Becoming Makers:

Hackerspace Member Habits, Values, and Identities

Austin Toombs, Shaowen Bardzell, and Jeffrey Bardzell

Indiana University Bloomington

ABSTRACT

This paper explores factors that lead to individuals' adoption of the maker identity presented in a small-town hackerspace. This paper presents the findings of a 15-month ethnography of the hackerspace and a series of targeted interviews focused on the self-made tools of that hackerspace. We present findings indicating that the formation of our subjects' maker identities are shaped heavily by the individual's ability to use and extend tools, adopt an adhocist attitude toward projects and materials, and to engage with the broader maker community. We also consider how maker identity manifests itself in both making processes and also visual stylizations of their projects. We present and explore the formative roles of materials, the significances of imprecise tactics such as "futzing," and the role of the hackerspace as a special place where "normal" attitudes and practices are suspended in favor of an alternative set.

Author Keywords

Self-made tools; ad hoc; improvisation; hacker; hackerspace; maker; makerspace; homebrew; DIY-

INTRODUCTION

In recent years, there has been a surge in cultures of making, from DIY, craft, and repair to hacking, 3D printing, digital fabrication, and electronic tinkering. Many of these cultures of making are supported in diverse ways by the Internet, from the sharing of patterns and code libraries to social tools supporting the creation and maintenance of social groups of interest. Coinciding with and supporting these cultures of making are new educational environments (e.g., The Maker Education Initiative, the Fixit Clinic), conventions (e.g., Maker Faires, and less-branded maker gatherings), shared working/hobby spaces (e.g., hackerspaces, Makerspaces, Techshops), local meetups and events (e.g., FutureEverything, Ars Electronica) and online knowledge exchanges and alliances (e.g., Creative Applications Network, LilyPond, Instructables, and Ponoco.com) that support the activities and ongoing learning of these hobbyists.

Not surprisingly, this emerging culture of making is increasingly of interest to research communities, including Human Computer Interaction (HCI), Science and Technology Studies, cultural studies, among others, for reasons including the following: making's relations to technical innovation; embodiment in new forms of technology-mediated collaboration; asserted potential for increased

democratization of technology use, innovation, and production; asserted potential for enhanced educational experiences concerning technological fluency through maker education initiatives; and so forth. In HCI, this research includes studies of online communities of expert amateurs (Bardzell 2007; Kuznetsov & Paulos 2010; Pace et al. 2013); examinations of digital fabrication methods and their connections to technological innovations (Mellis et al. 2013; Mota 2011); practices of appropriation in everyday life (Rosner & Bean 2009; Wakkary & Maestri 2007, 2008; Tanenbaum et al., 2012); the distribution and adoption of open-source toolkits (Buechley & Hill 2010; Mellis & Buechley 2012a); creative reuse and repair of everyday objects (Jackson in press; Maestri & Wakkary 2011; Rosner et al. 2013); the education of both children and adults on issues concerning technological fluency (Buechley 2010; DiSalvo et al. 2008; Mellis & Buechley 2012b); how handwork relates to the aesthetics of self-expression as well as the politics of material resource use (Bardzell 2012; Rosner 2011) and general presentations of these makers and hackers as new kinds of users with whom HCI should be familiar (Bardzell et al. in press; Mota 2011; Tanenbaum et al. 2013; Wakkary & Tanenbaum 2009).

The present work contributes to the growing body of research on making through an empirical study of the development of the maker identity shared by members of a small town hackerspace. We access this identity formation through a long-term engagement with the hackerspace, as well as through targeted interviews focused on the *ad hoc production tools* fashioned by the hackerspace's members. These tools are often lightweight, off-beat, inexpensive, unpolished, and pragmatic. They showcase makers' spontaneity, intuition, style, and their familiarity with the hackerspace and the materials, tools, and other resources it has to offer. Often they highlight their makers' frustration with the limits of existing tools and therefore they reflect not only purposefulness but also an expression of the maker in that moment. Interestingly, we have found that in some cases what hackers call "tools" are not even tools at all, at least in any obvious sense, which suggests that among other things hacking involves reconceptualizing certain basic vocabulary. These self-made tools provide a unique level of access to understanding more deeply the individual's claims to the maker identity. We argue that the formation of this maker identity is informed by three primary factors in this hackerspace: 1) the development of a tool and material sensibility; 2) the cultivation of an adhocist attitude as an approach to making in general; and 3) engagement with the maker community, both in the space and on a larger scale.

KEY CONCEPTS

Maker Identity and the "Established" Maker

Throughout this paper we discuss the process of adopting a "maker identity," which we understand as an individual's identification with the modern maker movement in any of its various forms, from people who perform DIY home repair and craft activities, to people who subscribe to *Make* magazine and imagine building projects, even if they never do. Our conceptualization of the maker identity is also influenced by related identities described as the Expert Amateur (Kuznetsov & Paulos 2010), the Everyday Designer (Wakkary & Tanenbaum 2009), Makers (Anderson, 2012), and Hackers (Levy, 2010). Each of these identities describes people who build things for themselves, sometimes as part of an anti-consumerism statement, but often for a practical outcome. We view each of these identities as variant formulations of a maker identity, which we can define broadly speaking as incorporating a collection of attitudes, skills, behaviors, practices, and expressions around DIY activities.

We distinguish the more general maker identity from what we refer to as becoming an "established" maker. Maker-ness manifests in degrees, which range from one who occasionally participates in DIY activities, to one who regularly creates their own processes and situations for DIY activities. All of the participants included in this study are members of a local hackerspace and, due to the nature of the hackerspace, we automatically categorized as those who have adopted or are working to adopt this identity. In this paper we refer to the members of the hackerspace as "makers," even though the members themselves use both "makers" and "hackers." In this particular hackerspace these terms are interchangeable, but we simplify this to "maker" due to common misconceptions and negative baggage associated with "hacker." Throughout this study we have recognized the gradual evolution the makers of the hackerspace undergo from one degree of maker to another, constantly striving to become even more of a maker. But how exactly does one become an established maker? What sets this identification apart from those who are happy to simply follow the steps of an Instructables document without creating their own? The present work explores these questions through investigating the process of becoming an established maker, and one of the ways we do that is through an investigation of tool the makers make for themselves.

