'Making' an Impact: An Ethnographic Approach to University Maker Spaces

Ms. Meredith Frances Penney, James Madison University
Mr. James Deverell Watkins
Bryan Levy, Georgia Institute of Technology
Dr. Julie S Linsey, Georgia Institute of Technology

Dr. Julie S. Linsey is an Assistant Professor in the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technological. Dr. Linsey received her Ph.D. in Mechanical Engineering at The University of Texas. Her research area is design cognition including systematic methods and tools for innovative design with a particular focus on concept generation and design-by-analogy. Her research seeks to understand designers' cognitive processes with the goal of creating better tools and approaches to enhance engineering design. She has authored over 100 technical publications including twenty-three journal papers, five book chapters, and she holds two patents.

Dr. Robert L. Nagel, James Madison University

Dr. Robert Nagel is an Assistant Professor in the Department of Engineering at James Madison University. Dr. Nagel joined the James Madison University after completing his Ph.D. in mechanical engineering at Oregon State University. He has a B.S. from Trine University and a M.S. from the Missouri University of Science and Technology, both in mechanical engineering. Since joining James Madison University, Nagel has helped to develop and teach the six course engineering design sequence which represents the spine of the curriculum for the Department of Engineering. The research and teaching interests of Dr. Nagel tend to revolve around engineering design and engineering design education, and in particular, the design conceptualization phase of the design process. He has performed research with the US Army Chemical Corps, General Motors Research and Development Center, and the US Air Force Academy, and he has received grants from the NSF, the EPA, and General Motors Corporation.

Dr. Wendy C Newstetter, Georgia Institute of Technology

Dr Wendy C. Newstetter is the Director of Educational Research and Innovation in the College of Engineering at Georgia Tech.

Dr. Kimberly Grau Talley P.E., Texas State University, San Marcos

Dr. Kimberly G. Talley is an assistant professor in the Department of Engineering Technology, Senior Research Fellow and Maker Space Co-Director for the LBJ Institute for STEM Education and Research at Texas State University, and a licensed Professional Engineer. She received her Ph.D. and M.S.E. from the University of Texas at Austin in Structural Engineering. Her undergraduate degrees in History and in Construction Engineering and Management are from North Carolina State University. Dr. Talley teaches courses in the Construction Science and Management Program, and her research focus is in student engagement and retention in engineering and engineering technology education. Contact: kgt5@txstate.edu

Dr. Shaunna Fultz Smith,

Dr. Shaunna Smith is an Assistant Professor of Educational Technology in the Department of Curriculum and Instruction at Texas State University. She holds an Ed.D. in Curriculum & Instruction with an emphasis on technology integration and art education. Her teaching and research explore how the hands-on use of design-based technologies (e.g. digital fabrication, 3D modeling and printing, computer programming, and DIY robotics) can impact multidisciplinary learning that transcends traditional content contexts (e.g. arts-based STEM integration). At her free mobile makerspace for K-12 students and teachers, The MAKE Lab (http://themakelab.wp.txstate.edu), she is currently researching how recurring experiences within these design-based technologies impact self-efficacy and positive attitudes toward failure.

Work in Progress:
'Making' an Impact: An Ethnographic Approach
to University Maker Spaces

Abstract

In recent years, more and more attention has been given to the maker movement and the potential therein. To get a more complete understanding of maker spaces and their impact on students, it is necessary to take a closer look at the intricacies of the spaces. It is important to learn the underlying motivation behind the creation of these spaces and how the spaces are being used by the students. The research in this paper presents the first efforts to reach a deeper understanding of maker spaces and, in particular, university maker spaces. In order to reach this understanding, the research team employed ethnographic techniques to study the spaces, their users, and their owners. This paper reports preliminary results from an ethnographic study performed primarily at University A during the fall of 2015. Students as ethnographers have observed university maker spaces from their unique point of view, and in this way, the students were able to gain key insights of how the maker spaces work and some possible modes of improvement not seen by those already invested in the spaces. By knowing what drives the start of these spaces and what works in the current spaces, the research team hopes to be able to uncover the underlying practices that make for a successful space in order to share this knowledge with current and developing university maker spaces.

