Democratizing Technology: Pleasure, Utility and Expressiveness in DIY and Maker Practice

Joshua G. Tanenbaum
Simon Fraser University
Surrey, BC, Canada
joshuat@sfu.ca

Amanda M. Williams
Wyld Collective Ltd.
Montréal, QC, Canada
meta@wyldco.com

Audrey Desjardins
Simon Fraser University
Surrey, BC, Canada
adesjard@sfu.ca

Karen Tanenbaum
Simon Fraser University
Surrey, BC, Canada
ktanenba@sfu.ca

ABSTRACT
DIY, hacking, and craft have recently drawn attention in HCI and CSCW, largely as a collaborative and creative hobbyist practice. We shift the focus from the recreational elements of this practice to the ways in which it democratizes design and manufacturing. This *democratized technological practice*, we argue, unifies playfulness, utility, and expressiveness, relying on some industrial infrastructures while creating demand for new types of tools and literacies. Thriving on top of collaborative digital systems, the Maker movement both implicates and impacts professional designers. As users move more towards personalization and reappropriation, new design opportunities are created for HCI.

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INTRODUCTION

Technology has always played a central role in how we structure our societies. Marshall McLuhan's mentor Harold Innis distinguishes between communication media that are biased towards space (e.g. easily transported and disseminated) and media that are biased towards time (e.g. cast in clay, metal, or stone, and capable of enduring indefinitely) [23]. He argued that the dominant bias of communication technology in a society shaped the character of that civilization, both in how it was perceived through history based on what was preserved in the material record and in how it administrated itself while active. Following this, McLuhan went on to develop some of the earliest theories of electronic media, positing four "laws of media". These laws of media framed all technologies in terms of their social impacts within the context of human technological development. He argued that every medium *enhanced* or extended some human capability; that it *obsolesced* some previous technology or practice; that it *retrieved* a previously obsolesced practice or function; and that it had the potential to *reverse* into an unanticipated opposite outcome (a nod to our ability to imagine a dystopian extreme for any technological advance) [33]. Technological practices, from this perspective, are never isolated from their social or economic contexts, or from the history of previous technological practice.

The industrial revolution effected radical technological transformations of Western society that started in Britain and spread across the world. Industrial infrastructures thrive on interoperability, standardization of measures and components, and specialization of knowledge and labor. As advances in manufacturing, metallurgy, energy production, transport, textiles, and agriculture reshaped the landscape, the population exploded and a new "middle class" of workers emerged. With these technological advances came a host of social transformations: the spread of literacy, a new urban environment, and a newly framed relationship between work and leisure time [4]. The human capabilities necessary to achieve industrialization were quite different from those that were developed in pre-industrial societies. At the same time, the sum of human knowledge was exploding: philosopher Pierre Levy is commonly cited as identifying the period of 1751-1772 as "the end of an era in which a single human being was able to comprehend the totality of knowledge" [29]. As human knowledge grew, it became increasingly necessary for individuals to specialize, often at the cost of broader know-how. Whereas knowledge of basic handcraft and agriculture was once common, in the new urban environment one could go through life without ever having to repair a cart, milk a cow, or sew a dress.

If we broadly apply McLuhan's laws to the industrial revolution, we might say that it *enhanced* manual labor practices by extending and automating manufacturing and agricultural processes. It *obsolesced* many of the individual craft practices of the day, replacing handmade items with mass produced "products". At the same time, it *retrieved* a set of classical values around education and self-improvement through the rise of widespread literacy, and it *reversed* into a machine culture that treated everything as a resource to be consumed, while rendering the workings of that machine increasingly unknowable. The technologies underlying our modes of production continue to transform, however, with computation now heavily implicated in their evolution. While industrial mass production remains

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significant, we now see a return to individualized practices, as exemplified within the DIY (do-it-yourself) community. Within HCI, we have recognized this trend, but treat it mainly as a recreational practice. But the merging of craft and industrial methods has led to shifts in production that have been referred to as a "third industrial revolution" and thus is a phenomenon worthy of more serious study [3, 45].