Tools, Users, and Self-Made Tools

This study relies on three separate formulations of "tool." The first is our everyday understanding of "tool," which we used to recognize early on the importance of the role played by tools in the space, specifically homemade tools made by the makers. We saw this kind of making as one that separated the kinds of making found in the hackerspace from more mundane forms of making that exist easily outside of the space and, therefore, as a way in to investigating the process of becoming an established maker in this hackerspace. In this operational definition, an artifact is a tool if it is used in a process of creation separate from its own creation. In other words, we delimited these tools based on whether they were used by the maker to create other artifacts.

The second definition of "tool" is based on an emic account of the concept from the hackers themselves. When we began interviewing the hackerspace members about the tools they have created in the space, we were careful not to impose our interpretations of what constitutes a tool, instead allowing them to interpret "tool" and judge which of their projects would count. This allowed us to expand on our own notion of "tool" while staying true to an insider's perspective of the concept. As noted in the introduction, the emic account of "tool" surprised us, because it seemed much more inclusive than we anticipated.

This surprise prompted us to consider formulations of "tool" available in the research literature, which constitutes our third formulation. This literature includes works about tools from sociology, education, architecture, art, critical theory, and information design. Tools are instruments we encounter and use to accomplish tasks. Art historian Howard Risatti (2007) defines tools as "something used directly by the hand with an intention to make some*thing* by doing something to material" (pp 49-50, emphasis in original). Due to the fact that tools are used to make other things in a process or processes, they are instrumental and have a pragmatic function. A tool to McCullough (1988) is "a moving entity whose use is initiated and actively guided by a human being, for whom it acts as an extension, toward a specific purpose" (p 68). Tools are manually operated and are in Risatti's words, "kinetically dependent" in that they require us or something else to activate their function (2007, p 51). When such an operation stops, tools cease to work; accordingly, a tool is "some*thing* with a 'tooling' potential and that a thing becomes a tool in the process of being put into action, of being put to 'work'" (Risatti 2007, p 43, emphasis in original). Synthesizing, these formulations suggest that tools are material objects that are

put to work through intentional human action, and that their potential is latent except when they are used.

Such a description of tools reveals three additional characteristics about the relationship between tools and tool users: that tools direct our sensual engagement, that they require practice for mastery, and that identifying the right tools for the tasks at hand demands reasoned judgment. These activities are necessarily context and medium-dependent. A well-equipped shed is conducive to gardening. Through practice, a gardener knows how to operate a single tool for a particular medium, and when necessary, can select appropriately a combination of different instruments (e.g., lopping shears, pole pruners, hedge shears, and pruning saws, etc.) to trim overgrown branches. For McCullough (1988), tools "come to stand for the processes. This symbolic aspect of tools may help you clarify your work…Holding a tool helps you inhabit a task" (p 61). There is a reciprocal relationship between work and the tools that are used to make it (Gelber 1997).

Tools are also prosthetic, because they extend and enhance human capabilities. Sennett (2008) makes a distinction between *replicant* and *robot* tools. Replicant tools mimic human abilities while supplementing and amplifying them in specific ways. A spatula is a replicant tool because it expands our capacity for heat tolerance, allowing us to handle food beyond the body's natural ability, while nonetheless mimicking the manual behavior of flipping and arranging objects on a surface. A robot tool is "ourselves enlarged: It is stronger, works faster, and never tires" (Sennett 2008, pp 84-85). A car can be seen as a robot tool because its power moves us quickly, and we tire of riding in it far sooner than it tires of transporting us.

Tools provide opportunities for users to enrich the environment. As Illich (1980) writes, "An individual relates himself in action to his society through the use of tools that he actively masters...To the degree that he masters his tools, he can invest the world with his meaning" (p 22). Tools are thus future orienting, providing mechanisms for users to envision and then to bring about future worlds.

Summarizing this research, tools connect human understanding to the material world through the possibility of change; they extend or augment, sometimes radically, human capabilities; they require us to change our physical behaviors and skills of imagination and judgment to learn how to use them well; and, if all of this happens, they empower us to envision and pursue new futures.

We argue that the development of this kind of tool sensibility is an integral part of becoming a maker, as it has a profound impact on an individual's perception of their abilities. Research on hacker's and maker's tool use can reveal much about how an individual develops such an identity, and because, as we will demonstrate, self-made tools are especially expressive of their makers, their creation and use is an especially fruitful area for empirical inquiry.

Adhocism

Our interest in the concept of adhocism began as the result of our observations in the hackerspace, where maker activities could be characterized as informal and ad hoc. Rather than plan an entire project, they often relied on an assumption that they would be able to solve problems as they arose, and worked with more generalized guidelines informed by their experiences in the hackerspace. After many months of ethnographic work, we began to develop our etic understanding of adhocism, which we were then able to use as a lens for studying the tool making activities and behaviors of the hackerspace members.

