused learning environments becoming increasingly integrated into educational institutions and libraries (Koh et al., 2019). While there may be variations in design among different makerspaces, there are common elements that collectively give them their identity as makerspaces. This compilation of features is a response to a persisting issue inherent to makerspaces, namely, the long-standing lack of representation from diverse user communities.

A critical exploration of the spatial design and layout of a makerspace can delve deeper into the matter and foster meaningful discussions about how users perceive inclusivity based on the physical appearance of the space (Melo, 2020). This article offers educators, information professionals, and makerspace administrators a range of aspects to consider for design improvements aimed at creating an environment that prioritizes inclusiveness. Furthermore, it presents the initial findings from the first phase of a five-year research program. This research program investigates the information-seeking behaviors of historically excluded and marginalized users within makerspaces. To help address the issue of underrepresentation within makerspaces, a closer examination of the environment where these problems manifest is imperative, and a spatial analysis of makerspaces extends this evaluation.

Literature Review

Since the start of the maker movement in 2006, universities across the U.S. have integrated makerspaces into their institutional ecosystems, providing access to an unprecedented

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array of STEM-rich services and technologies for students (Nichols et al., 2017). The popularity of the university makerspace has also given rise to an enduring challenge: underrepresentation of users from marginalized student communities (Etzkowitz et al., 2000; Lewis, 2015; Schiebinger, 2008). This underrepresentation reflects the demographics of the maker movement more broadly: in 2012, *MAKE:* magazine, sometimes referred to as the bible of the maker movement (Hatch, 2014, p. 5), reported that its readership was 81% male, with a median age of 44 and median household income of $106,000. Of the 300,000 readers *MAKE:* described, 73% owned their own home, 97% had attended college, and 80% had postgraduate education (Maker Media, 2012). In the same report, Maker Media described the attendees of the Bay Area and World Maker Faires as 66% male and 34% female, with a median age of 46.5 and a median household income of $117,000. Of the 165,000 attendees described in this part of the report, 98% attended and/or graduated from college, 87% graduated from college and had completed some post-graduate work, and 43% had post-graduate degrees. In spite of the inequitable representation related to gender, income, and education here, rhetoric around the maker movement refers to it as a democratizing force (Kalil & Miller, 2014). While *MAKE:* and Maker Media did not report demographics related to race and ethnicity, Buechley's (2014) analysis of the first 36 issues of *MAKE:* found that no people of color were featured on the covers, nor on the magazine's staff. Buechley (2014) also analyzed the types of activities portrayed on the cover and found they featured electronics heavily, as well as vehicles, robots, rockets, and music. This offers a limited perspective on making, overlooking the kinds of crafting frequently practiced in across diverse communities. As Britton (2015) points out, "the Maker identity and technical DIY activities [featured in MAKE magazine] are not for everyone; in many ways [the Maker identity] actually reinforces an ingrained culture of white masculinity in the design and deployment of technology while rhetorically claiming universality."

Makerspace leaders and researchers have made attempts to broaden the access and appeal of makerspaces to attract people from underrepresented groups. The primary strategy currently used to improve equity in makerspaces is broadening the types of activity that count as making. Examples of initiatives directed at broadening making involve incorporating textiles and crafts into making (Buchholz et al., 2014; Buechley et al., 2013; Kafai et al., 2014), sponsoring locally-grounded making projects that are relevant to makers' lives beyond the makerspace (Calabrese Barton et al., 2017; Greenberg, 2020; Calabrese Barton et al., 2017), and providing activities explicitly designed for disabled users without changing the spatial arrangement of the makerspace (Brady et al., 2014; Seo, 2019).

Only a limited number of studies have explored the physical layout of makerspaces, and among these, none delve into the effects of this spatial design on individuals from underrepresented populations. Crawford Barniskis (2016, p. 1) conducted a multisite ethnographic case study of two library makerspaces, one in a small rural library and one in a large urban library, and focused on how spatial arrangement impacts power relations "among the library-as-institution, the library personnel, and the users." She identified four main themes: exposure, flexibility, expansiveness, and control. These themes will be further explored in conversation within our findings and discussion.

