MAKING CULTURE

A National Study of Education Makerspaces

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Introduction

Makerspaces and "maker learning" have captured the attention of education leaders and advocates for education reform. Many teachers, principals, superintendents, and board members are developing and investing in such spaces and programs as potentially transformative pathways for student learning. The landscape of makerspace literature consists primarily of well-intended playbooks, technology explainers, and how-to guides for designing the definitive makerspace. The greatest potential impact of education makerspaces, however, lies not in the equipment or procedures of making, but rather in the culture they enable, nurturing and promoting learning through creation, collaboration, and individual agency (control, autonomy, and choice). This cultural focus has been largely absent in other research and publications on making.

This study offers a detailed examination of the cultures of learning emerging in makerspaces across the United States and offers recommendations for those seeking to create an inclusive, vibrant, and collaborative culture of learning through making. It is the result of linguistic analysis of detailed interviews and observations from 30 sites across the country focused on formal, kindergarten through high school student participation, learning mindsets, and community connections within the context of education makerspaces.

What is a Makerspace?

Makerspaces are communities where participants design and produce creations using a variety of tools and crafts.[1] These spaces often combine both technical and artisanal approaches, fostering a sense of agency, engagement, ingenuity and problem-solving. Participants identify as "makers" and the activity within is called "making".

Makerspaces typically encourage members to embrace the physical act of design and production. They have traditionally incorporated the use of high-tech machinery combined with an artistic spirit, and many makerspaces prioritize creativity and exploration, encouraging participants to engage in personalized or collaborative challenges.

Education makerspaces facilitate an active learning environment in which students are encouraged to develop, design, and create their own content, projects, and products.[2] They are not single-dimensional; leaders claim there is room in makerspaces for myriad learning opportunities and personal empowerment for everyone.[3] As more and more education makerspaces are developed, it is increasingly important to fully understand the maker identity and adapt and expand certain aspects to offer additional pathways for student inclusion.

Learning through Making

The practices of learning through making can be traced to foundational research in education and learning science. Maria Montessori and Jean Piaget were advocates of building and making as necessary pursuits in the learning process of children.[4,5] At the heart of their work was identifying the tools and cognitive processes learners engaged with to construct knowledge in the physical world (known as constructivism). The modern maker movement began in the 1980s with Seymour Papert's theory of constructionism, a variation of Piaget's constructivism. Papert believed that humans learn most effectively through creating and making new artifacts.[6] Makerspaces are an extension of his work, integrating arts and technology to support learners in problem-solving, design, and physical production of their ideas.

While there has been substantial research on constructionism, underpinning the maker movement, there is relatively little academic research on makerspaces themselves:

> *"…despite a flurry of interest and activity around designing and creating makerspaces, we still know little about the content and processes of learning in makerspaces".*[7]

This report advances this discussion by focusing on the role and impact of maker culture on learning in a variety of different education makerspaces.

Making Culture

The culture of making is related to the do-it-yourself (DIY) philosophy of repair, modification, or enhancement of products or the built environment. Maker culture has progressed from localized DIY projects to a global network of spaces, skills, and means of production. Many experiencing the empowering culture of making develop greater self-efficacy and a strong desire to apply their skills in the community.[8, 9] While makerspaces can provide participants the opportunity to design and create for themselves, maker culture also celebrates collectivism, where the sum of parts benefits members of the community both in skill and sharing of knowledge.[10] The social and collaborative atmosphere surrounding maker culture presents the opportunity for members to bond beyond their knowledge and technical skills and engage across diverse areas of interest. This combination of mentorship, collaboration, and application has driven many educators to embrace makerspaces as a model for progressive education in both schools and informal learning environments.

While common cultural themes are shared across education makerspaces (stemming from the maker ideals described above), there are also significant differences. Some successful learning spaces focus on specific project themes while others encourage open exploration. Some programs emphasize coordinated team efforts (e.g., competitions) while others pursue individual showcase opportunities (e.g., "Maker Faires", a series of maker-themed events held nationwide). These outcomes do not simply happen on their own, but are the result of choices (intentional or not) and the cultural surroundings of a makerspace. In this report, we investigate these aspects so that those leading or planning such spaces can make informed choices about the culture of learning they seek to create.

Research Design

Our study was designed to explore culture as a force for changing student learning outcomes through participation in makerspaces. Over one calendar year, we interviewed 80 participants, including instructors, students, and administrators across a combined total of 30 formal (in-school) and informal (after/out of school) educational makerspaces. Given the difficulty of assessing qualitative cultural elements through surveys and quantitative tools, we employed an ethnographic approach for this research. Ethnography is the study of people (and cultures) in their own environment, using such methods as recorded observations, interviews, and the study of materials produced at a site.

With sites spread over multiple regions across the country, it was crucial to develop a unified language and framework of observation to better understand the aspects of culture within these spaces. We documented the participants and environment through video and audio recordings, which were transcribed to form an initial set of textual linguistic data, supplemented with additional handwritten notes. Loosely-structured conversational interviews focused on capturing participants' interpersonal and institutional experience in designing, building, and teaching at their makerspace site. We sought to surface the types of learning and engagement conducted in both formal and informal settings and on understanding how makerspaces form in different communities.