Architectural theorist Charles Jencks and architect Nathan Silver (2013) define *adhocism* as "a principle of action having speed or economy and purpose or utility, and it prospers like most hybrids on the edge of respectability" (p vii). Throughout their book, adhocism is presented simultaneously as a legitimate *production strateg*y and as its own *product style* for finished products, be they architectural designs or NASA's space equipment. As a production strategy, adhocism focuses on efficiency, economy, approximation, adaptability, and pragmatism, often drawing on "an available system in a new way to solve a problem quickly and efficiently" (Jencks & Silver 2013, p vii). As a product style, adhocism visually foregrounds the juxtaposition of these available systems, making explicit their connections and differences while showcasing their hybridity. Our conception of adhocism for this study is influenced by this work as well as Lucy Suchman's (1987), enabling a consideration of the situatedness of the maker's actions without necessarily labeling the adhocism we observe in those actions as intentional. The notion of adhocism as revealed in this hackerspace is closely associated with the maker's judgment throughout the making process—the judgment required to choose appropriate tools or methods to complete the project, the judgment used to decide whether to purchase or make a required piece of the project, and the judgment used to determine if the maker has the required competencies to complete the project. An adhocist project is not planned out ahead of time, but carries

the assumption that each piece of the problem will be figured out as it becomes important. There is an overall sense of the big picture of the project, but it is seldom expressed as more than just a sense. As we have seen throughout this study, the adhocist attitude common to many of the projects we investigated is more than simply an approach but is also an identity expression: “we work in this way because we can.”

RESEARCH APPROACH

Floraville, the fictional name of the small town in question, is a small Midwestern American city of around 80,000 people. Its hackerspace began in the summer of 2010 by a group of friends in a basement working on projects together, sharing their tools and know-how, after a robotics-centered club to which they belonged disbanded. As community interest in making grew, the group eventually moved to a shared workspace with another DIY-related group in town, thus becoming the first official hackerspace in the state. The space features up to 30 official dues-paying members (between 19 and 50 of age, including 2 females, one of whom being the founding member) and a handful of regular visitors sharing 1,400 square feet of workspace and donated and/or purchased tools of different kinds. About 7-9 members use the space regularly to work on projects.

The 15-month ethnographic study took place on site at the hackerspace from October 2012-December 2013. One member of the research team made, hacked, and tinkered alongside regular hackerspace members, gradually taking on tasks for the group, such as providing hands-on soldering and craft workshops to local making enthusiasts and youths as well as accompanying visitors on tours of the space, etc. The ethnographic work resulted in 3-5 hours of direct weekly engagement for a total of about 180 hours of direct contact, generating data in the form of jottings, field notes, photos, and audio/video recordings of special events.

We also conducted expert interviews of seven hackerspace members who create their own tools for tackling specific making/hacking tasks. The interviewees (all white male, between 19-40 of age) were recruited based on their participation in the space (because we were embedded in the group, we could easily identify those who are tool makers). The toolmakers had varying backgrounds in programming, web and apps development, and cyclotron operation. Whenever possible, interviews were conducted in the hackerspace where the tool making took place. Some interviews were done at local coffee shops and the homes of the interviewees, based on their preferences. All participants’ names have been changed. The interviews were minimally structured, intending to draw out conversation as

informally as possible. As broad conversation guides, we asked our interviewees to tell us about their backgrounds and experiences with making; specifically, questions centered on (1) how/why/when tools were made, (2) material engagements, strategies, and their ideation and construction processes, (3) the roles these self-made tools play in specific projects in particular and the hackerspace in general, and (4) the perceived value and meanings of these self-made tools to the makers. The expert interviews produced 12 hours of recordings, notes, and photos of the tool-making processes and the actual tools. We transcribed all video and audio content for analysis.

Data analysis was conducted through a procedure known as *explication de texte*, or close reading, an analytical method that originated in the humanities (Ogden & Richards 1923) and which involves the careful examination of diction, rhetorical devices, style, and other formal and thematic elements in a text. In the data interpretation phase, two researchers conducted their close readings independently of one another to identify an individual set of themes. Subsequently, the entire research team collaborated to combine, refine, and distinguish among themes before arriving at the critical synthesis of quality, described in the ensuing sections.

SIX CASES: MAKERS AND THEIR TOOLS

To investigate the development of a maker identity, we will explore six cases of makers and their tools. These cases are presented *in situ* to demonstrate how the individual maker relates to the maker community at large, their understanding and extension of tools, and how these behaviors function within an adhocist perspective on maker activity. Following the rich description of these five cases, we propose a set of factors that allow a maker identity to emerge: 1) a sensibility toward tool use and creation, 2) a viewpoint that is shaped by an adhocist attitude with an underlying confidence and identity security, and 3) a strong relationship with a local community of makers.

As described above, an intimate relationship exists between tools and their users; tools (especially self-made tools) come to represent the individual and her creativity and ingenuity, which goes beyond the final, built artifacts into issues of identity and self-expression. Our ethnographic fieldwork quickly revealed instances of ad hoc, ingenious tool-making, grown out of makers' agitation and pragmatic concerns for the fact that existing tools are not fit-for-purpose—they are, for instance, not good enough, too hard to use, overkill, unavailable, etc. The challenges led to a process of impromptu reinterpretation, adaption, and/or improvisation of materials and devices at hand to fashion the *right*

tools for specific purposes. They often are modified versions of familiar tools, built to better fit the purpose at hand, and many are based on plans for similar tools found online through a variety of resources, such as Instructables, YouTube videos posted by other makers, and hackerspace wikis. These self-made tools are representative of their makers' adoption of the maker identity, showcasing their abilities with tools and material at hand, their adhocist attitudes toward production processes, and their engagement with the maker community.

Mike: Lock Picking Tools

Mike, an undergraduate student at the local university studying computer science, is a lock picking hobbyist. Lock picking is seen as a sport to those in the security and hackerspace communities. Mike made several lock picking tools for his hobby. The first, a tension wrench, is a small piece of metal used to apply tension to a lock while it is being opened by a pick, which Mike made by hammering a piece of metal he found on the floor of the hackerspace into a shape that complemented the other tension wrenches he owns. His second tool, a bump key, is a key blank he filed down to an estimated average of where the pins in a lock need to be set for it to open. The bump key is "bumped" while placed in a lock to set the pins in the right place and open the lock. Bump keys can work very quickly for certain situations, but are more of a novelty tool than a practical one because there is a high risk of permanent damage to the lock.