In this paper we take an interdisciplinary approach to investigating *democratized technological practices*– a broad cultural shift in how people engage with technology. As practitioners as well as researchers, our participation in DIY and Maker cultures provides us with a valuable perspective on this material, but it also frames and inflects our analyses in complicated ways. We variously self-identify as scholars, designers, makers, artists, Steampunks, and entrepreneurs with professional practices that encompass academic and industry research, ethnography, and technology design. Our research employs a range of qualitative methodologies, including online and in-person ethnographic studies of Steampunk Makers [44], participant-observation with Thai crafters, and interviews with hobbyist and professional programmers. Some of our fieldwork has taken place at Maker Faires and similar events in Vancouver BC, Montréal QC, Portland OR, Beijing, Shanghai, and the San Francisco Bay Area. Our participation in these events has been as Makers, organizers, and teachers: we have shown our own creations, coordinated larger participatory installations, and led workshops and classes on specific making techniques. It is in the negotiation of these different perspectives that we have observed the emergence of a wide range of democratized technological practices in Maker culture. To a certain extent, our participation in these communities encourages us to adopt a sort of "unflinching optimism" about the value of these practices: there is a prevailing ethos in these communities that "making is better than buying" and we acknowledge that we share many of these values with the community. However, even as Maker and Steampunk cultures celebrate the act of making, so too do they critically engage with the role of making within a broader consumer culture. In this paper we embody and reproduce this tension between celebration and critique.

From these qualitative studies of Steampunk, hackerspaces, and DIY subcultures, we have articulated critical elements of a democratized practice with technology. Our aim is not to present a comprehensive analysis of these groups, but to draw on examples from a variety of practices to illustrate our position on the democratization of technological practices in our culture at large. In the next section we provide background on the DIY movement, including relevant literature from HCI, STS, and the DIY community itself. We then describe what we consider to be key elements of democratized technological practice: playfulness that includes cultural and material engagement, decisions around tool use, the leveraging of industrial infrastructures around materials and standards, and the crucial role of knowledge sharing and building new literacies. Our presentation of these elements, admittedly, reflects our enthusiasm for them as participants. However, our later discussion of the implications for our own professional technical practices and society at large takes a step back from this optimism to reflect on the complex politics and challenges of democratized technologies.

DIY FOR HCI

The practices of hacking, craft, and DIY have been of increasing interest to HCI researchers in recent years. A 2009 CHI workshop attempted to establish a dialog between CHI attendees and DIY aficionados, many local to the conference venue [12]. A paper on IKEA hacking highlighted the relationship between standardized parts and materials and the ease of distributing and following craft instructions [42]. A survey of DIY practices from mileage runs to Maker Faire characterized these "productive leisure practices" as concerned with identity production, skill, reputation, participation, norms of sharing, learning through teaching, and communities and collectives of practice [48]. Discussions of "expert amateurs" examine the underlying value of low barriers to entry to creating DIY projects, creativity, learning and sharing [28, 44]. This collection of literature from the HCI community has emphasized the pleasure, expressiveness, and communicative practices involved in DIY and crafts, rather than the utility of their end products or their ability to generate profit.

Hedonized Technology and HCI

In this respect, the trends described in the HCI literature fit the definition of "hedonized technologies". Science, technology and society (STS) scholar Rachel Maines notes that "any technology that privileges the pleasures of production over the value and/or significance of the product can be a hedonizing technology" [31]. While Maines' discussion of hedonization provides a good theoretical fit for hobbyist Maker practices, she moves beyond a simple discussion of creative pleasures to emphasize their recent *democratization*. Refuting Marxian claims that work-like hobbies emerged ex nihilo from the industrial revolution and its increased alienation from daily labor [20], Maines traces hedonized needlework practices back to the nobility of the middle ages and asserts instead that contemporary means of production have made these pleasurable crafts available to an unprecedentedly wide audience.

In this paper, we suggest that while hedonization of technologies is a significant development, this concern with pleasure is not necessarily opposed to a concern with the quality of its product or its profitability. The democratization of craft technologies that Maines points to makes it possible for pleasure, expression, and utility to coexist in the practices of Makers and crafters. It is this democratization, and its impact on professional practices such as our own, that we wish to examine.

Contexts of Democratized Technological Practices

The rise of DIY and Maker cultures owes much of its success to the excesses of current industrial economies, processes, and breakthroughs in batch fabrication technologies. Our current economy thrives on regular obsolescence, generating a surplus of "disposable high-technology" that greatly lowers the costs of hacking and experimentation. At the same time, the explosion in new materials and new small scale fabrication technologies such as 3D printing, laser cutting, and garage-scale CNC mills has given hackers and hobbyists modes of production previously only available to large organizations [34].