Motivation & Introduction

Many universities are building campus maker spaces[1] with the hope of engaging a generation of digital natives lacking the hands-on tinkering, fixing, and making experiences of previous generations. These spaces leverage rapid prototyping equipment (e.g., *Maker Bot*), magazines (e.g., *Make*, *ReadyMade*), and festivals (e.g., *Maker Faire*) to entice students to try prototyping and building what they imagine. Some want to claim that maker spaces have the potential to positively impact retention rates by serving as havens for students less successful in or motivated by the traditional analytical curriculum. These claims, however, are only promises for what these spaces can deliver. Promises that will only materialize if we are better able to understand and optimize them, such that they support exploration, risk-taking, rebounding from impasses, inclusion, diversity, and above all, learning. This paper reports on our initial attempts to get a feel for, or to test the waters of, what these spaces are and are not. Our team's long-term goal is to understand and leverage these potentially powerful learning environments to achieve shared aims in engineering education: encourage student autonomy and exploration, grow diverse learning communities and environments, and positively impact retention for those students at risk of leaving.

Prior Work on Maker Spaces

To date, there have been a number of studies of academic and non-academic maker spaces that provide answers to important questions. To identify best practices for those planning new maker spaces, Wilczynski[2] conducted a review of six of the first university maker spaces illuminating

the need for 1) a clear mission statement, 2) user training, 3) proper staffing, 4) collaboration, 5) alignment with student work schedules, and 6) attention to creating a maker community on campus. Similarly, Barrett et al.,[1] reviewed university makers spaces identified at 35 of the top 100 (actually 127) engineering undergraduate programs as ranked by *US News and World Report* identifying trends in tooling, use, location, and supervision. A study of collaborative co-working spaces at Arizona State University, Stanford University, and North Carolina State University found that a student led organizational structure, access to the latest technology, and possible partnerships with for-profit maker spaces were important for growing and sustaining these spaces.[3] O'Connell[4] interviewed five new maker space users at Tufts, three librarians and two engineers, finding that accessibility led to changes in perception for participants with regard to making in general and seeing themselves as makers.

In a paper touting the promise of maker spaces for education, Martin[5] identifies three elements of the maker movement that are essential to consider in determining potential possible affordances for education: 1) digital tools, including rapid prototyping tools and low-cost microcontroller platforms, that characterize many making projects; 2) community infrastructure, including online resources and in-person spaces and events; and 3) maker mindset, aesthetic principles, a failure-positive approach, collaboration, and habits of mind that are commonplace within the community. Similar to Martin's "the maker mindset," Kurti et al.,[6] the authors of *The Philosophy of Educational Makerspaces: Part 1 of Making an Educational Makerspace,* identify three guiding principles for an educational makers space: embrace failure, expect things to break, and collaborate with others.

It is noted that school-based K-12 digital fabrication and making have their roots in progressive education (Dewey), constructionism (Papert) and critical pedagogy (Freire) in that children can actively construct with technology rather than just consume technological products helping to build self-esteem.[7] Such environments make it possible for students to go through multiple design cycles that encourage failing and redesigning as a learning mechanism. This process simultaneously empowers users without previous engineering or manufacturing experience to learn the skills necessary for success. One may assume that the learning processes at play in a university maker space or similar to those in K-12 digital fabrication and making spaces, but evidence is still lacking.

Taken together, these previous studies and papers provide important groundwork in regards to building and sustaining a making community. What they have not told us is what is happening in these spaces: What is the nature of learning? How are these spaces used and when? What are these spaces used for; is it class projects, personal products, birthday gifts, product design for a start-up, research? Who is comfortable in these spaces and how did that happen? Who is not and why? Are there identifiable learning pathways to sustained membership that we can identify and nurture? How do males and females experience these spaces; is it the same or different?