Participants

We selected sites and populations to research according to specific criteria related to the following factors: makerspaces serving K-12 students, location in an urban metropolitan region, and access to a curriculum or pedagogical model that researchers could review and compare.

K-12 Learning Makerspaces

From the many types of makerspaces across the country (e.g., institutionally-affiliated, entrepreneurial, community-based), we specifically selected sites offering K-12 education programming to better understand the impact of making on student learning. We sought to include both formal (in-school) and informal makerspaces to provide a diversity of perspectives on maker culture.

Focus on Metropolitan Regions

Education makerspaces are more common in more affluent schools and districts, often in suburban locations.[11] We were particularly interested in studying makerspaces located in urban, metropolitan regions, which tend to receive less education support per student than suburban counterparts, to enable educators and researchers to understand how diverse urban populations are specifically impacted by maker culture. There are relatively few examples in such locations, and it would be helpful to share their learnings with similar communities.

This Study Consisted of 30 Site Visits to Makerspaces Across 12 Urban Regions.

Access to a Curriculum or Pedagogical Model

This study focused on makerspaces with an established curriculum or pedagogical model. This criteria was established to focus our research on more mature curricula and pedagogical design rather than experimental or ad hoc methods. This approach also allowed us to identify makerspaces that had found some degree of sustainability in serving student cohorts for three years or more.

Linguistic Coding

To best capture the broad range of topics, properties, and responses encountered in the makerspaces visited, we employed a hybrid analysis framework to organize the large amount of qualitative information collected. The interview data from participants in makerspaces was analyzed using linguistic qualitative coding analysis with the primary goal of identifying patterns.[12] We selected this method of linguistic qualitative coding (i.e., language coding) for its robust capacity to

quantify the coded data. Language coding assigns meanings to patterns and occurrences and marks each with a unique code.[13] Examining these unique codes and building specific coding filters helps us to understand the ways in which culture is shaped in makerspaces. Our process of coding 4,600 data points involved researchers meticulously reading and categorizing words or short phrases and ascribing meanings.

Our methodology employed a coding scheme consisting of 3 hierarchical levels. Below are some examples of Level I codes, representing the most general concepts.

Table 1. Examples of Level I Codes Utilized

Code Name	Code Description	Examples
Agency	The subject references agency and self-motivation within the makerspace (and its activities).	"It's organic. It's their idea. I don't force any ideas. I try to make the space for them, so they pretty much control, most of the time, what they're making. I don't try to push on any ideas unless they're in a class setting when we make together." "What I love about this space is I'm able to have control over the curriculum, and I feel like coding is very important. I'm hearing a lot of people who are in undergrad or grad school, they're not coding until they get there. If we can give them the exposure before they get there, they can start coding in high school, and they can be exposed … They can put these skills in their resume."
Community	The subject references community engagement (internal or external) with the makerspace.	"Our makerspace will serve as this kind of community outreach for these middle schools to come here." "…we have open house in our makerspace with parents and the community, the are in aww, oh my God I can't believe that there's this happening, I had no idea that my students were engaged in these activities or had the opportunity to be involved in learning spaces like this." "A lot of them [parents] say they wish they would have had it when they were here. They would have never left this room if it was here when they were here. Just like the opportunities they're giving these kids now, learning through these experiences."
Culture	These are instances when the speaker references "culture" or "maker culture" in reference to makerspace	"…just because you put in the makerspace in that school doesn't mean that's going to change culture of that school for the better." "Most of our kids have existed since there was an iPhone in this building so getting our teachers to pick up on that and to share the same philosophy that some of the work that has to be done." "I… don't give a s**t if you put in a Makerspace, that is not going to change the culture around your school. I mean maybe it is an entry point if you can bring the maker culture with it."

Our findings focus on three prominent cultural aspects of makerspaces: participant identity within a space, the development of a "maker mindset" in students, and community engagement inside and outside the space.

Section 1: Equity and Inclusion

Maker culture, rooted in STEM (Science, Technology, Engineering, and Mathematics) disciplines, presents itself as a "DIY", merit-based, and equitable environment. Our study focused intently on understanding how urban makerspaces related to these cultural frames, particularly with regard to gender equity. Cultural bias has been well-documented within the traditional STEM disciplines, as evidenced by the lack of diversity in many programs, leading to environments hostile towards women and minorities.[14] We sought to understand if maker culture includes similar biases through interviews with makerspace leaders, instructors, and students. In addition, we also examined recruitment materials for both instructors and students (job postings, flyers, etc.) to better understand factors related to equity and inclusion in these spaces.

The data collected from site visits and interviews, detailed below, revealed pervasive, implicit gender bias, from leadership recruitment to the labeling of student participants.

The Gendering of Making

The spaces included in our study exhibited gender imbalance within leadership positions: 76% of the leaders were men and 24% were women.

Gender parity was documented in K-8 makerspace participation, where girls made up a nearly equal proportion of student participants. The spaces included in our study, however, exhibited a sharp decline in makerspace participation among girls between the K-8 grades and high school, where female representation dropped to 25%.

Examining the materials used by spaces in our study to recruit makerspace instructors reveals they may contribute to, and even reinforce, gender disparity in leadership positions. The imagery most frequently used in instructor recruitment exhibits a substantial gender bias. Similarly, student recruitment materials used by the spaces in our study also makes more frequent use of male-gendered imagery.