Methodology

Approach: Qualitative Research Informed by Grounded Theory

Grounded theory informs the design and implementation for this qualitative study. Grounded theory is used to generate theory, to offer an explanation around a phenomenon, and/or to outline the relationships between seemingly disparate concepts. Leveraging this theoretical framework offered a method to "ground" the data analysis and subsequent discoveries directly from leaders overseeing university makerspaces. (Charmaz, 2014; Creswell & Creswell, 2018). The research program's data collection was guided by this research question: "What constitutes the key features of a makerspace?" The aim of this study was to itemize the traits of a makerspace by recognizing recurring elements within the environment that contribute to its defining characteristics.

Participants

The researchers from this study used purposive sampling to recruit participants (Wildemuth, 2009). The University of North Carolina (UNC) system is comprised of 17 universities. The research team reviewed the student services that each university provided to determine whether it included a makerspace. Of the 17 institutions, there were 12 universities with a makerspace. The UNC system provided an apt sample population to work with: the researchers are a part of this network and the intention of the research program is to recursively apply findings (e.g., design interventions) back into this ecosystem. The UNC system also convenes a diverse set of universities that include historically Black institutions, rural and suburban locations, as well as a school for the arts. While makerspaces can vary in terms of communities served and services provided, the researchers used the following criteria to determine its fit for this study:

- The primary audience is either for students, staff, and/or faculty
- The makerspace is available to all disciplines (i.e., it is not a members-only, paid, and/or department-specific makerspace)
- Projects supported in the space are for both personal and academic use
- Users must be able to use the equipment directly (i.e., not a 3D printing service)
- Includes equipment beyond a traditional computer lab

Makerspace leaders from the 12 universities were invited to participate in the study. This included interviews that were facilitated via Zoom and lasted 30–60 min in length. All interviews were conducted in 2020 after the outset of the COVID-19 pandemic. In total, 15 participants from 11 universities were interviewed. Additionally, the researchers included data from a pilot study, which added one more university and two more participants to the sample. There were 21 makerspaces total that are representative of the data and findings. During the interview, participants were asked a series of sense-based questions: What do you see, hear, feel, and smell in a typical makerspace?

The purpose of collecting sensory data was to build a comprehensive picture of a typical makerspace, covering all aspects from a 360-degree approach. The conventional makerspace took shape through the collection and analysis of data. This visualization directly contributed to the creation of a virtual reality makerspace for future iterations across the five-year research study.

Findings and Discussion

The intention for this analysis is subtle but impactful: to shift the "site" of the problem. The analysis moves the focus from why diverse user communities do not use a makerspace to how a makerspace communicates exclusion through its key characteristics (sight, scent, and sound). It is a critical shift that decenters the problem site from being placed onto individual/community members and centers it on the environment. The makerspace leaders we interviewed described common features that provide a general depiction of a university makerspace.

By applying various lenses that consider race, gender, disability, and/or class, educators and information professionals can gain a deeper understanding of how makerspace design is intertwined with larger systems of oppression. For example, these findings can be placed in conversation with the application of a power analysis of an operational makerspace (Marshall & Author, 2020). As the power analysis framework depicts in Author X and Marshall's (2020) article, elements of a makerspace could be examined, such as the descriptions of physical features (e.g., openness, wall colors), the people in the space (e.g., user demographics), specific assets (e.g., tools, materials), smells, and sounds. There is also recognition that a makerspace is not solely composed of visual, auditory, and olfactory features, but also affective elements (Melo et al., 2022).

Makerspaces are also defined by the affective estimation that users make, as they invoke certain feelings and provide affordances and limitations around behavior (Davis, 2020). Along with the thinking and decision-making that users are making, they too are assessing how the space feels to inform their decision whether to enter the space (Melo et al., 2022). The findings outlined in this section are organized under these larger headers, and can be engaged collectively and/or individually to provide entry points to identify pain-points and opportunities to create a more inclusive makerspace environment.