Nolan: RS232 Cable and Bubble Etcher

Nolan is a server administrator at Floraville and is one of the board members of the hackerspace as well as one of its founders. He modified an RS232 cable to connect an LED marquee to his computer, and built a bubble etcher for etching printed circuit boards (PCBs). The marquee came from a yard sale and did not have the proper cables for programming it; Nolan's self-made tool fixed the problem and eliminated the need to search for a replacement part, which would have been difficult to locate. Described by some of the hackerspace members as "a proper hack," Nolan's RS232 cable was created by splicing open an extra straight-through cable, soldering it to the inside of a connection jack, and soldering parts of it to itself to mimic the 5 volt connection signal the proper cable would have communicated. Nolan's second project, the bubble etcher, is a tool used to speed up the process of etching PCBs while also requiring less etchant solution (in this case, hydrochloric acid), resulting in an overall more sustainable solution than traditional etching methods. This self-made bubble etcher is made

from two pieces of plexiglass, an aquarium bubbler, plastic tubing, and silicone caulking, and is based on several designs Nolan found online.

Drake: PDUs and LED Lighting Tools

Drake works for a contracting company in town that builds software and robotics solutions for the government, and in his spare time he builds his own robots. Robotics projects, like many other large-scale electronics projects, consist of a variety of electrical components, each with its own electricity needs. To satisfy these needs, these projects often require power distribution units (PDUs), which distribute the electricity from the power source to match the specific requirements of each component. For his robots, Drake often makes his own PDUs by soldering together the proper components on a custom circuit board. Though each PDU is a one-off (unless a future project requires the exact same kind of power distribution), self-made PDUs can be less expensive and their customizability for specific project needs make them more effective in doing their jobs. Fused with his passion for LEDs, Drake also made unique LED lighting instruments for his experimental hydroponic system, powered using PDUs he built and complete with heat sinks (i.e., a passive heat exchangers that cool devices by dissipating heat into the surrounding medium) appropriated from previous projects or found materials.

George: Power-Generating Bicycle and Metal Pulleys

With a background in electronic engineering, George operates and manages a large nuclear physics machine during the day and has been tinkering with power generators for decades. His signature self-made tool, an electricity-generating stationary bicycle, has been used locally in several public events as an example of alternative energy sources (i.e., it generated enough electricity for George's wife to telework from home when they were snowed-in with no electricity from the grid). The bicycle power generator is a stationary bike with a set of pulleys and motors that together generate electricity through induction when the pulleys are activated. George appropriated the stationary bike frame and welded parts of it together with the help from a fellow hackerspace member who owns the welding equipment in the space. George also machined the pulleys that are integral to his bicycle power generator out of cubes of aluminum using the metal lathe and the milling machine.

David: Sharpening Jig and Push Tools for Table Saws

David is an application developer who has made several tools specifically for everyone's use in the hackerspace. These tools are intentionally made from spare pieces he found around the space, and in

David's own words, the tools "*cost nothing but time*" to create. When the hackerspace received a set of dull wood lathe chisels, David created a sharpening jig to attach to the bench grinder, making it easier to sharpen the wood lathe chisels by holding them at a steady and constant angle. In his second project, motivated by altruism and his concerns for the safety of his fellow members, David made several push tools (i.e., tools that are used to push materials across the table saw) to reduce risk of injury while using the table saw. These push tools mimic commercially available push tools, but they were made from scrap pieces of wood found in the space.

Charles and Joshua: Buddipoles

Charles and Joshua are both amateur radio operators (also known as "Hams"). Charles telecommutes as a developer for a popular operating system, and Joshua is a freelance developer. Together Charles and Joshua own several portable high frequency antennas known as "Buddipoles." Charles built his homebrew, modular Buddipole by following the plan for them created and shared freely online by its creator known as "Budd W3FF" in Redding, CA. Joshua put his Buddipole together from a kit he ordered online. Common materials include stainless steel telescopic whips, PVC pipes of varying lengths, PVC adapters, insulated speaker wires, electrical connectors, antenna adaptors, alligator clips, and banana plugs, among other things. These Buddipoles work well on any band from 10 to 80 meters, and operate as a portable high frequency antenna—a phrase that used to refer to an impossible Ham setup.

BECOMING A MAKER

We now turn to our synthesis of the individual cases of makers and their tools to present a set of factors that appear to contribute to the formation of a maker identity. These include the development of a tool and material sensibility; the adoption of an adhocist attitude toward make projects and tool use; and an engagement with a local community of makers.

Developing a Tool and Material Sensibility

Earlier, we referred to the development of a tool sensibility as an integral part of becoming a maker. We define this tool sensibility as being comprised of a deep understanding of existing tools and how they are used, an ability to judge which tools are the most appropriate for the task at hand, and a sophistication concerning the materials and medium available to the makers.

Learning to use their tools

Our participants expressed an emphasis on practice and extensive engagement. When describing others' astonishment at his accomplishments, Nolan comments, "*When you see people who put out lots of successful projects, what you don't see are all of the failed projects. For every one that's successful, there's at least a dozen that are not, for various reasons*." This emphasis on working on many projects as the way to develop as a maker was presented in all of our interviews and was an evident value in our observations.

In addition to a general practice of making, it was clear that knowledge about how to use specific tools is important to members of the hackerspace. We saw this emphasis in the workshops and classes put on by the hackerspace members and in the focus on the tools given during visitor tours, but we saw it most clearly in the self-made tool projects we investigated. To be able to make a self-made tool, a maker must first have an embodied understanding of the limitations of existing tools. Oftentimes the impetus of tool making comes from the constraints of existing tools, and Drake's tools demonstrate this. Drake rationalizes making his PDUs this way:

> *There is no board that's going to do exactly what I need to do. There's not going to be a single board that has the number of pinouts that I need … a good form factor. Building and constructing [one] myself is going to be more beneficial than trying to hack and slash something into my rover.*

Existing tools challenge Drake in that they are not fit-for-purpose, which as Sennett observes, "send the message of clarity, of knowing which act should be done with which thing" (2008, p 194). By thinking with and through the limitations of imperfect tools, Drake is empowered to make his own. Moreover, ~~as summarized earlier,~~ tools are future orienting. While they may lack tooling potentials, these imperfect tools nonetheless act as catalysts that activate Drake's intuition and imagination into different possibilities. Sennett (2008) describes these possibilities as "grounded in feeling frustrated by a tool's limits" (pp 209-210), and Jencks and Silver (2013) agree: "In technology, inadequacy, not necessity, is the mother of invention" (p 107). The makers' abilities to recognize inadequacy in their tools in the first place is part of what makes them makers, and is a skill they develop through extensive engagement and a deep understanding of their tools.