Our study

This research project is investigating three very different universities with engineering programs that have embraced the maker culture: University B, University A, and University C. Each of the spaces are different, reflecting the differences in the institutions. University B is first and foremost a technological institute with the majority of undergraduates majoring in engineering.

Its maker space, housed within the Department of Mechanical Engineering, is operated by a 70 person team comprising of 65 undergraduate volunteers and 5 non-student members. The maker space comprises five rooms totaling 2,500 square feet that includes a **rapid prototyping suite** with six 3D printers having various material, resolution, and geometric capabilities; **a woodworking suite** with three belt sanders, 12" disk sanders, a 14" band saw, DeWalt 12" double-bevel compound sliding miter saw, a full set of DeWalt handheld power tools and a drill press; a **Plastic/Metalworking suite** with an abrasive waterjet machining center and three 40W laser cutter/engravers; and a **CNC machine shop and mockup suite** with a three axis CNC mill, a three axis mill, and two lathes, a Tormach PCNC 1100 personal CNC mill, a Grizzly belt sander, DeWalt scroll saw, and four Ultra-Vibe 4S tumblers with media for polishing a variety of materials.

University A is a comprehensive university with a majority female population (~60%) majoring in the liberal arts and sciences. The engineering program was started in 2008 as a single degree granting program with an emphasis on engineering design, systems thinking, and sustainability. To support the engineering program, a variety of curriculum-focused making and studio spaces have been designed and developed. Example spaces include: a **sophomore design studio** to support flexible design, ideation, and construction activities with mobile white boards, video projection, two computer workstations, movable tables and stackable chairs, two floor mounted drill presses, one band saw, and various hand tools such as jig saws, drills, Dremel tools, and sanders; a **general fabrication studio** with drill presses, belt/disc sanders, a horizontal double mitre band saw, a 12" single-bevel compound mitre saw, 3' x 6' metal top workstations with vise, a 10" table saw, a tube bender, a router, a panel saw, and assorted hand tools including jigsaws, grinders, drill/drivers, wrenches, files, hacksaws, tap and die sets; and a **digital fabrication studio** with seven 3D printers having various material, resolution, and geometric capabilities, three 3D scanners of various types, a 2D laser cutter, a 2D vinyl cutter, and six computer workstations.

University C is a Hispanic-serving emerging research institution that was originally founded as a teachers college. The maker space workshop area is small (20' x 30') but is efficiently configured and well equipped with a variety of tools for creative exploration. The maker space is equipped with a laser engraver, 2D vinyl cutter, 3D printer, desktop CNC milling machine, embroidery machine, worktables, four computer workstations, and a couch. The equipment selection was intentionally a mixture of industrial (e.g., the desktop CNC mill) and craft (e.g., the embroidery machine) oriented in order to value the wide range of previous making experiences of the student body.

Given the differences in these institutions and spaces, we would expect to see differences in local practices and student experiences which will be valuable; however we are also looking for instances of transference, where phenomena observed in one setting are also found in another.

Our approach to these spaces is informed by the situative perspective[8] which contends that learning occurs within intact, recurring, and emergent systems of activity. As such, this learning theory is highly relevant to maker spaces where building and making with the tools and equipment are to a large extent the essence of membership. On this theory, systems of activity comprise people, artifacts, and structures that coalesce into the formation of communities of practice that have shared goals, values, methods, and beliefs.[9] Newcomers to such communities

seek and are offered opportunities to take up and legitimately participate in community-valued activities on the periphery. "A person's intentions to learn are engaged and the meaning of learning is configured through the process of becoming a full participant in the sociocultural practice." [9(p29)] Through regularized and progressive participation (*legitimate peripheral participation-LPP*) in the varied and changing activities valued by that community, newcomers come to identify with that community thereby solidifying their relationship and commitment to the community values. [10] Learning in such communities is very often a collaborative activity between a novice and a community mentor that is enacted through physical and cognitive apprenticeships[11] where expert practitioners make tacit processes explicit to novices.