Physical Features

The physical features of a makerspace align with Crawford Barniskis' (2016) exposure theme, which has two facets: exposing users to the possibilities of the makerspace and showcasing available materials to users of the space. While both library personnel and users felt exposing users to a variety of opportunities, technologies, and ways of thinking about creation were valuable, barriers to this theme included two ideas: one, the library personnel assumed users had knowledge they lacked, providing most information about the makerspace online rather than in the space itself; and two, the users' lack of awareness of what tools were available in the space. When equipment and materials were hidden, such as behind cabinet doors, users felt that the equipment and materials were not accessible to them. As Crawford Barniskis (2016, p.6) points out, "the mere arrangement of free tools in a space does not constitute access if users cannot benefit from the tools or space." Table 1 details the physical features of makerspaces, their prevalence, and direct interview quotes from makerspace leaders.

Color

Ten interviewees made a case for the importance of incorporating bright colors in makerspaces. Two makerspace leaders rationalized that colorful spaces facilitated imagination, with one participant specifically referencing psychology by asserting, "bright walls make you more creative." Saturated colors have long been regarded as facilitating an excited emotional response to architecture (Franz, 2006). Four participants specified these bright colors work best as "pops" or "accent" walls. As one participant reasoned, "bright colors work really well. Pops of orange and red and things like that,

Table 1 Physical Features of Makerspaces

Feature	Description	Prevalence	Example
Bright colors	Vivid colors associated with facilitating creativity	**10**	"[I]t doesn't need to be neon, but you do need a color pop."
Openness	Openness encourages outsiders to enter the space	**10**	"So I think makerspaces should have at least one glass wall, at least, and that is because I think it's important for people to be able to walk past it and see into the space…a general ability to look in and see people work and feel less intimidated by the space."
Check-in Area	Presence (or lack thereof) of a designated check-in or welcoming area	**Pro: 9**	***Pro check-in area:*** "[A] check-in area, or a place with guidelines that tells you how to interact with the space your first time…some sort of maybe information station where you could tap your card to check in or somebody would be there to answer your questions."
		Against: 5	***Against check-in area:*** "I think sometimes in my experience, check-ins can be a little bit intimidating…so I think that having signage that kind of explains what is happening is mostly what I would like to see anyway."

bright blues, neons. I think those…get you excited, they're energizing." Four other participants also detailed the use of school colors, with two noting a combination of accent walls and university branding.

Bright splashes of color as an interior design trend are also seen in the 2020 Library Design Showcase, the American Libraries Magazine's annual collection of new and renovated library spaces (Morehart, 2020). However, a 2008 study of computer classroom accent wall colors found students prefer "cool" options (e.g., blues), although the authors note this preference may reflect participants' prior knowledge that "bright and stimulating color is not traditionally suitable for a computer classroom" (Wang & Russ, 2008, p.12). Other layout considerations related to light and openness, which have also influenced recent library interior design trends (Bell & Cottrell, 2015, p.123), are discussed next.

Openness

The theme of "openness" from the findings resembles the themes of flexibility and expansiveness (Crawford Barniskis, 2016, p. 7). Flexibility in this context pertains to the adaptability of a space to cater to a diverse range of library programming. The challenge lies in finding a balance between offering flexibility and setting limitations. Both library makerspaces in the study (representative of urban and rural locations) provided plenty of open space with multiple large, uncluttered work tables. Patrons mentioned that they could spread out in the space as they needed too. Some patrons, however, interpreted this openness to mean that they should not interact with other users in the space. Crawford Barniskis (2016) suggests that more intimate spaces could provide opportunities for interaction. Although this data was gathered at the peak of the pandemic, considering the ongoing impact of COVID-19, it was challenging to envision makerspaces transitioning towards offering more intimate spaces in the foreseeable future at that time.

Ten interviewees in this research study included openness as a desirable aspect of makerspace layouts. Most frequently, this was achieved through using windows or glass, either as a means to include natural light or a way to entice more users (by advertising the space and tools). Making the facility openly visible was perceived as a method to foster a sense of inclusivity and to encourage a more diverse range of users. One respondent, however, first described their desire for an open space to display activities, but later reflected on the need to "frost" it to prevent users from feeling watched:

> I think there is a sense that you want to show off what you have...you want to show off what you have and get interest so that people can see, 'oh look what they are doing,' when they come in. So some glass...But then we found through observation there were times that the people using VR feel like they're in a fishbowl and people are watching them, and they're not so keen on that. So we were in the process, before COVID, of frosting the other side of the glass to give a better sense of space.