With this shift in the availability of raw materials and access to production facilities comes an explosion in technological literacies: after school programs are starting to teach robotics, electronics, programming, and machining basics [38]. More importantly, perhaps, the rise of Maker culture is creating new values around technological practices. We see this happening in the heart of the Steampunk community with optimistic reimaginings of modern technology that actively reject the mass-produced, the sterile, and the impersonal [44]. We see this happening in the Maker Faire community with its emphasis on education and empowerment through DIY. We see this happening in the rise of community hackerspaces where resources are pooled to maintain and provide access to an impressive array of industrial machines and knowledge.

In the developed world, these practices are typically facilitated by no small amount of social privilege: the current generation of Makers and hackers is often possessed of sufficient free time and access to resources to engage in relatively risk-free making. As in the example of surplus disposable technology, this freedom to self-determine thrives on the edges of established industrial infrastructures. Makers in the developed world represent a growing group within the middle class that is re-negotiating the social contracts around the production and consumption of technology. This is a form of resistance that manages to hide in plain sight. Researchers have taken note, emphasizing the critical possibilities of material making [40] and the politics of citizen science [39].

In contrast, DIY practices in developing countries, though valorized as innovative and creative endeavors, are typically characterized as being concerned with utility or disaster relief rather than the pleasures of making. A case in point might be William Kamkwamba's creation of a windmill to provide electricity to his village in Malawi, despite being 15 years old and self-educated after middle school [25]. DIY disaster-relief was famously highlighted in blogs and tumblrs about "Thai Flood Hacks" that proliferated during the massive floods of Fall 2011 [8, 9]. Though this was a tragic event that killed hundreds and left thousands out of work, the makeshift boats, pet life preservers, and elevated vehicles revealed a sense of whimsy even in coping with a natural disaster. An eminently practical project from the King Mongkut Institute of Technology – a floating device meant to save lives by detecting current from submerged electronic devices – was topped with rubber ducks for no apparent practical purpose (Figure 1). These "flood hacks" took place against a backdrop of everyday DIY, such as the small businesses that unlock mobile phones or the carpenters at Bangkok's port who make furniture from discarded shipping palettes. Such hackery allows craftspeople to earn a living in a way that lets them control their schedule, express creativity, and maintain a sense of dignity. More deeply than that, it embodies a tradition of work that intrinsically includes elements of fun, sociality, and communal effort. Agricultural work in Thailand is still characterized by a vibrant sociality and loose schedule as well as hard physical labor. Workers who take "modern" urban service jobs have financial incentives to adhere to a dualism of work and play [10], but that does not mean they perceive it as natural, that they like it, or that they cannot conceive of alternative configurations [43]. In fact, the *separation* of work and play is remarkable, in contrast to a perception prevalent in North America that finds "productive leisure" noteworthy because it appears to constitute a contradiction in terms.

Figure 1. Flood Ducks detect voltage in flooded homes.

Despite our perceptions of great differences between first and third world DIY, these Maker communities are converging, with Maker Faires now occurring in China, Africa, Chile, and India. We would argue that DIY in developed and developing nations is not altogether different to start with. Elements of play are evident in the Thai flood hacks, while an increasing number of North American Makers are attempting to make a living at it. At the Bay Area Maker Faire, hobbyist Makers mingle with startups selling 3D printers, electronics kits, and educational games. While locality and geography are certainly relevant factors for different DIY practices, we would suggest that their relevance is more complex than could be encompassed by the binary opposition of developed vs. developing regions. Access to venture capital for entrepreneurial Makers, for example, does not break down by continent, but in a much more local ways, where Makers in Bangkok may indeed have less access than those in Silicon Valley, but (due to variations in funders' expertise) Makers in Montreal have less direct access than some in Shenzhen.

From Hedonized to Democratized Computation

Documented hedonized computation dates back to the creation of the videogame *Spacewar!* in 1962. This form of technological play was available mostly to educated white males who, for example, might have access to MIT servers [17]. Now high technology is beginning to support its own democratization, with profound implications for the professional practices of HCI and system development.