Maker spaces, as physical, intellectual, and practice spaces, engender all aspects of a community of practice. As such, they have the potential to support situated learning through participation in the life and activities of the maker community. In this way, such spaces can serve as a significant affordance for learning. This is one hypothesis we are working with in our study.

Three notions formulated in science studies are also useful for the initial framing of our study of maker spaces: *boundary objects, trading zones,* and *conscription devices*. In their study of how workers at the Museum of Vertebrate Zoology (curators, amateur collectors, professional biologists, occasional field hands, and science club members) managed both diversity and cooperation, sociologist Susan Leigh Star and philosopher James Griesemer[12] introduced the notion of *boundary object*. The example they use is dead birds, which had differing meanings for the intersecting worlds of amateur bird watchers and professional biologists in the context of various problems involved in museum work. They designated as boundary objects:

> "...those scientific objects which both inhabit several intersecting social worlds ... and satisfy the informational needs of each of them. Boundary objects are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual use. These objects may be abstract or concrete. They have different meanings in different social worlds, but their structure is common enough to more than one world to make them recognizable as a means of translation." [12(p393)]

For our study of maker spaces, we are interested in developing a better understanding of whether and how boundary objects are able to bring about cross-disciplinary interactions and activities across engineering, science, and design arts.

Boundary objects can lead to the construction of places for interaction between disciplines— what the historian, Peter Galison,[13] characterized as *trading zones*. In his study of particle physics in the 20th century, Galison[13] sought a metaphor that would evoke movement and interactions across boundaries that occurred within the several cultures of physicists. He sought a term that could capture when "different traditions of theorizing, experimenting, instrument making, and engineering meet—even transform one another—but for all that do not lose their separate identities and practices." [13(p782)] The notion of a *trading zone* designates a bounded space between disciplines where trading processes can occur because each participant group needs something from the other to address problems that lead to shared projects and goals. In his

analysis of the trading zones, "language" is expanded to mean any structured symbolic system, which can include graphical and mathematical representations.[13] The central metaphor is *exchange*. In our study, we would expand the analysis even further to include physical space and the various sorts of machinery, tools, and equipment in that space.

Finally, in Henderson's ethnographic study of the role of visual representation in the process of designing a turbine engine package, she coined the term *conscription device* to signify some kind of device in her case engineering sketches and drawings, to "…enlist the participation of those who would employ them in either the design or production process…" [14(p452)] For our study, we are interested in discovering potential conscription devices that carry with, and foster the creation of, knowledge and group interactions. Conscription devices, according to Henderson,[14] serve as boundary objects because they are flexible enough to respond to local needs and uses, while still retaining a shared identity among different users of the device. As an example, in the maker space at University B, there is an embroidery machine which has been overheard being labeled by male students as the "embroidery CNC", a hybrid indexing evoking both women's world of making and sewing and the shop world of computerized parts making.

Research design

Our research objective is to discover the situated practices and lived experiences of university students desiring to enter, learn, use, and become members of the maker community on their campus. Given this objective, the qualitative methods of collecting field notes through observation of situated practices and interactions among people and equipment; informal on-the-spot interviewing; and more formal interviewing of community members, collecting related documents, and artifacts pertinent to rules and regulations are all appropriate. Taken together, these constitute an ethnographic approach to research, essential to capturing *learning-in-the-wild* of the kind found in unscripted, informal doing and learning spaces. This kind of study is in sharp contrast to survey studies in that we have no particular *a priori* expectations about what we will find. Survey studies identify in advance what is interesting and then seek evidence of its presence. Our specific research questions are:

1. What is the nature of activity, work, and learning in the maker space?
2. How do its members experience the space?
3. What does it mean to them?
4. How and to what extent does participation in the maker space impact its members?