Learning to judge a tool's appropriateness

When working in a small machine shop environment like this hackerspace, the ability to use specific tools is only half of the battle: knowing which tool to use for the job is an important type of judgment that hackers develop by becoming familiar with the tools available to them, and through them the possible abilities on which they can capitalize. George describes his process of creating an impromptu pulley for his bicycle generator as a casual experience: "*I just went over there and I had never used a metal lathe before in my life and what was it, about an hour or two hours later I've got a pulley*." He makes it sound as if the knowledge for creating this pulley just came to him, but we know from our observations that George spends a large part of his time at the hackerspace in the shop area near the metal lathe, where he can watch, and engage with, Nolan as he works on the lathe. This experience participating in the shop and observing other's activities helped him develop a sense for which tools are appropriate for which jobs. Even though this was George's first time using the metal lathe, he knew what it could be used for from watching others use it. With this knowledge he was able to create his own tool, demonstrating his familiarity with the tools and materials in question, as well as the tool's role in enabling George to be future-orienting: he could imagine the creation of this pulley *because* he knew how this tool worked.

Materials and medium

Intimately related to this development of a tool sensibility is the familiarity with a particular material. In the case of the makers in Floraville, metals, wood, plexiglass, and other everyday materials both inspire and constrain their creativity. We see from our data time and again the process of tool making is very much driven by toolmakers' intimate and deep respect for the medium they work with. In Drake's own words:

> *I do a lot of light mods. Love LEDs, love the colors, love the whole photoelectron effect. I think it's a lot of fun, very interesting. And I learn-- through that obsession, I learned a whole lot more about light than I thought I ever would have. There are six distinguishing units of measurement for light, which a lot of people just didn't know.*

Drake's personal knowledge about LEDs is given an outlet: he knows what he can pull out of them and what they can do for him. Similarly, Nolan's projects demonstrate a high level of sophistication and familiarity with the material within which he works. Toolmakers' understandings of materials, as McCullough observes, do not come from something abstract and theoretical, but is grounded on direct involvement with them, oriented toward "workability and practices" (McCullough 1988, p 196). Nolan's

modified RS232 cable is case in point. To connect to the LED marquee, he needed a cable that could create a bridge between their computer and the marquee using RS232 protocol. Nolan's extensive engagement with—and knowledge of—straight-through cable enabled him to appropriate it in this *ad hoc* way.

This familiarity with the material possibilities available to a maker is especially helpful when it comes to navigating the physical environment of the hackerspace. Jencks and Silver (2013) discuss the importance of "browsing" in any information system (p 177), and a hackerspace full of tools and materials can certainly be considered such an information system. Without a sense of the material possibilities available to the maker, the materials strewn about the hackerspace would be seen as just another mess, instead of as a possibility for a project or self-made tool. As a lock-picking enthusiast, Mike is intimately familiar with the material requirements of his tools. The tension wrench he created came from a piece of steel he found on the floor of the space which he then hammered into the shape he needed to complement his other tools. Without the level of familiarity he has developed with his tools and the materials they are made out of, the piece of steel on the floor could have easily been overlooked.

As with Drake's and Nolan's projects, we recognize in Charles and Joshua's antenna projects—both the buddipole projects and the other antennas they have built over time—that engagement with materials is personal, and the conversations between the toolmakers and the materials (i.e., materials' "talking back") unfold over time. Charles related his experience developing his interest in Ham radio and building his own antennas:

> *… so building antennas, tweaking antennas, designing my own, you know, that's always been a fascination. I think that actually grew from being a broke teenager trying to get into the hobby and needing an antenna on the cheap… I looked into well you can take this wire and if it's the right length, and situate it in the right direction it works just as well.*

Building on his engagement with the materials and understanding of how antennas work, Charles was able to work within a set of constraints to build his tool and further develop his interest in Ham radio while also developing his skills as a maker.

One of the ways we see the importance of this overall tool sensibility is through how the makers are identified within the hackerspace by the tools they can use and the skills they have. Many of the members are introduced to visitors through a description of their capabilities, projects, or which tools they own in the space. For example, George is introduced as an electricity expert and through his bicycle

generator project. Charles as a Ham, Drake as a roboticist, Mike as a lock picker, and David as "laser-man," because of his recently acquired expertise with the laser cutter. These tools become identifiers for individual makers in the hackerspace, and the makers are reflexively seen as tied to these tools. Developing this experience with tools and medium helps solidify one's identity as a maker, but can also act as a barrier if this level of understanding, practice, or involvement is not reached. John was a regular visitor of the hackerspace for a few weeks, and even eventually became an official member, before he suddenly stopped showing up. John had a hard time seeing himself as a maker, and commented once while looking at one of the products of the machining workshop during a visit, "I need to get in on this, I don't know how to do anything. Where do you have a list of all the classes?" Shortly after this comment John stopped coming to the space and stopped paying dues. His lack of a connection to the larger tools and their capabilities was a barrier to *feeling* like a maker that he was not able to overcome in his short time at the space. If John had focused more on acting like a maker, or adopting a makerly attitude, then he might not have been as intimidated by his lack of experience.