The increasing corporate and governmental interest in the Maker movement provides one indicator that democratized technology is no longer solely about hedonism. Maker Faire Africa has attracted sponsorships from Microsoft, GE and Google; Maker Faire Bay Area has also been sponsored by GE and Google as well as Intel [36]. Although not listed as a sponsor of the Faire itself, DARPA awarded the Make organization a grant to further its educational programs, which has sparked controversy in the DIY community [15]. The Obama administration's funding of STEM education and a 3D printing research center, along with a notable hardware-based startup accelerator–"HAXLR8R"–based in Shenzhen and Silicon Valley [6], indicate that Maker culture has commercial value. Yet much of this commercial activity is rooted in democratized practice: the popularity of 3D printing was ignited by grassroots projects like RepRap, and HAXLR8R aims to make Shenzhen's manufacturing services available to small businesses and artists.

Democratization of creative practices now applies not only to knitting, car modding, and ham radio, but increasingly includes the technologies and practices that the HCI community deals with professionally: computer-aided design, programming, microcontrollers, mesh networks, tangible interaction, and mobile applications. It is deeply implicated in our professional practices as HCI researchers.

ELEMENTS OF DEMOCRATIZED PRACTICE

We see the democratization of technology as bound together in shared practices across a wide range of social contexts. We explore how practitioners rely on playfulness with technology and critically examine the role of tools, infrastructures, and knowledge sharing in DIY practices.

Playfulness

Playful inventions

Critical engagement with technology is often characterized by a sense of play around technological norms. This was especially evident to us when interacting with Steampunk practitioners, who often use obsolete and appropriated materials to create improbable fictional technology designs that combine high-tech and Victorian sensibilities.

One example is the CELL (Compact Electromagnetic Linguistic Launcher): the creation of Aaron, a professional programmer and Steampunk enthusiast (Figure 2). The CELL consists of a wooden box core with a porthole displaying Edison bulbs, brass gears, and clockwork. On the side, a piston rotates and animates the machine, while an antenna and key are set on the top. Two copper cables follow Aaron's arm to reach a telegraph key used to type messages, which illuminates the porthole to signify the message has been sent. Asked about his motivations for designing this, Aaron explained:

Figure 2. Aaron wearing the CELL on his back.

> "The idea was to recreate a mobile device for communicating, this is also in reaction to the fact that today everyone has a cellphone, but this was unimaginable in that era. I wanted people to react and realize what technology we have today. I also make the joke that I only created one machine, so I can't communicate with anyone now. This is the ironic and funny side."

To complement this contraption, Aaron also created its fictional inventor: Baron Celsius von Fahrenheit. This use of ironic humor and historical winking at the present is common in Steampunk practice. As discussed above, however, playful hacking is not limited to the Steampunk movement, nor is it necessarily isolated from utility. Like the Flood Ducks, these are playful acts of appropriation. Conversely, several Steampunk practitioners at the Bay Area Maker Faire sold their creations commercially.

Embodied Cultural Imagination

Maker and DIY cultures use artifacts to explore a new present and future of design, fabrication, and consumption. These designs often embody cultural imaginations, engaging in the relatively recently articulated concept of *design fiction* [7, 16]. Bleecker presents design fiction as a

> "…conflation of design, science fact, and science fiction. It is an amalgamation of practices that together bends the expectations as to what each does on its own and ties them together into something new. It is a way of materializing ideas and speculations without the pragmatic curtailing that often happens when dead weights are fastened to the imagination." [7]

Design fictions aim at creating conversational pieces that aid discussions on how this imagined future would look, feel, and be lived in; it is a technique for reflecting on what technology we should, or should not, design. The Steam-punk movement centers on a design fiction that re-imagines a world inspired by the Victorian era but technologically similar to modern times. This fictional starting point guides the decisions of individual practitioners as they create costumes, props, and machinery that are unique to them but also part of a larger shared world [44].

Other Maker and hacker cultures also offer an imagined vision of what the world could be if personal and creative production of design artifacts was spread democratically across individual creators. Nostalgic movements like urban homesteading or needlework/knitting communities suggest a different way of approaching the future of food and textile production by revisiting past ways of making. In these cases, the potentially abstract envisioning of a different past or future is supported by the physical practice of making. By contrast, China's Maker and hackerspace community might be described as forward-looking (though rooted in existing practices of scrappy, resourceful *shanzhai* manufacturing), embodying a practice in which material creation is intrinsically bound up with a vision of China's future as a hub of creativity as well as fabrication [30]. What is envisioned and created by one person becomes part of the discourse around these shared visions, supporting and complementing the inventions of others. Collectively, subculture members create a common vision of what that subculture is, and how the practice of making fits in.