To conduct this research, we have enlisted and are training engineering undergraduate and graduate students in ethnographic methods to be our primary data collectors. This has its strengths and weaknesses. On the one hand, as students, they might naturally find themselves as members of these communities, so following the pathway from outsider to insider is potentially much easier than if one of the faculty members were to attempt something similar. On the other hand, learning the intricacies of the ethnographic stance takes experience and practice. To prepare these students, we have conducted training sessions which included reading excerpts of books (e.g., *The Ethnographic Interview*[15] and *Participant Observation*[16]), papers (e.g., *Of Green Monkeys and Failed Affordances*[17]), and examples from ethnographic work including field notes, and various models derived from observations—flow, sequence models, artifacts, cultural, and physical, pathway accounts. Training is on going as we review their field notes, develop coding

schemes for the data, and consult with the students about issues we see in their observational strategies or accounts.

The immersive process has undergone two iterations at this point in the research. During the first phase, five engineering students were trained in ethnographic research and sent into University B's maker space as student users. The five students involved had the following demographics seen in Table 1: three graduate students, two undergraduate students, three males, two females; four of the students were new to the space, while the remaining student was a graduate student who had worked in the space. The graduate student volunteered three hours a week as one of the prototyping instructors that run University B's maker space. The undergraduate students were from University A, while the rest were University B students. The students, who had never been in the space, were outsiders in the sense they are outside the makerspace community, but they were engineering students making them members of the student engineering community. Being an outsider is preferred for ethnographic work because it reduces bias and allows for a more open view to what is happening in the space.

Table 1: Demographics of student ethnographers

Student	Male/ Female	Graduate/ Undergraduate	Home Institution	Familiar/ Unfamiliar
1	M	Graduate	University B	Familiar
2	M	Graduate	University B	Unfamiliar
3	F	Graduate	University B	Unfamiliar
4	M	Undergraduate	University A	Unfamiliar
5	F	Undergraduate	University A	Unfamiliar

The students were instructed to approach and use the space as they would under normal conditions and make note of their observations using methods of participant observation with field note generation/analysis and unstructured interviewing. As engineering students and researchers, the students participated in the maker spaces along with other students using those spaces. Observational and interview data were recorded by the investigators as hand-written notes in a field note journal, then expanded and uploaded to a secure network drive for analysis. The observations were recorded daily after exposure to the space and carried out over approximately eight weeks during the summer term. The ethnographers did not share their observations until the conclusion of the study so as not to bias their observations. This phase one data collected at University B is not analyzed in this paper.

After the completion of this first phase of the immersion study, the two undergraduate students involved in the first phase of the study were then sent to the maker space at University A with the same objective. Observations were again taken from the perspective of the student user. Like with phase one, the students participated in the maker spaces along with other students using those spaces. Activities in the spaces at University A included working on class projects and assignments as well as participating and enrolling in training programs and pop-up classes. When interactions with students in the maker spaces extend beyond more than just causal interaction or short term observation, the student researchers have been permitted to perform more structured interviews following receipt of verbal consent.

Observational and interview data is again recorded by the investigators as hand-written notes in a field note journal, then expanded and uploaded to a secure network drive, and much of the observational data is ethnographic in nature (i.e., students recording their own experiences using the maker spaces as students, including how they interact with the materials and other students within those spaces).

Using constant comparative analysis,[18] the students' field notes were coded by the authors in three stages: 1) open coding by all, 2) axial coding by all, and then 3) sorting the codes. In the first stage, all of the researchers read the source data (the field notes) and noted items that stood out by assigning a word or phrase as a suggested code. After meeting to discuss initial impressions and what main themes and codes stood out to the research team, each member of the research team attempted to group their own codes into axial codes. The axial coding was a way to group similar codes under a broader heading. By doing so, the team was able to identify some emergent themes that were common across the research team's axial codes, which was the sorting phase (step three).