COVID-19-related precautions also impacted other areas related to openness and special considerations. One participant admitted their dismay at closing up their space in response to pandemic restrictions:

> It's going to be less open. It's going to be a lot more behind glass partitions, and being accessible through a digital platform via chat to talk to those staff members to be able to utilize materials. Contactless pickup of items to where you actually have to schedule times to come in and pick up the items. So less of that open

> robust space and more, I mean I hate to say it, more shut off from that experimental space.

This description of "glass partitions" evokes the use of plexiglass and other transparent space dividers – a tactic for COVID-19 avoidance described by the WHO (2020) and the CDC (OSHA, 2020). While this intuitive solution offers one mitigation strategy, related research on its effectiveness is lacking (Doheny, 2020). Moreover, short barriers may not protect against aerosolized transmission, which travels around non-full-length partitions like smoke and is now considered to be the most likely method of COVID-19 spread (Jimenez, 2020). A review and hierarchy of preventive measures includes physical barriers where enhanced ventilation and social distancing is not feasible (Dehghani et al., 2020, p. 775). This vision of an open space is conducive to spreading out users, and more specifically, one with ventilation that avoids air recirculation, may offer the safest choice in preventing the spread of COVID-19.

Check-In Area

The flexibility and expansiveness of makerspaces are limited by control mechanisms. Features such as closed and locked cabinets, sections concealed by partial walls, and computers exclusively designated for staff use serve as indicators of the restrictions on patrons' activities within the space. Crawford Barniskis (2016) reported that patrons seemed to understand these limitations implicitly, in contrast to the difficulty they may have imagining what they can do in the space. Her research concentrates solely on the spatial organization of makerspaces, with case studies specifically sourced from makerspaces within public libraries. The leadership in the two libraries differed with respect to their feelings on controlling the space; the manager of the urban library was satisfied with this level of control, while the director of the rural library "was dismayed by the thought that patrons needed permission to use the space" (Crawford Barniskis, 2016, p. 8). In a similar vein, the primary objection to check-ins was rooted in the concern for fostering a welcoming environment and avoiding any sense of intimidation among users:

> I think sometimes in my experience, check-ins can be a little bit intimidating...so I think that having signage that kind of explains what is happening is mostly what I would like to see anyway.

Interestingly, four interviewees who argued for check-in areas did so because it offers a means of facilitating connections via personal greeting. One participant explained:

> [S]ome way to check in or somebody there to greet you...the ones that I've seen would probably have something like that. Although the one I didn't see that had that I thought it was weird. I was like, 'doesn't anyone want to know who I am?

Safety was also a concern for two interviewees. One participant focused on making sure people were available to answer newcomer questions. Another participant concentrated more generally on restricting access to people who were previously trained:

> I would say the space should be secured...because of safety. People have to be trained in order to enter the makerspace. You have to take the training as far as safety and other people's safety...[Perhaps] card access of some sort, you scan your ID for the door to open for you to enter the maker space.

People, Diversity, and Inclusion

Along with physical features, participants also described the people commonly seen inside makerspaces. Table 2 identifies the common themes found in interviewees' characterizations. Participants brought up issues related to diversity, equity, accessibility, and inclusion, particularly in conversations about the hypothetical individuals present in a conceptualized makerspace. Participants tied their descriptions of diversity in makerspaces to the exclusionary history surrounding who was welcomed in makerspaces and technologically-centered spaces more generally. This included age, gender, and race. As one participant succinctly responded:

> I would be lying if I didn't say it was what I think people deem as nerds, or people who are more tech savvy, or you know, when you ask kids what does a scientist look like and they draw a white dude in glasses in a lab coat I think there is some bias built in to everybody when it's a STEM-related area. That's, I think, what makerspaces are typically thought of.