Cultivating an Adhocist Attitude

The skills to actually pick out and use a set of tools and materials are an important part of becoming a maker, because ultimately makers make things. However, the personality and the attitude required to really become an expert maker can be even more important. When asked which skills or processes he relies on continuously throughout his making process, Charles, who grew up making his own antennas for his amateur radio hobby, said,

> *It's hard to say skills more than it's I would say just my nature of curiosity and wanting to tinker. It's not really a skill. It's just a personality trait, I guess… Maybe the biggest skill there is just knowing how to research and figure out the skills that I'm missing.*

For Charles, making is not just a way to get by or be frugal, but is also an experience that plays on his personality. We argue that this adhocist attitude centers on practicality as a motivation, practicality as an identity constraint, and an underlying confidence in abilities.

Motivating Practicalities

For the makers at this hackerspace, practicality is an approach to and motivation for making. This relates to Jencks' and Silver's (2013) distinction between practical adhocism, which they describe as relying on "*ad hoc means,*" with intentional adhocism, or using "*ad hoc ends*" (p 110). The distinction here is between working to create an artifact through a set of ad hoc processes and working to

create an artifact that represents a purposeful conglomeration of other artifacts juxtaposed in one entity. In this hackerspace, adhocism is a means for navigating, overcoming, or building on the constraints of the make projects while also working to remain practical on various fronts, including both monetary and time limitations. In many cases, simply buying the parts for a project can be the most frugal decision, even if the part could be made relatively easily. We see this approach in Drake's schema for when to purchase his PDUs. Where Mike says, *"The thing I have the most of is time, not money*" about his decision to make his lock picking tools, Drake offers a different and more nuanced perspective:

> *If it weren't my money, then I would always buy. Because there are enough modules out there that you could make it fit, you could make it work. And there are companies who will fabricate individual integrated circuits for you if you told them what you were looking for…[But when it is my money,] if it can be quickly found cheap and delivered quickly, then purchase [it], but if it's something that's really arbitrary or if it's something I need now and I have parts on hand, I build it myself.*

Drake is open to purchasing tools as long as they are *"cheaper to buy than it is worth my time [to build]."* Tool making for Drake is thus a premeditated act, where working through a series of contingencies involving self-imposed resource constraints is the norm.

We have seen with both Drake's and George's tools how the incompleteness and limitations of the materials and resources are a norm in this hackerspace, and how as tool makers they have a very pragmatic attitude toward such constraints, and in fact, rely on them to give rise to creative expressions. George relates a conversation he had with a group of high school students when he demonstrated his electricity-generating bicycle at a local high school. When questioned by students about the bicycle's gear ratio, George comments that "*sometimes it's a case where what you have on hand is what you use rather than going out and buying or whatever*." For a tool such as the bicycle electricity generator, a higher gear ratio would be more effective, but George has to (and enjoys) working with what is available and is at peace with having a "good enough" final product. As Gauntlett (2011) observes, "the best tools are not merely 'useful' or 'convenient' additions to everyday life, but can unlock possibilities and enable creative expression, which are essential components of a satisfactory life" (p 172). We have seen this play out in the processes our makers use to create their tools, where the methods that are "convenient" are discarded for what can result in a more creative expression.

With his sharpening jig, David shares a similar sentiment to George's about working within constraints and being at peace with a "good enough" solution:

> *It seemed silly to buy or spend too much time on a more elaborate jig, because we're really not a woodworking shop as much. You know, that's just an aspect. But we're not going to use the lathe super extensively.*

This quote brings about an interesting characteristic of self-made tools: approximation. To some, tools made with inexpensive materials, scraps, and found objects or even junk laying around in the hackerspace are perfectly acceptable as long as they are made "well enough" or "close enough." In other words, while these self-made tools might not be perfect, they are nevertheless optimum for the context and means. Jencks and Silver (2013) argue that "approximate solutions are very often the best when requirements are multiple or complex" (p 119), and here we see that multiple and complex limitations, such as a need for efficiency or frugality, can also be met through approximate solutions.

Practicality as an identity constraint

Practicality can also play out as an identity constraint, where practicality and frugality are often desired *expressions* of projects, even if the process of obtaining that expression ends with an overall less frugal or less efficient output. This is especially true of the projects that Charles works on relating to his ham radio hobby. His stories about how he got his start with this hobby, and how he started developing as a maker, begin with creating his own antennas just to be able to participate. But now that he's older and that barrier no longer exists, he still makes many of his own antennas. For him, having a homemade antenna plays into the *sport* of making. He says "*half of the fun is actually talking to someone on, you know, across the country and across the world, on pieces that I've actually built myself.*" This sport focuses on the *appearance* of frugality and practicality, even when the process of making these tools and products might actually end up costing the maker more in the long run. Through participating in this "sport," the makers are expressing an affiliation with pragmatism and adhocism, even if it's not actually the case.

One of the primary limitations we have seen with this predilection towards practical adhocism is the fact that there are no general-purpose tools created in the space. Rather, every tool we have seen is created as fit-for-purpose, to inhabit a specific part of the making activity. Creating a more general-purpose tool would require a focus on the creation of the tool itself, instead of the focus we have seen on the solution to a problem. Another limitation we have identified with this focus on practical adhocism is the narrowed scope of what activities can and cannot exist in the space. If the activity is not already happening in the space, or it is not an activity closely tied with the broader maker culture, publicized

online in various venues such as Instructables, *Make* magazine, or Adafruit, then it is very difficult for that activity to gain traction within the hackerspace. This limits the potential reach of the space to those who self-select into this particular subset of the community. For example, other making subjectivities that *could* exist in this space but do not as of yet include: makers who mend or create their own clothes, makers who focus on gourmet foods, makers who bind their own books, makers who write, etc.