Material Aesthetics

Steampunk practitioners are motivated by embodied pleasures of working with historical materials. The physical act of using their own hands to create something is a source of pride and satisfaction. Aaron explains that it was the aesthetic aspect of Steampunk that caught his interest at first, but it is the physical engagement with his machines and costumes that keeps him hooked on the practice today.

Scavenging raw materials from surplus stores, garage sales, and flea markets is an essential part of Steampunk practice. Many enthusiasts accumulate large collections of objects in brass, wood, and leather, allowing for serendipitous finds and playful combinations, fostering creative making and remaking through exploratory bricolage. Adrian, a professional prop maker and a Steampunk practitioner, describes his ideation process as starting with sitting and pondering items on his workbench (Figure 3).

Figure 3. Adrian's workbench

The importance of materials in the process of making for Steampunk echoes Rosner's proposition that materials have agency and influence the design process. She notes that

> "…materials have a 'say' in the process. The materials tell us they are not passively confined to the things made from them but have their own propensities for mixing, mutating, swelling or shrinking. In this sense, materials are not imbued with agency but exhibit agency by rising above other material activity…. This suggests we consider how digital materials have an equal say in work practices, and how our interactions sometimes preclude listening." [41]

In a study of techniques and values of master craftspeople, Bardzell et al [5] reiterate the importance of embodied practice with materials, as well as the sorts of material-driven explorations that often motivate democratized technical practices. Though atoms and bits are frequently contrasted in HCI discourse as being, respectively, immaterial and material [24], our interviews with programmers reveal that they consider the *material properties* of the languages they work with, much as a crafter might select yarn of appropriate weight and texture for a particular garment. Gilles, who programs professionally and for fun, says:

> "C++ is my favorite, it's the one that I use when I program on my own. What I often do, is I use C++ to code the low-level stuff, and I mix that with some high-level programming language like Javascript or Lua…if you're making a game you can have your graphics engine and your physics engine, they're probably not going to change, but then when you want to add new things to the game, new objects and behaviors and stuff like that, you can do that without changing those things. So I do that in scripts."

Some of these decisions are deeply personal–one might simply enjoy C++ more than Java. Specifically, Gilles distinguished between languages he chose for his own enjoyment and less-preferred languages like C# and Java that he used for collaborative projects. Other considerations also matter: how much control does the language give over low-level functions, where does speed matter (e.g. graphics rendering), which aspects of the program are unlikely to change frequently (e.g. the database), and which will need to change quickly and frequently (e.g. interface elements)? As is often true of craftspeople, experienced programmers have a deep knowledge of what tasks are made easy or difficult by different languages, tools, or materials.

Tools for Production

Along with a focus on materials comes a focus on the tools used to work these materials. When concern for the end product is secondary to or balanced against a concern for the pleasures of production, the tools of creation need to satisfy different criteria than they would in industrial or professional production. A straightforward example is the resurgence in the use of wooden knitting needles as hobbyist needlework became widespread in North America. Though steel knitting needles are durable and allow the knitter to work faster, making it a superior choice for professional production, they simply "do not feel as good in the hands" as wooden needles [31]. This previously obsolete tool gained popularity with hobbyist knitters because it fulfilled a desire for pleasure in production. But it was the democratization of this hobby that ensured enough demand to support a *market* for these new-old tools.

In the digital realm, tools also range from professional and efficient to easy-to-learn software that might be more pleasurable to use for amateurs. The C++ language is well-suited for scalable professional programming that demands fast processing times and efficient memory use, and indeed, many experienced programmers like Gilles find pleasure in it. Its relative difficulty, however, puts up barriers to entry for hobbyist programmers without formal training. Programming in C++ is optimized to create a sleek and efficient end product rather than ease of learning or instant creative gratification. The Processing environment, by contrast, has a low barrier to entry as a free download with extensive online tutorials and examples[19]. It allows quick cycling between code and visual output so that programming interactivity is especially fluid. Intended for educational and recreational purposes, it is now used for professional work in cases where innovative interaction design is the focus rather than speed or scalability.