Furthermore, describing typical users of makerspaces with aspirational or idealized language was evident in four interviews. We further describe this tension inherent in definition work, and its relationship to values and beliefs, in our upcoming article about the descriptive theory of makerspaces (Melo et al., 2022).

Staff and Users

Ten interviewees described makerspace staff as looking similar to users. For example, one participant noted:

> What's interesting is you often you may not be able to tell who is the worker...we have lanyards for the workers, but a lot of our makerspace workers look like the students working because often we hire the people that

Table 2 Descriptions of People in Makerspaces

Theme	Description	Prevalence	Example
Staff look similarly to students	Staff and users are visually similar	**10**	"So their physical look wouldn't necessarily differentiate them as staff people but their attitude towards things and people coming in would."
Young adults or "Student-age"	People in the space are young adults	**6**	"So I guess the bias that I bring to it is that I see mostly college-age people, so I see mostly people between the ages 18 and 30 in the space."
Skew male	Male users are most prevalent	**6**	"[T]hey also tend to be a lot of white male students, which like I said is not a bad thing, but I do think it's important to have kind of a well-rounded thing."
Skew white	Users and staff depend on surrounding community, signaling mostly white	**5**	"Racially our university isn't as diverse as I would like it to be…so that's determined who comes in…"
Intentional staff differentiation	Use of visual cues to differentiate staff and users	**Staff in support of uniforms, name tags, or lanyards: 4**	***Staff wear uniforms, name tags, or lanyards:*** "I think generally there is some sign that you can [differentiate] with a badge or special uniform that they're wearing that you know who the staff people are…"
		Against: 2	***Specifically rebuked differentiation:*** "We tried name tags and lanyards but it went against the culture that we were intentionally trying to create. […] [I]t starts to make your job feel a little bit too regimental and that undercuts…the collaborative free thinking almost loose nature of making in maker spaces."
Couched responses related to diversity	Responses related to identity include aspirational or idealized language	**4**	"I think it should be independent of race, or independent of gender, so I would hope to see in these spaces a mix of male, female."

> come in and work. And so it's not clear, necessarily, except for the identifying [lanyards].

Along with this participant, three other interviewees described the use of uniforms, name tags, or lanyards by staff for easier identification. As one individual explained, "I think generally there is some sign or that you can tell with a badge or special uniform that they're wearing that you know who the staff people are…" Two participants also detailed the use of 3D printed name tags as a means to showcase makerspace capabilities, as well as staff members' individuality. On the other hand, two participants argued against using formal staff identification:

> We tried name tags and lanyards, but it went against the culture that we were intentionally trying to create. I mean, everybody likes to have their badge, but to walk around with it, it starts to make your job feel a little bit too regimental and that undercuts …the collaborative, free-thinking, almost loose nature of making in makerspaces.

This decision not to differentiate staff in order to encourage more collaboration offers a clear connection between leadership choices and goals for the space.

Makerspace Assets

All fifteen interviewees offered their own interpretations of defining features, which ranged from the identification of specific tools (e.g., 3D printers, circuitry materials) to more intangible characteristics (e.g., self-expression, collaboration – discussed further in Melo et al., 2022). Responses with more than one key trait were coded multiple times. A list of frequently described assets present in makerspaces is outlined in Table 3.