These examples from both instructor and student recruitment highlight the implicit bias embedded within emerging makerspace culture. The imagery employed is perceived by many, particularly those deeply invested in making, as positive, productive, and dynamic, but can simultaneously exclude potential participants.[15, 16, 17]

Participant interviews provided greater evidence of a more pervasive gender bias within makerspace culture. Interview subjects were invited to engage in an open-ended discussion concerning gender equity and participation within their spaces. These discussions were coded and analyzed to inform our

Table 2. Most Frequent Imagery Included in Makerspace Instructor Recruitment Flyers

References	Images in Instructor Job Postings
	Gendered
11	Male Engineer
8	Dynamite
6	Power Tools
	Neutral
4	Gears
1	Paint Cans
1	Easel

Table 3. Most Frequent Imagery Included in Makerspace Student Recruitment Flyers

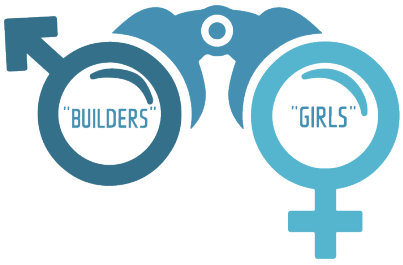
References	Images in Student Recruitment Flyers
	Gendered
15	Hammer
11	Rocket Ship
7	Saw
	Neutral
2	Stars
2	Numbers
1	Hands

knowledge of gender dynamics across makerspaces. Perhaps most strikingly:

> ***Instructors primarily referred to male students as "geeks", "builders" and "designers" (never "boys"), but most frequently referred to female students as "girls" or even, "helpers".***

The sheer number of identity references based entirely upon gender ("girls") is deeply unsettling. Also note that the use of "boys" in referring to makerspace students did not occur at all in these interviews. This gender imbalance shaped attitudes and activities within the makerspaces:

- Boys were twice as likely to hold leadership positions in group makerspace activities;
- Boys were more likely to steer major project topics (robotics challenge, Lego, solar car design);



We also observed a gender disparity in expressed design agency (ability to design or guide project activities) in formal vs. informal learning makerspaces. Boys expressed greater agency in formal spaces whereas girls expressed greater agency in informal spaces.

This evidence suggests a persistent, but possibly unintentional, culture of bias reinforced by makerspace leadership. Research into boys and girls engaging in STEM learning reveals that girls and boys have equal potential to become proficient in STEM subjects (evidenced in our study through nearly equal makerspace participation in grades K-8).[18] While most leaders believe that makerspaces have the potential to function as a safe space where girls and young women can engage in an open collaborative learning environment while dismantling gender stereotypes, our research also indicates that more must be done to achieve an inclusive culture of gender equity.

Table 4. Identity References From Instructors to Male and Female Students, With More Neutral Identity Markers for Comparison.

Identity Markers	References
Referring to Male	
Geeks	20
Builders	18
Designers	15
Engineers	13
Referring to Female	
"Girls"	92
Helpers	11
More Neutral - Referring to Both	
Entrepreneur	3
Creators	1
Innovators	1

Table 5. Common Terminology in Recruitment Materials for Makerspace Instructors and Participants.

Job Postings	*Student Flyers*
Tinkerers	Hackers
Passionate	Shop Nerds
Builders	Geeks

Explicit "Maker" Identity Cues and Participation

Beyond gender, interviews with stakeholders and participants revealed consistent language patterns related to explicit identity cues, such as references to makerspace members as "hackers", "tinkerers", and "builders". Coding for these explicit identity

cues revealed bias in the recruitment of instructors and students to join makerspaces. Some job postings for hiring makerspace leadership and instructors employed bold typeface or all capitals for the terms "techie," "gear-heads", and "tinkerers." These explicit language cues, though celebrated by many Makers, also point to a particular form of experience, which may exclude other qualified applicants. In fact, when addressed by interviewees, such language made some applicants hesitant to apply as they were unsure whether they had all the necessary skills to lead a makerspace. Our study also found that similar explicit identity cues were replicated when recruiting a "type" of student for a makerspace, as indicated in the table.

The most common framings encountered within internal school recruitment for makerspaces were (paraphrasing):

"Students who are a bit geeky and can innovate"

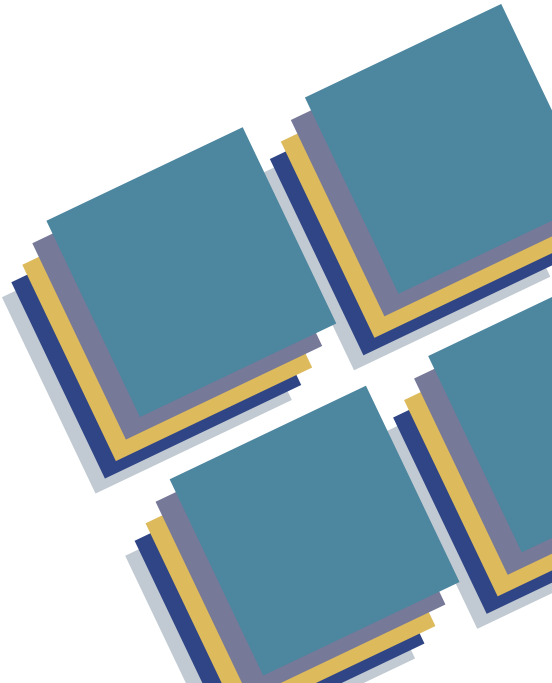
"Smart kids who like to tinker"

This declaration for a specific participant identity presents a potential barrier for broader inclusion in a makerspace. It is evident that explicit language cues used for hiring leadership found their way onto the student recruitment flyers.