In the production of material goods, industrial methods for mass production have typically focused on techniques like injection molding, die cutting, and vacuum forming, which present a high fixed cost for creating an initial template, and low marginal costs for stamping out many identical objects. In contrast, methods like 3D printing present a low fixed cost, allowing users to create one-offs or small batches of plastic creations. While it is possible to create DIY vacuum formers, it is the 3D printer that has exploded among hobbyists and small businesses, with Makerbot alone selling about 8000 printers since 2009 [13]. Even amongst 3D printers, there are differences between hobbyist and industrial machines that respectively emphasize ease of production and affordability, against quality of final product. The increased availability of both low and high-end printers has helped to drive their proliferation.

Industrial Infrastructures

As a result of the industrial revolution, many materials and products are standardized to support interoperability. Local and individual solutions often rely on these standards to mix and match products as well as to share solutions and strategies with other practitioners.

Materials

Ikea hacking has previously been studied in HCI as a way to highlight “skilled, creative reuse and customization” of mass-produced products [42]. Ikea hackers from around the world use Ikea products as resources for creating new combinations of items or transforming products to better fit their local needs. These Makers then share their products and processes with others online. Rosner and Bean contend that it is the *standardization* of Ikea products that supports this community of shared hacks by facilitating the re-creation of projects shared on the Ikea Hacks website [42].

A recent article in MakeShift magazine also describes how “technological disobedience” stemmed from a period of rationing and shortage in Cuba [37]. In the 1970s, many Cubans repurposed a limited set of broadly distributed and uniform brands in order to solve common problems, leading to repeatable solutions. For example, a kerosene lamp was built with “a cylindrical glass container–13 cm high and wide–and inside, dipped in kerosene, a wick holder made from a tube of toothpaste…This transformed Cuba’s most recognizable container into its most common kerosene lamp” [37]. Both Ikea hacking and Cuban technological disobedience show that standardized resources can be an opportunity for Makers to create personal solutions that can be shared and reproduced within a community, originating either from necessity or pleasure.

Standards

Though hacking and craft are often intended to create personalized objects, their practice is often supported by the mass production and ubiquitous availability of standardized materials and infrastructures. Standardization creates conditions favorable to knowledge-sharing; instructions are easier to follow if the learner has access to the same materials, tools, and measurements as the instructor. This was evident as far back as the 1850s, when standardized apparel sizes facilitated Butterick’s first publications of home sewing patterns [31]. By the 1900s the standardization of needle gauges, yarn thickness, and stitch abbreviations gave hobbyist knitters greater access to each other’s patterns, captured in mass-market publications [31].

The ZigBee standard for personal area networks presents a contemporary and computational example of standards in action. The ZigBee standard defines communication protocols for low-cost, low-power, low-data-rate ad-hoc mesh networks, maintained by companies that manufacture hardware for wireless sensor networking. Because this standard supports low-cost radio design and allows users to program devices at a high level (focusing on application design rather than, say, routing protocols), it has facilitated the creation of cheap and accessible hardware for hacking together ad-hoc networks for domestic sensing or inter-active clothing. Digi International’s Xbee, for example, costs $25, is configurable via a GUI, and presents users with a few default settings that work for many applications.

Standardization supports collaboration, interoperability and modularity but it can also stifle innovation, by ossifying into rigid practices that adapt poorly to new techniques and technologies. Maker communities must continually grapple with this “codification”. On the one hand, standardized platforms support the development of deep shared literacies and platforms for Making. On the other hand, investment in standardized platforms is fundamentally conservative: it leads to a convergence of practices similar to what happened in the first Industrial Revolution. Even as Maker communities adopt their own internal standards, new sources of authority are established or reified by the community. The technologies that Making depends upon potentially extend existing systems of authority, while also empowering new voices to power: a difficult paradox for a community that deeply values independence.

Knowledge sharing

Personal initiatives and new uses for tools and materials from around the world are shared through online and offline communities and events. Previous research in HCI has looked at sharing in DIY communities, including [28, 46, 48]. The use of rich media such as high resolution images, videos, and step-by-step descriptions facilitates distributed craft knowledge sharing [28]. For example, the Youtube channel ExpertVillage pulls together experts who demonstrate, via high definition video, skills like knitting, using power tools, and electronics [1]. The clear quality of the visuals enables the viewer to learn important details of the making process. Similarly, Instructables allows high-resolution photos of step-by-step circuit assembly to sit beside more abstract circuit diagrams yielding a richer environment for practice-based learning by example [26].