Preliminary Results (Emerging Themes)

This initial ethnographic study of the various University A maker spaces is already uncovering some emerging themes that warrant significant further study through both ethnographic and other approaches. These emergent themes are discussed in the following subsections.

Entry and Orientation
As ethnographers, we are interested in transitions because they signal a change from a previous personal state to a new state, which can be either smooth or rocky. The decision to begin using a maker space signals the motivation/interest in transitioning from a non-user to a user. As such, this event might seem somewhat trivial, but in some initial data we collected over the summer at University B, we discovered that the simple act of going into a maker space for the first time for each one of our student researchers involved emotions ranging from insecurity to anxiety to fear. We also discovered that gender might play a role in how the spaces are initially perceived and entered. One of our female graduate students who had every reason to be in the maker space for research purposes admitted that on her first attempt, she was very close to giving up and walking away. She described walking down the stairs to the maker space entry and then retreating back up those stairs seeking a kind of sanctuary from this first encounter, unready to step through the doors. Interestingly, she cited her fear as deriving from a reluctance to "impose" on people in the space. Importantly, this student is a mechanical engineering graduate student. Others on the team also voiced qualms associated with their first visit.

In the University A study, we see a similar pattern of insecurity among our University A undergraduate researchers at their own school about first visits. More specifically, we see a need and desire to make sense of the space and not to appear out of place. In the following quotes we learn about their first visits to the maker spaces.

> I was a little <u>apprehensive</u> while approaching the art studio building. I took the bus there, and it drops you off out at the street, which seems a bit like it is dropping you off in the middle of a part of town you are not familiar with rather than being on campus.

Walking in, I was <u>unsure</u> where exactly was appropriate to sit

There were various things around the room that <u>lacked explanation</u>…

I walked over there around noon and as I walked in I was <u>unsure</u> of where to go. There was a desk in the front and there was a set of keys and cell phone on the desk, it seemed like <u>someone should be there</u> but they had gotten up to go somewhere. I stood around and waited for a couple minutes.

For discussion sake words from the field notes are underlined that instantiate the sense of unease that first encounters entail. They feel *unsure,* even *apprehensive,* needing *explanation* by someone *who should be there.* Familiar circumstances and practices engender a sense of knowing, manageability, and security, all desired states, while first entries to these spaces for our student researchers seem to imply alternative states of insecurity (*unsure),* unmanageability (*explanation from someone who should be there)* and even fear (*apprehensive).* This is one theme of great interest to our team. Are these reactions typical for many students, and if so, what needs to be done to alleviate these anxious emotions? Are there ways to script first encounters for non-users that diminish or counter these emotions of insecurity, unmanageability, and fear? So far we have potentially found two. A graduate student researcher on our team shared, that on his first visit to the University B maker space as an undergrad, he went with his roommate. When asked if he would have gone alone, he said "No", even though the space is in the mechanical engineering building, home to his major and where he spent much of his time. At University A, an undergrad researcher encountered an instructor in one of the designated maker spaces who "…asked me to remind him of my name and invited me to come by anytime". The first time duo and simple invitational encounter, a hand welcoming and encouraging the student, could both be ways to counter first time jitters.

Physical Arrangements, Contents And Use
The arrangement and contents of physical spaces significantly impact how they are perceived and used. First time users will be particularly sensitive to the layout, contents, and feel of a place because they have fresh eyes to see and interpret. First timers are also implicitly seeking the familiar in what may appear strange, looking for footholds to orient and anchor understanding. With more and more use, this ability to notice will diminish. Thus, the students wrote extensively about the physical arrangement, the look and feel, and capacity of the various spaces.

It was very modern and inviting. The floors were concrete and the room was a bit cold, but it did not bother me… Teams were allowed to sign up for a room and either work in the rooms or keep all of their stuff relating to the project in there. They were a bit small but nonetheless I thought very useful.

The room felt closed off…..The space is a concrete box that lack sunlight and much needed decoration…..It was quiet but at the same time when someone spoke the room filled with their voice.