We interviewed both student members and non-members of makerspaces, to get a better sense of how these explicit identity cues were shaping participation. Students who became members agreed that the explicit identity cues confirmed how they saw themselves as makers. Across our interviews, non-member students pointed to the expectations from flyers as adding pressure and presenting a less-welcoming environment. One student explained that identity cues on the flyers made him reluctant to join because he did not identify as a hacker or geek. Other researchers have studied the negative consequences of this hacker and geek culture narrative built into many STEM and coding camps, where participants are rewarded for exhibiting self-confidence and expert level skill.[11] Our student subjects articulated similar frustrations regarding these dominant identities found within makerspaces.

Positive Makerspace Impact on Broader Groups

In our research, we observed the potential of makerspaces to improve engagement with English language learners (ELL) and students facing disciplinary issues. First-generation English learners expressed greater agency and self-confidence from their experience in makerspaces. These students felt empowered to work on new language skills in the open and collaborative environment through conversations with their peers. Student interviewees suggested that working on creative problem-solving projects reduced the fear of making mistakes when speaking out loud, fostering greater fluency and retention:



- ELL students referenced reduced anxiety with language around school activities based on collaboration in makerspaces.
- ELL students referenced using technical manuals as part of their literacy development.
- ELL students expressed being more comfortable using their native language to problem solve or complete assignments in the makerspace than in other STEM settings.

Teachers also frequently referenced specific changes in behavior in their ELL students from makerspace participation, leading them to believe that engagement had improved.

In students with prior disciplinary issues, teachers reported changes in behavior, including increases in overall focus and completion of assignments. This change was documented while interviewing non-makerspace teachers in formal school settings.

Teachers felt the makerspace offered students an opportunity that traditional learning environments did not, and the new practices and norms of the makerspace challenged students' behaviors. Teachers reported that makerspace involvement had a positive effect within the traditional classroom setting, revealing a marked improvement in behavior.

Table 6. Teachers' Most Frequent References to Behavior Changes in English Language Learners in Makerspaces.

Increases	Decreases
Attendance	Isolation
Leadership	Solo projects
Peer Teaching/ Sharing	Deferring group responsibilities

Table 7. Teachers' References to Behavior Changes in Students With Prior Disciplinary Issues After Enrolling in Makerspaces.

References	Behavior
40	Completion of Assignments
27	Attendance
13	Less disruption
10	Leadership

Section 2: Makerspace Culture and the "Maker Mindset"

Our research sought to explore ways in which makerspace cultures facilitate the development of a "maker mindset". According to Dale Daugherty, founder of Make Magazine, the maker mindset is:[19]

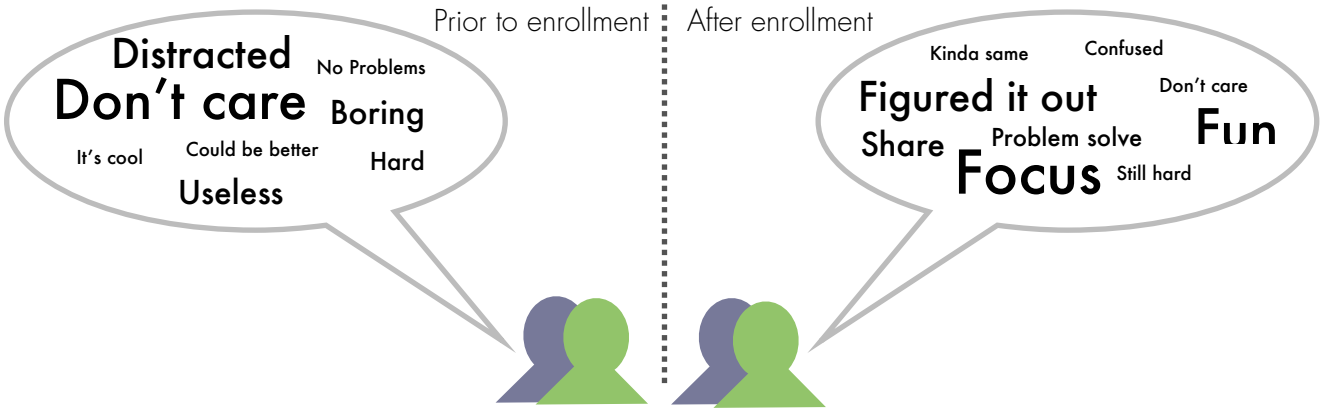
- A "can-do" attitude that can be summarized as "what can you do with what you know?"
- An invitation to take ideas and turns them into various kinds of reality.
- The process of iterating on a project to improve it.
- A chance to participate in communities of makers of all ages by sharing your work and expertise.