In Futz We Trust

Each of the self-made tools we investigated in this study and much of the ethnographic data demonstrate a high level of optimism and confidence on the part of the makers. Some of this optimism can be attributed to the tool and material sensibility described in the previous section, but we also see this attitude coming from a demonstration of trust in the maker's adhocist process. When working on a project, the makers avoid planning out each step of the make process (sometimes explicitly and deliberately), instead relying on the belief that they will be able to figure out what needs to be done at each stage of the project. A common phrase to be heard around the hackerspace, especially when discussing possible group projects, is "*We're a hackerspace, surely we can think of something*." Playing into this trust in their ability to know how to research what they need to know when the time comes is the comfort in knowing that their projects are approximate solutions that only have to be "good enough" for their purposes. In fact, an overly meticulous or powerful project could be seen as overkill. The hackerspace also demonstrates a clear acceptance of failed projects as a legitimate and necessary form of practicing one's skills.

The emphasis on confidence is further established through how hackerspace members approach maker education for children. Jennifer, one of the founding members of the space who also organizes many of the space's events, characterizes her favorite part about the bug bots class she leads every year at the children's museum as "futzing," saying "*you have to futz with them, and I like that*." This idea of futzing refers to tinkering with the bug bots while building them because they are not particularly well designed *on purpose* so that the children have to play with them and take charge of how pieces should be bent and configured to make sure that their bug bot actually runs well. The exercise forces them to develop enough trust in their judgment to be able to perform that level of tinkering without fear of failure, while also accepting a certain level of approximation, learning when to stop "futzing" and just experiment with what they have.

A certain level of confidence is required for makers to be able to make just for the sake of making, one of the characteristics that seems to separate general makers from more established or expert makers. When describing the projects he works on, Joshua says, "*They're all useful and they all work. [But] I haven't gotten to the point of just making things just to make them, because I don't really know enough yet. Though I'm almost there. I have a couple projects in the works that I haven't made yet that probably won't be all that great or useful*." Once makers have developed enough trust in their abilities, either because they have learned to adopt this adhocist attitude full-heartedly or because they have started to view themselves as experts with the tools and materials they work with, then they start to see themselves as established makers. Drake relates the experience he had when he realized exactly what it was he already knew how to do with his robotics projects: "*Everything from there, from robotics on, has just been an extension of that mindset, that holy crap, I'm empowered. I know how to learn the stuff. I know a lot of this already. Why not just take it seriously?*" For Drake, realizing he could do these projects already because he knew how to learn how to do this projects was a big step toward becoming an established maker.

A Community Focused on Tools

In addition to promoting a focus on practical adhocism and building a level of confidence among members, this hackerspace's maker attitude also emphasizes the importance of community. The members work actively to share what they know with each other, either through advice on individual projects and problems as they come up, or through creating educational opportunities in the form of workshops, classes, or shared interest groups within the hackerspace. More expert makers—with developed tool and material sensibilities and a growing demonstration of experience and expertise—act as mentors for other makers. Sennett (2008), citing Harper's *Skill and Community in a Small Shop*, discusses the role of "sociable experts" and their ability to become mentors for other experts, enabling a transfer of knowledge that can otherwise be quite difficult to perform. We see such transfers of knowledge in the hackerspace community time and again in our observations. For example, in the process of building his bicycle generator, George relied on help from other members to weld parts of the frame together and to learn how to use the metal lathe. We also found this transfer of knowledge to often be tied up in expressions of care for other members: to express his concern for other members' use of the table saw, David built several push tools not just so they could be used for the table saw but to remind other makers to use safety tools in the first place.

In our observations it became clear that Nolan plays a strong mentorship role in the hackerspace, as he is often the subject of an informal queue of members seeking advice on various projects. When we asked him about this experience, he said,

> *"I really like to see someone be able to work on their own after I've helped them, and so I'm still on the phase of trying to do that. I don't know, I mean, I think I'm just kind of a run-of-the-mill geek. I know a little bit about a lot of things but not a lot except my certain specialty areas. I'm very glad that I've been able to be helpful to a lot of people in a lot of different areas."*

Nathan recognizes his role as a mentor to others, and uses this privileged position to instill in his mentees a common maker ethos of independence and confidence in their abilities.

This concern for community extends beyond the borders of the hackerspace itself to the community at large in Floraville. Members of the hackerspace have worked (without compensation) to set up an annual maker convention in the town; to teach various workshops with children including soldering lessons, stop motion animation workshops, and DIY speaker workshops; and to provide a space for others to work at the hackerspace each week during the public hack nights, including access to any of the spaces tools, human resources, and social activities. At the beginning of our ethnography, the hackerspace seemed to us to be very tool-focused, with a constant emphasis to visitors about what tools are available in the space, what workshops they can take that will teach them to use certain tools, and which members are experts on which tools. However, having spent over a year with them, a different social understanding of the space emerges: the space has more to do with providing a social atmosphere for its members, operating as a third space, one that is neither home nor the office, for members to relax and visit with each other, where members can work on projects that fail without fear of judgment, where members learn to engage with their materials and tools on a deep level, both through hours of practice and through learning experiences set up by more experienced makers.

CONCLUDING DISCUSSION

In this article we have presented one kind of maker out of many possible variations, focusing on the process these individuals go through to develop and cultivate their "maker-ness." We presented three primary concepts that stand out in our data as primary drivers of the formation of a maker identity: the development of a tool and material sensibility that relies on an extensive engagement and practice with tools and materials to learn how to use them well, how to judge which tools are appropriate for which situations, and to understand how to use available materials appropriately; the cultivation of an adhocist

attitude, which involves learning to trust one's intuitions and judgments through a maker process and adopting practical approach to project building and learning; and developing a sense of community engagement with other makers. These characteristics set "established" makers apart from the more generalized kind of maker, who can adopt the identity after their first Instructables walkthrough or the first time they learn to use a sewing machine. What we have found is that the process of becoming such an established maker seems to rely less on inherent abilities, skills, or intelligence per se, and more on adopting an outlook about one's agency. We believe this process of becoming an "established" maker can be usefully applied to other situations, particularly those that involve individuals who have not traditionally felt empowered. To instill such a creative sensibility, along with the practical skills to act on it, appears to be one of the primary purposes of the hackerspace—an intriguing idea for researchers seeking to understand these spaces and extend their creative practices beyond their walls.