… it felt especially dungeon like in there today. With the concrete floors, high ceiling, lack of windows and an added cold breeze. Today I sat closer to the garage door and noticed that the draft was very real.

The concrete floors and lack of organization make it feel like a place you shouldn't be…. I can hear whispers bounce of the walls and I wonder if they even know I am in here.

There were plenty of available plugs for my electronics, which I appreciated, and I even noticed that a cord was on the table that would allow me to plug in a laptop to the tv."

The biggest thing I pick up on today was the frustration of the plugs around the room. On 4 different occasions people left the pit because their computers were dying and all the wall space was taken. I know that the table in the space have plugs on them, but sometime do not work or do not reach the students computer, this was the case today in the pit.

"…museum-ish vibe to an industrial one, with high ceilings, concrete floors marked with yellow and bare white walls. Looking into it made me feel like I was going to need safety glasses on to go through….."…space is heavily used and lived in…" *There was another space connected to this one that is also graphic design based; a small, thin room with awful beige walls that looked almost abandoned…..One thing that was pointed out to me was that the space had a red floor which sectioned it off from the rest of the area, rather than a wall or rail. It made me feel as if it was a completely different room, even though it was not separated by anything besides a change in color.*"

It is clear from these initial descriptions that the spaces vary in their initial impressions, which find expression in metaphors. One space at University A feels like a *dungeon,* while another gives off the vibes of a *museum.* Are their cultural cues in the spatial arrangements and materiality that would conjure these metaphors for others and do they matter? Should we be concerned that a space feels cold, dark, and uninviting to one observer? This undergrad seems to be searching for boundary objects as a point of transition but finds none. Both note something concerning electrical plugs—a boundary object? But in neither case, is there anything in that space that could serve as a conscription device. The design studio suggests other notions ranging from a *museum* to *industrial* to scientific (*safety glasses)* to *abandoned.*   What could be going on to create such a hodgepodge, such an incoherency of impression? Should this be of concern? Ideally spaces should be designed to convey identified, desired, but subtle messages. If there is anxiety associated with these spaces, should they feel dungeon-like or confusing? What would it mean to craft a coherent visual and materially mediated environment that is useful and welcoming?

Summary & Future Work

It seems that university maker spaces create a unique learning environment where students can freely design, build, and test their ideas. The explosion of maker spaces internationally on college campuses seems to indicate that many educators see these spaces as a complementary part of the university experience. Maker spaces seem to hold the promise of a place that can foster creativity through open environments which can promote designing, building, and collaborating. But without knowing the *why,* the *how,* or the *what,* how can we say that these spaces are matching their promise. The methods described herein provide us with critical information required to understand what is happening in the spaces (e.g., how communities are

forming and norms are being established or how learning occurs) and is part of a larger project with other methods of data collection (e.g., surveys and ethnographic interviews). Together these studies are meant to provide clues to key factors such as retention, improved self-efficacy, ability to design, and creativity.

Beyond dissemination of results, we seek to operationalize our learning. At University A, the engineering program will begin a remodel of making and learning (formal and informal) spaces during the summer of 2016. Many of the spaces currently housing the program have been inherited as the program has been developed. Emergent themes identified in this research are influencing the current redesign of making spaces such that windows provide not only natural lighting, but also better lines of sight into rooms. Openness of spaces is being considered to avoid the following noted feeling, *"Inside, it was fairly dark, a bit cave like even, with the small hallway opening to the larger space."* Flooring is being chosen carefully to provide subtle cues as to the use of the space (e.g., creative brainstorming activities or making and prototyping) such noted with the aforementioned red floor color. Statements such as "*I could very clearly hear the roar of the vents overhead ... it was significantly louder than one would expect it to be*," are causing us to consider the acoustics of our spaces. Ceilings, floor, and wall coverings are being considered to help with these student noted issues of noise.