In our study, we examined the role of makerspace culture in developing this maker mindset in students, through choices of curriculum, out-of-class opportunities, and preferred avenues for presentation and dissemination.

A Positive Shift in Mindset through Makerspace Participation

Through the coded data of students' interviews, we were able to evaluate how participants' experiences are shaped by makerspaces.

From Student Interviews: Most Frequent Terms About School, Prior to and After Enrollment in Makerspaces.

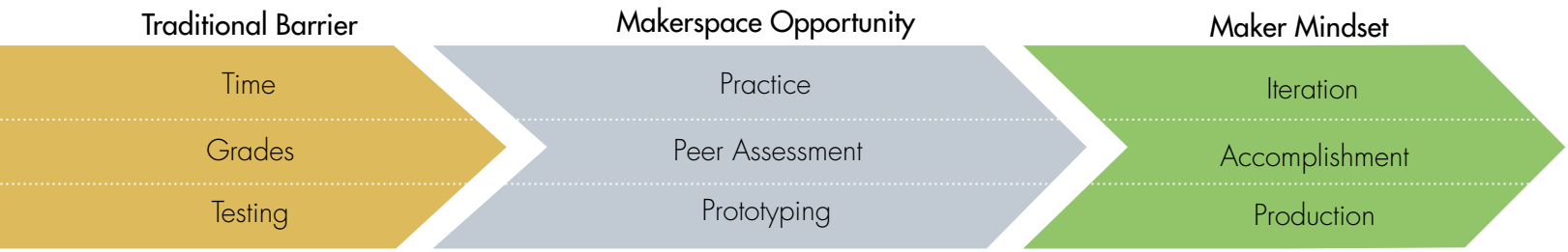


Through these interviews, participants differentiated their experiences in the makerspace from other experiences at school, fostering a markedly more positive mindset. Students also voiced newfound connections between what they learned at school and the world around them from makerspace participation (i.e., "seeing the world differently") and were more likely to share their work with friends and family.

The students interviewed also articulated the explicit role of their makerspace activities in helping to overcome challenges encountered in traditional classrooms. The most frequent classroom barriers mentioned were insufficient time, grades, and testing. Students referenced specific aspects of maker culture, practice, competition, and building, as tools for meeting their classroom demands. These

self-reflections reveal a significant shift in mindset, no longer focusing on the impediment, but rather on the outcome from the challenge presented. While the sample is small, we find the connections expressed below to be quite powerful and revealing.

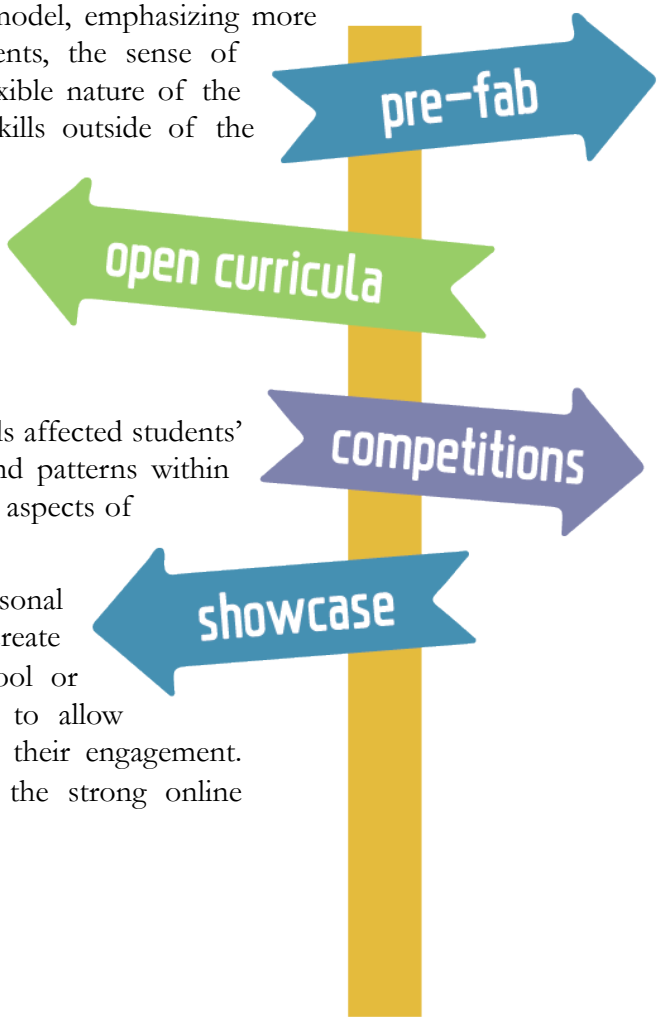
Evolution of Student Responses: From traditional classroom barriers, to makerspace opportunity, to maker mindset



Approaches to Facilitating a Maker Mindset

Many makerspaces we observed used pre-constructed lessons, packaged instructions that came with makerspace kits or curricula developed by governing organizations, such as Fab Lab (in our survey, the majority of the Pre-Fab makerspace material came from the Fab Lab foundation). Administrators and teachers we interviewed welcomed these lessons because of their connection to the Fab Lab global community and online resources. Some students articulated that having detailed designs and creation processes reduced anxiety and provided a guided opportunity through new makerspace experiences.