Table 3 List of Defining Makerspace Assets

Asset	Prevalence	Example
Furniture		
Work tables/benches	13	"[Instead of individual workspaces, there are] community workspaces tables set up, it's not just the equipment. I think that would differentiate a lab from a makerspace, that there's open seating, open tables where you can work, most labs don't have those types of spaces just because you just need your general work table associated with whatever equipment that you're accessing."
Cabinets/drawers	6	"I see a couple that are raiding the art supply cabinet because they have a diorama that they have to make for a class."
Shelving	5	Three participants: proponent for holding tools "[W]e…finally have a shelf now where the sewing machines are prominent and that's very key to us." Two participants: desire for project displays "So I like the idea of a place where you can have a physical display, maybe clear shelving and it's got some stuff that people have let us use, so whether that's like 3D prints or projects or whatever."
Displays		
General examples on display	11	"So literally just a wide variety of examples of items that folks have created for class work, but also for pleasure work as well because maker spaces might not necessarily just be for academic course work."
3D Print examples	5	"So we have 3D print examples of varying types and colors and they're on a clear shelf that mounts to the glass wall so you can see it from either side and any angle and it does spark interest and possibilities."
Pop-culture examples	5	"Geek and nerd culture" including Pokémon characters and *Star Wars*
Early attempts/failed projects	4	"I always appreciate this sort of in-process kind of objects that are around or scrap mistakes, so you know the 3D print job that went bad or the scraps of fabric that kind of got sewed into a bracelet or something and you kind of have the remnants of that around."
Signage		
Welcome (including name/purpose of space)	9	"There's a welcome sign when you come in. I would think most spaces have that to be like, 'hey come to this space.'"
Safety	8	"[S]igns by different machines and different workstations and things saying here's the safety protocol, here's what you would need with this."
Tool reminders/how-tos	7 Specifically included QR codes with how-tos: 3	"So each machine has a standard operating procedure laminated and hanging from it, but that's just an 8 ½ × 11 sheet that is a reference or reminder." Three participants specifically included QR codes with how-to information: "[Instructions] are conveyed in a combination of print and potentially QR codes that you can scan and it's a video walkthrough, so it's as ADA compliant as it can possibly be."
Marketing (e.g., billboards, banners, university logo, upcoming events)	6	"I'd say it would be more design focused and less like wordy, so it could be the logo of the space or even the name of the space, or some sort of motif that kind of goes through the rest of your marketing…they're not like fancy posters you get from a vendor or something like that, kind of home grown sort of stuff."
Permission-related (authorized access needed, what not to do):	5	"[T]here's signage around the controlled access."

Table 3 (continued)

Asset	Prevalence	Example
Tool labels or specialized zone areas	4	"[L]abels of what the tools are or work areas, metal shop, wood shop, sewing area, electronics, if they're split up like that and sometimes they're not so it's not that clear."
Inclusion-related	3	"Motivational posters, like we have pictures of famous women scientists around."
Tools		
"General" tools (e.g., handheld or digital tools)	11	"[E]ntering the door of the makerspace, I would see tools on the wall that [are] available to me to use."
Specific tool as defining feature (e.g., sewing, 3D printing)	5	"[S]ome of the common things that I see are 3D printers, laser cutters, [a] variety of hand and power tools."
		Tools mentioned/alluded to as part of space more generally: • 3D printers – 16 • Laser cutter – 12 • Electronics – 11 • Sewing machines/textiles – 9 • Computers – 9 • Hand/power tools (e.g., drills, wrenches) – 7 • Art supplies (e.g., paper, markers, paint, clay)—6 • CNC – 5 • Culinary/kitchen—4
Materials		
Materials as defining makerspace feature	4	"[A]ccess to materials that are … low ceiling, low floor, so you can just get in and start using them."
Materials mentioned/alluded to as part of space		• Acrylic/plastic – 13 • Wood – 12 • Circuits/electronics – 6 • Paper – 5 • Metal – 5 • Fabric—4
Smells		
Burning/melting	11	"Burnt plastic, those printers are smelly. If the laser cutter is running, then burnt wood."
Acrylic/plastic	11	"Probably a somewhat burnt plastic smell from the 3D printers."
Wood	10	"[T]he CNC, when it's running, you definitely smell like a wood shop. And depending on what wood we're cutting, it might have a different flavor."
Metal	5	"If you're working with metal it has a different smell."
Sounds		
Conversations/talking	14	"I know that the equipment itself can be noisy, but I think what really identifies it as a makerspace is the natural conversations that come up between different people who are working."
Equipment Noises	8	"So there is a steady hum with the machines, most of them kind of stay on."
Music	5	"[W]e actually have a playlist that the users of our lab kind of add to, as the lab grows the playlist kind of grows. There's a variety of music being played…Like we just learned about K-pop, so someone likes K-pop and they selected a K-pop group to add to our playlist."
3D Printer Noises	4	"If you're using a tool, 3D printers have sort of a beep boop bop kind of songs that they sing so there's sort of a constant electronic kind of sound going on."