In addition to online structures for sharing, physical spaces like hackerspaces and Fab Labs allow practitioners to learn from one another, collaborate, and share projects. One of our informants, Adrian, shared that he likes going to hackerspaces especially when he is missing a tool, needs advice, or simply to share his extensive knowledge of fabrication techniques with others. Like other Makers [48], he mentions that helping others also helps him learn and master his craft. While most hackerspaces schedule a weekly open-house, some, such as Shanghai's XinCheJian, explicitly schedule presentations and demos to educate members and the public. Conventions and Maker Faires also provide opportunities to meet other Makers, show off projects, and exchange information on ways of making. Beijing's first Maker Carnival, which one of the authors attended in April 2012, included accessible workshops on toy hacking, conductive dough, Arduino for beginners, DIY musical instruments, and learning how to solder.

Literacies

In order to share knowledge and instructions effectively, the audience must be assumed to possess certain underlying capabilities and literacies, or those literacies must be cultivated. One of the authors of this paper owns a decades-old book of banjo music that includes 20 pages on building one's own banjo. These instructions assume that the reader has a well-equipped woodshop and the ability to cut curves accurately on a bandsaw. Make Magazine's considerably simpler instructions on how to create a cigar-box guitar are probably more appropriate for a contemporary audience [32]. However, as discussed previously, rich media allows us to bootstrap the audience's knowledge, creating the literacies needed to read and act on instructions, diagrams, patterns and blueprints. The printing and widespread distribution of pattern books with clear photographs helped create literacy in knitting pattern notation and the resurgence of nearly-lost traditional patterns [31]. Similarly, forums for Arduino and Processing allow experienced users to cultivate the literacies that new users need to effectively use these systems, and Instructables' store sells several products for which its instructions might generate demand.

DISCUSSION

Our examples of democratized technological practice demonstrate how Maker cultures challenge traditional conceptions of the technology user. The dominant paradigm of user-as-consumer gives way to alternative framings of the user as creative appropriator, hacker, tinkerer, artist, and even co-designer or co-engineer. These behaviors, taken as part of a broader movement, begin to form a politics of appropriation. The Makers described here draw on cutting-edge CAD and CNC manufacturing to critique the outcomes of industrial practices. Yet they also rely on industrial infrastructure to provide them with the tools and raw materials that fuel their practice. This tension creates an area of simultaneous participation, critique, and resistance.

As well as shifting the notion of the user from consumer to appropriator, these practices shift us from considering technology use as primarily a productive or useful experience to an aesthetic experience as well. From the copper cables of CELL to the feel of wooden needles, form and materiality come to the forefront. Functionality plays a role, but it is leavened with aesthetic explorations as well. This relationship to technology is characterized by a spirit of playfulness combined with a commitment to critical resistance and material creation, both challenging and celebrating the current conditions of technical production.

Returning to McLuhan's framework, we can now apply it to the democratizating practices of the Maker and DIY communities. First, these practices *enhance* the ability to create personal, contextually relevant technical artifacts using the advances of the industrial revolution in tandem with both traditional and new methods. They *obsolesce* the notion of the "consumer" as a passive receptor of "products" defined by their function. They *retrieve* areas of knowledge and practice that are not universally necessary in the industrial age (personal food production, hand-craftsmanship, understanding the inner workings of machines), but that bring people pleasure and purpose to know. Finally, these practices have the potential to *reverse* into a loss of regulation of dangerous technology: a scenario that is already the subject of significant debate as individuals begin 3D printing working firearms [21].

Politics of Democratized Technology

We contend that DIY practice is a form of nonviolent resistance: a collection of personal revolts against the hegemonic structures of mass production in the industrialized world. The fact that Makers rely upon these same structures to engage in and disseminate these practices complicates, but does not negate, their revolutionary nature.