Other spaces based their efforts on an open curriculum model, emphasizing more personal self-directed projects. According to some students, the sense of empowerment and agency they developed through the flexible nature of the open curriculum allowed them to apply their acquired skills outside of the makerspace environment.



Formal learning spaces tended to use pre-fab curricula, while informal spaces generally favored an open curriculum model.

We sought to better understand if different curricular models affected students' mindsets. When interviewing student participants, we found patterns within the two curricular models emphasizing positive, yet distinct, aspects of the "maker mindset".

Students in an open curriculum expressed a greater personal interest in their work and had the ability to modify and create local engagement or projects (primarily inside their school or organization). The openness of the curriculum seemed to allow students to be more creative in the ways they expressed their engagement. Students within a pre-fabricated curriculum emphasized the strong online

community through websites where they could gain tips and share ideas. They also found work in the pre-fabricated curriculum was more directed (e.g., "straight to the point"), allowing them to proceed efficiently and effectively (especially those who had no prior makerspace experience).

Instructors in the open curriculum found that students were developing their identity through their projects (Table 8). Teachers also referenced seeing problem-solving skills and personal growth development within the open curriculum. Teachers using a pre-fab curriculum made greater references to the resources available and support they received. Thus, using a pre-fabricated curriculum allowed many of the instructors (some who had never previously used or taught in makerspaces) an entry point to the Fab Lab communities to look for support. They found the organization of the materials favorable, accelerating development within their makerspaces.

Table 8. Most Frequent Terms in Participant Responses From Open Vs. Pre-Fab Curricular Designs Related to the Maker Mindset.

Students	Teachers
Open Curriculum	
(Personal) interest	Identity
Modifying projects	Problem Solving
"Local" work	Growth
Pre-Fab Curriculum	
Website (community)	Resources
"Straight to the Point"	Support
Network	Organization

The Role of Unstructured "Open Hours" in School Makerspaces

In our study, we found many instances where makerspaces were available to students before school, during lunchtime, and after school. These periods of "Open Hours" were created to provide students with an opportunity to interact and play with the resources and tools within the space. Open hours benefitted makerspace students who felt constrained by time or those who did not feel they could use the tools and materials for work not connected with their primary projects. Some instructors felt they were not reaching a large enough student population through structured classes, particularly students on the fringes of engaging in the makerspace. The open hours enabled more students to explore and use tools they were not using in their structured class time.

Based on student and teacher interviews, there were frequent references to the benefits of open hours in reinforcing particular components of the maker mindset. Open hours enabled students to explore and take more risks and also allowed participants to bring friends along to the makerspace, introducing more students to new tools and design skills; in some cases, this provided another entry point to becoming a regular member of the makerspace.

Instructors observed that during open hours, students took notes, read technical materials, and asked leaders more questions. Furthermore, instructors reported that makerspaces with open hours before school led to increased student attendance.

Demonstration of Maker Experiences and the Maker Mindset

In presenting and demonstrating their work, the makerspaces in our study pursued two primary outlets: showcases and competitions. Makerspaces pursuing an open project environment tended to engage in showcases,

locally or nationally. Makerspaces that favored pre-fabricated curricula preferred competitions, which provided rules, structure, and in most cases, materials. When interviewing students and teachers about their experiences in either Maker Faires or competitions, responses emphasized positive, yet culturally differentiated, components of making:

Maker Faires emphasize "sharing", "learning", and "growth" while competitions focus on "winning" and "preparation" among students and "opportunity" and "drive" from their teachers, demonstrating that, among these positive associations, different cultures of exhibition or competition naturally reinforce different aspects of the maker mindset.

Table 9. Most Frequent Terms Used by Students and Instructors in Reference to Showcases and Competitions.

Showcase	Competitions
Student	
Relaxed	Winning
Sharing	Preparation
Open	Leadership
Instructor	
Learning	Opportunity
Growth	Drive
Sharing	School Pride

Section 3: The community of makers and Making in Community

Leaders of the maker movement point to community as being central to the culture of a makerspace, citing both the internal community of a space and its connections to an external community. To understand its role in defining the culture of maker spaces, our research examined both the internal community of individual makerspaces and connections between individual spaces and national community leadership (e.g., Make Magazine and Fab Lab). Our effort was aimed at better understanding the features of makerspace communities and how these define the culture of spaces. We also investigated experiences and activities commonly shared across makerspaces and regions.

Internally Distributing Makerspace Knowledge and Activity

Knowledge sharing is often cited as a key facet of the maker movement, and we found this to be a consistent component voiced by the student participants in our study. Content knowledge and technical skills were commonly shared among participants within a space, with student experts in certain tasks sharing their acquired knowledge with less-experienced participants. This reinforces a culture of distributed knowledge within the makerspace, which becomes vital in the sustainability of activities and the building of internal community. Student participants also made frequent references to sharing and applying maker knowledge through other school activities, such as student government and school-wide functions.

Students across a range of spaces and regions also demonstrated the propensity to initiate improvements of their immediate school/space surroundings, using the design principles and skills acquired through makerspace participation. Most commonly, participants contributed improvements to classroom design (e.g., repairing for tables, chairs, and wall hangings). Sports facilities were also the focus of a number of makerspace projects across regions, followed by school-wide student government activities. Table 10 depicts how this type of external involvement was common to makerspaces across most of the regions in the study.