Furniture

Most interviewees (13) cited work tables and benches as a prevalent feature of makerspaces. In fact, one interviewee claimed collaborative tables are a differentiating factor between labs and makerspaces. Other furniture reported often in responses included cabinets or drawers (six interviewees) and shelving (five interviewees). Three of the five participants discussed in detail how shelves function to store equipment. More information about displays will be covered in the next section.

Displays

Eleven participants described displays showcasing projects that were created in the makerspace. For example, when they were asked to describe how the walls might be decorated, one participant discussed shelves, "[Makerspaces] can also be a space that you can come in and experiment on your own so like a whole variety of [project displays] look at all the cool things you can do here." Nevertheless, the incorporation of project displays comes with a set of advantages and disadvantages that need consideration.

Educators adhering to Lowenfeld's (1987) early methods in art instruction may fear showing examples intimidates students and/or encourages imitation. However, contemporary educators consider showcasing models of work as an important component of self-directed creative projects (Simmons, 2007, p.87). Following Berger's (2003, p. 31) understanding of project-based learning and craftsmanship, examples provide "a taste of excellence" and allow students to see "where they're going," compare their work, and problem-solve disparities between the two. Instead of showcasing only high-quality work, four participants further specified that their examples also included early attempts or failed projects. These interviewees believed featuring imperfect work lowers user inhibitions by helping users feel more comfortable starting (and failing) projects.

Tools

Eleven interviewees mentioned basic hand tools (e.g. hammers, screwdrivers, and pliers) as a defining feature of makerspaces. One participant specified "in-your-face technology that tells me what it is for" was needed to ensure the space was intuitively recognizable. Others used general terms such as "digital," "analog," or "handheld" tools in their responses. Five participants mentioned specific tools while describing their key features of makerspaces. This included circuitry and electrical materials, sewing and textile-related tools, and laser cutters/CNC machines. A list of all tools frequently mentioned by participants more generally is outlined at the bottom of Table 3.

While four participants explicitly mentioned 3D printers as defining features, twelve others mentioned the presence of these machines elsewhere in their interviews (in total, 16 participants). As one participant remarked, "in today's makerspaces, obviously one of the prominent pieces of equipment you have are 3D printers." However, three participants detailed their objections to its overuse. One individual mused:

> [W]e came up in the age where 3D printing was associated with the makerspace. Makerspace 3D printing equaled making plastic crap that was figurines or whatever...It's like we're trying to break out of that mode

In response to a prompt asking why 3D printers were so popular, another interviewee responded:

> I think it goes back to...I have this technology that nobody else has that's super special and I can do all these things...It feels silly to me because you're downloading something off Thingiverse, and like printing it, and you're not actually making anything…but yeah, it's baffling to me.

One participant revealed their hesitation at the immediate inclusion of 3D printers versus other tools:

> [W]hen schools come to us and say, 'we want to build a makerspace, we want to get a 3D printer,' I'm always kind of hesitant to say get a 3D printer at first. Because you can only serve two or three kids...So I always recommend the [3D Doodler] for schools...because a lot more kids can use them...Maybe when you think about that word making, it's also like this thing makes things out of the thin air... I mean, they're amazing machines. I mean, I got 3D printed stuff everywhere. So you know, I'm not one to knock a 3D printer, but yeah.

Materials

Of the five participants who mentioned specific tools, four also described access to materials as a defining feature of makerspaces. For example, after describing specific tools, one participant continued:

> Also maybe the things that go along with [the machines listed], maybe some supplies available for students to use to get those projects done. So the paper, the wood, plastic, the sheets and things like that so you can actually use those things to complete your projects, depending on the space. Some spaces have you bring those in yourself or purchase them, and some spaces provide them to you.

This quote also highlights the tendency of participants to directly cite their own experiences in their responses, as is described further in Melo et al. (2022).