We recognize that minimizing barriers to entry and creating welcoming and useful spaces is an ongoing process requiring continual assessment and iteration—a process often (and unfortunately) dedicated only to curriculum, but we see our spaces as a critical component of our curriculum and an enabler of learning. Consequently, the approaches discussed herein will continue following the space redesign. Comparisons will be made between the spaces, and further iterations and redesign will occur.

Additionally, the immersive ethnographic work will be expanded in the future and targeted at specific maker spaces. The two universities chosen at this point in the study were selected due to ease of access and used to help build ethnographic skills in the new ethnographers. This summer an additional set of students from University C will learn the skills being used at University A, and during the 2016-17 academic year, these students will explore the maker space at University C. As data is collected at these different universities, we will be able to compare the spaces as well as gender and demographic differences resulting from campus populations and differences between our student-ethnographers.

In the future, these ethnographers or others trained in the same manner will be sent to specific locations found in the research to demonstrate different key characteristics such as operational model or location. In this way, the ethnographers will be able to get a more complete view of the options for maker spaces and be able to observe the impacts that each system presents to its users. This will allow for a more valuable assessment into the best practices associated with maker spaces.

Acknowledgements

expressed in this material are those of the authors and do not necessarily reflect the views of National Science Foundation.

References

1.   Barrett T, Pizzico M, Levy BD, et al. A Review of University Maker Spaces. 2015 ASEE Annual Conference and Exposition; 2015; Seattle, WA.
2.   Wilczynski V. Academic Maker Spaces and Engineering Design. 2015 ASEE Annual Conference and Exposition; 2015; Seattle, WA.
3.   Myers J. *Creating Collaborative Spaces at the University of Arizona: Ways to Encourage Interdisciplinary Research and Ideas*: College of Architecture, Planning, and Landscape Architecture, The University of Arizona; 2015.
4.   O'Connell B. Going from Curious to Maker: New User Experiences in a University Makerspace. Paper presented at: National Collegiate Inventors and Innovators Alliance. Proceedings of the... Annual Conference2015.
5.   Martin L. The promise of the Maker Movement for education. *Journal of Pre-College Engineering Education Research (J-PEER).* 2015;5(1):30-39.
6.   Kurti RS, Kurti DL, Fleming L. The philosophy of educational makerspaces: Part 1 of making an educational makerspace. *Teacher Librarian.* 2014;41(5):8.
7.   Blikstein P. Digital fabrication and 'making'in education: The democratization of invention. *FabLabs: Of machines, makers and inventors.* 2013:1-21.
8.   Greeno JG, Middle School Mathematics through Applications Project Group. The situativity of knowing, learning and research. *American Psychologist.* 1998;53(1):5-26.
9.   Lave J, Wenger E. *Situated learning: Legitimate peripheral participation.* Boston: Cambridge University Press; 1991.
10.   Wenger E. *Communities of Practice: Learning, Meaning and Identity.* Cambirdge, UK: Cambridge University Press; 1998.
11.   Brown JS, Collins A, Duguid P. Situated cognition and the culture of learning. *Educational Researcher.* 1989;18(1):32-42.
12.   Star SL, Griesemer JR. Institutional ecology, 'translations' and boundary objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social studies of science.* 1989;19(3):387-420.
13.   Galison P. *Image and logic: A material culture of microphysics.* University of Chicago Press; 1997.
14.   Henderson K. Flexible sketches and inflexible data bases: Visual communication, conscription devices, and boundary objects in design engineering. *Science, technology & human values.* 1991;16(4):448-473.
15.   Spradley JP. *The Ethnogaphic Interview.* Harcourt; 1979.
16.   Spradley JP. *Participant Observation.* Holt; 1980.
17.   Newstetter W. Of green monkeys and failed affordances: A case study of a mechanical engineering design course. *Research in Engineering Design.* 1998;10(2):118-128.
18.   Glaser B, Strauss A. *The discovery of grounded theory; Strategies for qualitative research.* New York, NY: Aldine Publishing Co.; 2012.