Some of the makerspaces we studied were more involved and influential in terms of overall school development projects, such as the creation of new courses, school design, and fundraising. These efforts were limited to a few regions in our study. Because our study was not designed to be a representative sample of all education makerspaces, we believe this greater influence in school development initiatives in certain regions reflects the ethos of the local ecosystem, in

Table 10. Most Frequent Student References to Distributing, Sharing, and Applying Knowledge, Within and Beyond Makerspaces to the School Community.

Area Shared	References
Other Subjects	
Math	3
History	3
Science	2
Making Beyond the Makerspace	
Student Government	20
Art Class	13
School Improvement	11

which maker programs are more prevalent and integrated into the efforts of school leadership. As makerspaces expand into more schools and districts, these cases of integration warrant further study.

Table 11. Makerspace Student Involvement in Various Types of School Improvement and Development Activities and Projects Across Metropolitan Regions.

Involvement	Austin	Newark	Philadelphia	Pittsburgh	Portland	Seattle	Washington DC
			School Improvement				
Classroom Design	✓	✓	✓	✓	✓	✓	✓
Sports Facilities	✓	✓	✓	✓	✓		✓
Student Government			✓	✓	✓	✓	
Faculty Spaces	✓				✓	✓	
Clubs/After School	✓						
			School Development				
Elective Courses	✓			✓			
School Design				✓	✓		
Equipment Recommendations	✓			✓			
Fundraising Projects	✓			✓			
External Partnerships	✓				✓		

Frequency and Quality of Resource Distribution

We also found emerging patterns by clustering and examining two types of makerspaces: those more technology-centric vs. those more focused on arts and crafts. In both clusters, we observed ties to institutional (school or organization), local, and global communities. Through participant interviews, we mapped references to community connections with external knowledge and resources, and Table 12 depicts how each cluster connects across the different scales of community.

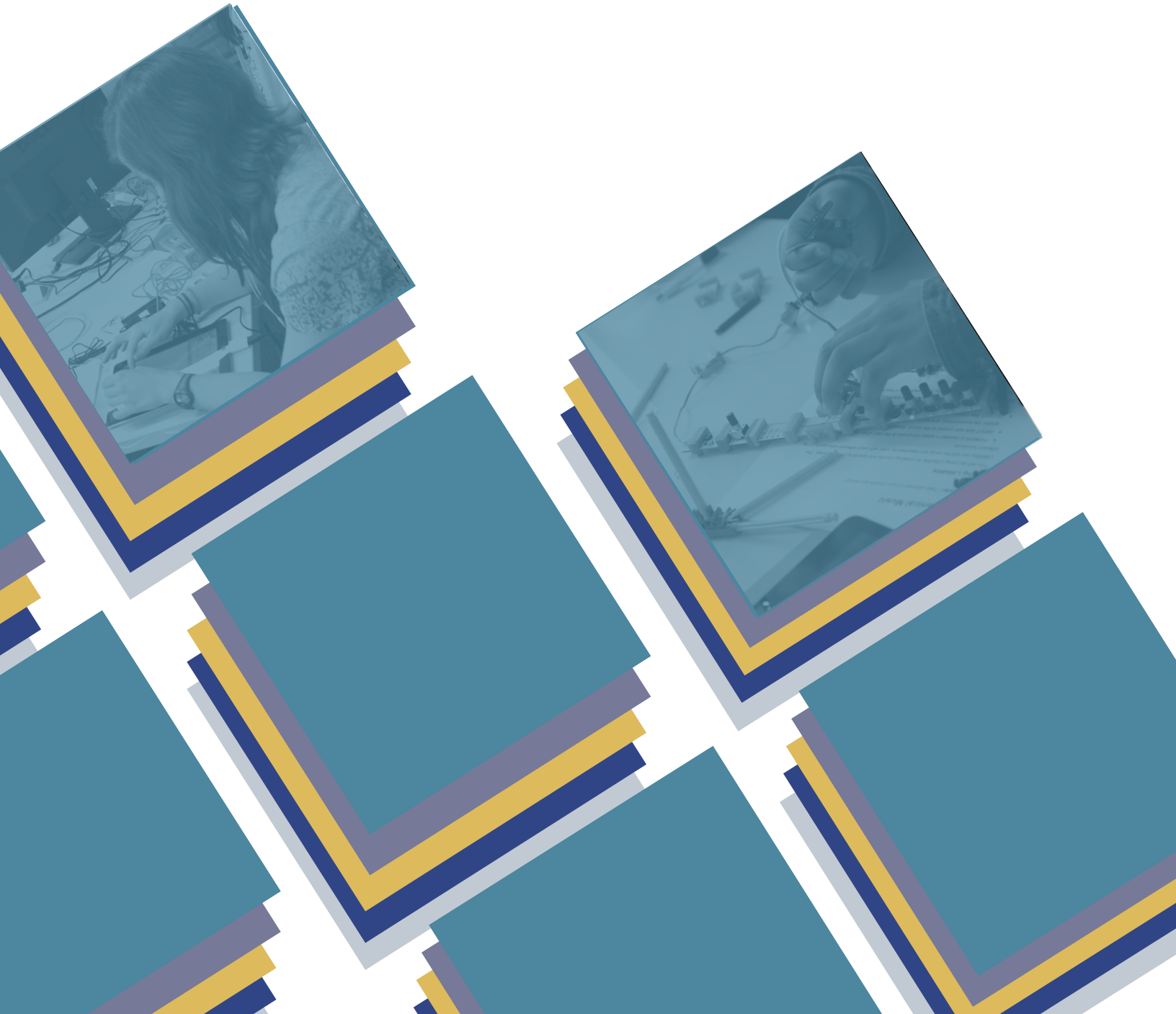
Artisanal (generally, non-technical) makerspaces shared resources and