Smells and Sounds

The materials mentioned earlier, along with their associated tools, are popular choices that align well with the smells and sounds commonly described by most participants. As one individual remarked, "I think [smell] conveys what's happening, and you know, same with the sounds. It's just what's being used…what tools, what materials." Eleven interviewees described a burning or melting smell, either from plastic filament for 3D printers (PLA) or from wood. Another participant considered the impact of ventilation while describing the burning smell associated with makerspaces. For two participants, burning wood smelled like a campfire. Unexpectedly, melting PLA filament smelled differently to participants. Aromas such as popcorn, pancakes, and maple syrup were noted. More generally, eleven people mentioned the smell of acrylic or plastic, ten described smells associated with wood, and five specified metallic smells.

By far, the most popular sound mentioned (14 participants) was people talking to one another. One participant reported some of the discussions they might overhear:

> Conversations about cost, conversations about technological platforms that they're utilizing, actually walking individuals through how to use individual pieces of equipment or particular site at that point in time. So a lot of it is centered around the space itself and actually learning how to utilize what's in it.

Eight people cited a general hum of equipment or mechanical noise and four specifically mentioned the noise of 3D printers. One interviewee detailed this "symphony" of mechanical sounds. Five participants included music in their descriptions of the sounds present in a makerspace. A participant described the use of a collaborative playlist:

> [W]e actually have a playlist that the users of our lab kind of add to, as the lab grows the playlist kind of grows. There's a variety of music being played… Like we just learned about K-pop, so someone likes K-pop and they selected a K-pop group to add to our playlist.

On the other hand, another participant confessed, "Well if I let the students choose the music they usually put on bad Disney music and so let's get that right, it will drive you nuts." This highlighted the challenge of maintaining a balanced and enjoyable atmosphere for all.

Putting Research into Practice: Guiding Questions for Makerspace Leaders

To ensure a makerspace is inclusive and accessible, makerspace leaders could explore a range of questions related to key characteristics and features. The questions can be organized based on the different aspects outlined in this research study, including physical features, people, tools, materials, smells, and sounds. Responses will help identify potential areas for improvement to create a more welcoming and equitable environment. Here's a schema of questions makerspace leaders can start with:

Physical Features:

- How can we use bright colors to facilitate creativity while considering the sensory experiences of all users?
- How can we maintain openness in the space while ensuring it's welcoming to a diverse audience?
- Should we have a designated check-in area, and if so, how can we make it inclusive and not intimidating? Signage?

People:

- Do our staff members look similar to our users, and is this a potential barrier to diversity?
- Are there specific age or demographic groups that we see more often in the space, and if so, how can we broaden our user base?
- How can we address and challenge biases associated with STEM-related areas to create a more inclusive environment?

Tools and Materials:

- How can we make the presence of general tools and specific tools more intuitive for all users?
- Are there any tools or materials that are underutilized or overemphasized, and how can we balance their availability?
- How can we ensure access to a diverse range of materials to accommodate various user needs and projects?

Smells and Sounds:

- Are there any strong smells in the makerspace that could be uncomfortable or problematic for users with sensory sensitivities?
- How can we maintain a balance between the sounds of equipment and machines and the comfort of natural conversations in the space?

- What measures can be taken to ensure that sound and music choices are diverse and considerate of different preferences?

These questions should serve as a starting point for makerspace leaders to assess the inclusivity of their space. Regularly seeking feedback from users, conducting surveys, and engaging in discussions with diverse community members can provide valuable insights to make the makerspace more welcoming.

Conclusion

This article outlined the importance of enumerating the common features of an academic library makerspace. While every individual makerspace may be different, we found common overarching features. These commonalities provide an entrypoint to interrogate and engage with the potentials (and pitfalls) of the space as a curated environment, particularly in regards to engaging with underrepresented user populations. The interviews with makerspace leaders provided an incisive perspective into the design rationale governing these popular STEM-rich learning environments. The utility of the findings from this study create starting points for information professionals to identify which features support or detract from serving the needs of their user communities.

Data Availability The datasets generated and analyzed during the current study are not publicly available at this time, as the research program is ongoing. The datasets will be released to the public upon the completion of the program.

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