ACKNOWLEDGEMENTS

This research was funded by NSF IIS Creative IT (#1002772) and the Intel Science and Technology Center for Social Computing. We thank our participants and gratefully acknowledge the encouragements, insights, and suggestions of Colin Gray.

REFERENCES

Anderson, C 2012, *Makers: The New Industrial Revolution.* Crown Business Books, New York, NY.
Bardzell, J, Bardzell, S, and Toombs, A in press, "Now that's definitely a proper hack": Self-made tools in hackerspaces. *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems.*
Bardzell, S, Rosner, D & Bardzell, J 2012, 'Crafting quality in design: Integrity, creativity, and public sensibility', *Proceedings of the ACM Conference on Designing Interactive Systems,* pp. 11-20.
Bardzell, J 2007, 'Creativity in amateur multimedia: Popular culture, critical theory, and HCI', *Human Technology*, vol. 2, no. 2, pp. 12-33.
Buechley, L & Hill, BM 2010, 'LilyPad in the wild: How hardware's long tail is supporting new engineering and design communities', *Proceedings of the ACM Conference on Designing Interactive Systems*, pp. 199-207.
Buechley, L 2010, 'LilyPad Arduino: rethinking the materials and cultures of educational technology', *Proceedings of the 9th International Conference of the Learning Sciences*, International Society of the Learning Sciences, pp. 127-128.
DiSalvo, C, Nourbakhsh, I, Holstius, D, Akin, A & Louw M 2008, 'The Neighborhood Networks project: A case study of critical engagement and creative expression through participatory design', *Proceedings of the Conference on Participatory Design,* pp. 41-50.
Gauntlett, D 2011, Making Is Connecting: The Social Meaning of Creativity From DIY and Knitting to

YouTube and Web 2.0, Polity Press, Cambridge, UK.
Gelber, S 1997, *Hobbies: Leisure and the culture of work in America,* Columbia University Press, New York, NY.
Illich, I 1980, *Tools for conviviality,* Harper & Row, New York, NY.
Jackson, S in press, 'Rethinking repair: Breakdown, maintenance, and repair in media and technology studies today', In *Media Meets Technology*, eds. P Boczkowski, K Foot, & T Gillespie, MIT Press, Cambridge, MA.
Jencks, C & Silver, N 2013, *Adhocism: The case for improvisation*, MIT Press, Cambridge, MA.
Kuznetsov, S & Paulos, E 2010, 'Rise of the expert amateur: DIY projects, communities, and cultures', *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries,* pp. 295-304.
Levy, S 2010, Hackers: Heroes of the Computer Revolution. O'Reilly Media.
Maestri, L & Wakkary, R 2011, 'Understanding repair as a creative process of everyday design', *Proceedings of the ACM SIGCHI conference on Creativity & Cognition*, pp. 81-90.
McCullough, M 1988, *Abstracting Craft: The Practiced Digital.* MIT Press, Cambridge, MA.
Mellis, D & Buechley, L 2012a, 'Collaboration in open-source hardware: Third-party variations on the Arduino duemillanove', *Proceedings of the ACM Conference on Computer Supported Cooperative Work*, pp. 268-277.
Mellis, DA & Buechley, L 2012b, 'Case studies in the personal fabrication of electronic products', *Proceedings of the ACM Designing Interactive Systems Conference*, pp. 268-77.
Mellis, D, Follmer, S, Hartmann, B, Buechley, L & Gross, MD 2013, 'FAB at CHI: Digital fabrication tools, design, and community', *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, pp. 3307-3310.
Mota, C 2011, 'The rise of personal fabrication', *Proceedings of the ACM conference on Creativity and Cognition*, pp. 279-288.
Ogden, C & Richards, IA 1923, *The Meaning of Meaning,* Mariner Books, New York, NY.
Pace, T, Toombs, A, Gross, S, Pattin, T, Bardzell, J & Bardzell, S 2013, 'A tribute to mad skill: Expert amateur visuality and World of Warcraft machinima', *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, pp. 2019-2028.
Risatti, H 2007, *A Theory of Craft: Function and Aesthetic Expression*. University of North Carolina Press, Chapel Hill, NC.
Rosner, D & Bean, J 2009, 'Learning From IKEA hacking: I'm not one to decoupage a tabletop and call it a day', *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, pp. 419-422.
Rosner, D, Jackson, S, Hertz, G, Houston, L & Rangaswamy, N 2013, 'Reclaiming Repair: Maintenance and Mending As Methods for Design', *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, pp. 3311-3314.
Rosner, D & Taylor, A 2011, 'Antiquarian answers: Book restoration as a resource for design', *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, pp. 2665-2668.
Sennett, R 2008, *The Craftsman,* Yale University Press, New Haven, CT.
Suchman, LA 1987, Plans and situated actions: The problem of human-machine communication, Cambridge University Press, New York, NY.
Tanenbaum, J, Tanenbaum, K & Wakkary, R 2012, 'Steampunk as design fiction', *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems,* pp. 1583-1592.
Tanenbaum, JG, Williams, AM, Desjardins, A & Tanenbaum, K 2013, 'Democratizing technology:

pleasure, utility and expressiveness in DIY and maker practice', *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, pp. 2603-2612.
Wakkary, R & Maestri, L 2007, 'The resourcefulness of everyday design', *Proceedings of the ACM Conference on Creativity & Cognition*, pp. 163-172.
Wakkary, R & Maestri, L 2008, 'Aspects of everyday design: Resourcefulness, adaptation, and emergence', *International Journal of Human-Computer Interaction*, vol. 24, no. 5, pp. 478-491.
Wakkary, R & Tanenbaum, K 2009, 'A sustainable identity: the creativity of an everyday designer', *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, pp. 365-374.