Table 12. Makerspace Participant References To Knowledge and Resource Sharing With Different Communities by Project Area Orientation.

Project Area	Institutional	Regional	Distance/Global
	Artisanally Oriented		
Fabrics	9	3	2
Fine Art Projects	5	9	10
Music	2	4	6
Agriculture	11	10	7
	Technology Oriented		
Robotics	3	0	20
Game Design	2	0	25
Lego/Mindstorms	0	0	16
Solar	2	1	8

expertise more heavily with institutional and local (regional) communities. This sharing was facilitated through such activities as Maker Faires, local craft gatherings, and community wellness projects. Interestingly, we found much less sharing with a distance/global community in these spaces.

Conversely, with the technology-focused makerspaces, there were almost no references to sharing knowledge and resources with the institutional and surrounding communities. Table 12 shows a major shift in these spaces to connection with the distance / global communities. We suspect that because many robotics and game design makerspaces were more structured around competition, sharing information in the localized community might be viewed by participants as giving away a competitive advantage. Sharing or obtaining knowledge from a distant community was perhaps seen as more productive or less risky.



Recommendations

We hope this study provides a deeper understanding of the role of culture in education makerspaces. From our analysis, the role of culture is profound and crucial in shaping who participates (and benefits from) makerspaces and how they benefit from participation, the learning mindsets they develop, and how they connect with others, both within and out of the space.

Like many in the maker education community, we believe makerspaces offer tremendous potential to advance learning for today's students. Our research provides additional evidence for positive impact in shifting student attitudes, developing a "maker mindset", and helping some non-traditional learners. But with these evolving efforts, personnel, and curricula may come unintended consequences, as highlighted in our analysis of implicit gender bias. More must be done to address this side of maker culture. In this spirit, we offer the following recommendations:

1. **Start with culture:** The culture of a makerspace is paramount and will have a profound impact on student participation and whether benefits are equitably distributed. While makerspace planning efforts have traditionally focused on new tools and training, culture creation is often unintentional. We urge education leaders interested in developing makerspaces to be closely involved and highly intentional in designing the culture they seek to create in a makerspace. Be thoughtful in developing a culture through a diversity of input, including students and other school or organizational community members in planning discussions.

2. **Recruit inclusively:** The maker framework incorporates a strong mentorship model, where participants learn new skills and concepts from others. Fully committing to diverse representation in leadership, instructors, mentors, and participants, particularly in terms of gender and ethnicity, fosters a culture of inclusive and creative thought. This requires deliberate attention to recruitment language and imagery.

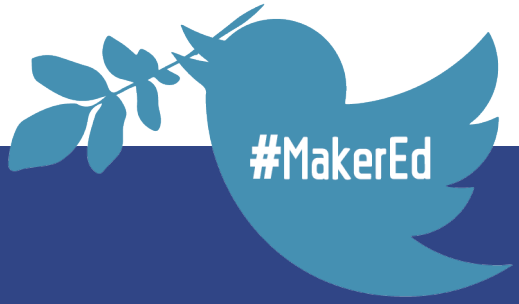
3. **Beware implicit biases:** Implicit bias is pervasive and insidious. Our evidence is specific to gender, but there may be other forms. We recommend open and frank discussions that raise awareness of implicit bias, particularly in language, internal and external communications, and design curricula that may lead to bias.

4. **Make intentional program choices for different outcomes:** Developing a new makerspace will involve choices (pre-fab vs. open curricula or competitions vs. showcase opportunities) that will foster different aspects of the maker mindset and different forms of external connection (institutional, regional, or distant). Different makerspace cultural options allow students to pursue projects that have authentic social and cultural significance. We advise makerspace planners and leaders to be intentional in making these choices.

5. **Maximize open hours for your makerspace:** Open hours, in which students can engage with makerspaces outside of class time, play a positive role in allowing participants agency over activities and presenting a more inclusive and welcoming environment. We recommend maximizing open makerspace hours before, during, and after school.

6. **Target projects that improve your organization:** Greater student agency and accomplishment can be encouraged by pursuing opportunities within the school/organizational community where students can apply skills and concepts learned in the makerspace. Such projects range from improving the immediate environment (fixing furniture, enhancing classrooms and facilities) to broader development opportunities (course design and fundraising).

7. **Share knowledge with your community, near and far:** The surrounding community of makerspaces benefit by encouraging the sharing of resources outside of the space itself, both within the school/organization and outside (in the local region and beyond). A culture of sharing knowledge with a broader community can lead to new learning opportunities and external, real world projects, developing greater agency within students.



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