Unlike many other forms of nonviolent resistance, however, the DIY revolution has managed to avoid drawing negative attention from the system that it seeks to transform. The DIY revolution is *nonthreatening* in a way that makes it effective at spreading its values to people who might otherwise avoid taking a political stance. Consider that the Occupy Wall Street movement was often met with armed response from local law enforcement agencies toward mostly nonviolent protesters[35]. Maker Faire, by contrast, has controversially accepted funding from DARPA, the research branch of the US Department of Defense [14]. Where OWS prompted militaristic *opposition*, some aspects of Maker culture appear in danger of being *coopted* by the military. This recent development has presented the DIY community with its first political crisis, prompting public withdrawals from Maker Faires and critical discussion within the community [15]. The issues posed by the channeling of defense spending into a movement whose practices often challenge military and industrial structures is directing DIY community discourse, such as Garnet Hertz's 'zine on Critical Making [22]. The zine itself was created explicitly because authoritative publications in the DIY community, such as MAKE magazine, did not provide a venue for "political" topics such as hackerspaces in China or DARPA's funding of Maker Faire. While publications such as MAKE attempt to remain ostensibly apolitical, this stance is increasingly being challenged as untenable.

Challenges for Democratized Technology

Much of the writing around DIY and Maker practices is unabashedly celebratory in nature. The Economist article entitled "The Third Industrial Revolution" [45] makes wide-eyed proclamations about the impact that 3D printing will have on traditional modes of production and distribution. While increased access to fabrication technology is indeed enabling an explosion in both hobbyist and entrepreneurial experimentation, there is also a growing awareness of the difficulties facing these new enterprises when they attempt to participate in more established economies, especially when it comes to scaling up production and distribution. While we are witnessing significant advances in the democratization of *production*, the infrastructures of warehousing, transport, and distribution remain tooled for traditional business models. One place where this is becoming apparent is in the Kickstarter community, where successfully funded ventures often encounter significant hurdles in fulfillment. These include, but are not limited to, conflicts around intellectual property, difficulties meeting unexpected production demands, unexpected tax burdens and other legal and economic hurdles [18]. These difficulties are currently the exception rather than the rule: proportionately few Makers have the means or the interest to scale up their practice to the point where they have to deal with warehousing, distribution, and logistics. However, the challenges faced by the "lucky few" highlight how ill-equipped some of our current infrastructure is to accommodate this "Third Industrial Revolution". One of the exceptions to this is in the digital sphere, where global networks have negated most of the traditional spatial barriers to physical distribution. The success of online code repositories and digital distribution of software and media provides some insight into one potential future where 3D printing technology acts as a point of interface between the digital and material worlds. In this highly science-fictional view of the future, home replication technology could do for material goods what digital distribution is currently doing for media. It is also important to recognize how much these democratized practices depend on existing industrial infrastructure. In the first industrial revolution, a vast new techno-social apparatus allowed many industries to discard previous modes of production; this is not yet the case in the DIY revolution. Without our current economies of scale, few of the hackers and tinkerers engaged in the Maker movement would have access to the raw materials or literacies that are driving these practices. Enabling platforms and protocols like the Arduino microcontroller rely on the mass production of electronic components to keep the cost of parts within reach of the casual hobbyist.

CONCLUSIONS

Implications for Design

The social and interactive technologies that HCI creates and studies have enabled the democratization of digital technologies discussed here. The creation of innovative software, new interactions, and physical prototypes is no longer restricted to well-funded professional designers and researchers. Are we about to become obsolete? Or are we on the cusp of a new family of design opportunities and a reimagined relationship with users? Here we suggest what some of these new opportunities might be.

Design to Enable Creativity

As discussed in the previous section, creative hacks are often supported by inexpensive, standardized materials (e.g. IKEA furniture) and by standards themselves (e.g. ZigBee, needle gauges). This suggests a role for institutional research and development that will continue to thrive; the creation of infrastructures to support individual and community creativity requires an investment of time and resources that these individuals and communities are often hard-pressed to contribute on their own. Some of the most successful platforms in the DIY world have emerged from universities: Processing, developed at MIT [19]; Arduino, from Ivrea and NYU's Interactive Telecommunications Program [27]; and the Lilypad Arduino, developed at CU Boulder [11]. 123D, a widely-used modeling application for consumer 3D printing, emerged from Autodesk. These platforms coexist with others, like Instructables [3], RepRap and Raspberry Pi [47], developed initially by startups, nonprofits, and open collaborations. We would suggest, then, that efforts in HCI to develop platforms, knowledge-sharing mechanisms, and tools would be a fruitful way to engage with a growing demographic of users who are not content to consume, but wish to customize, remix, and design for themselves. For researchers and designers of distributed, collaborative systems in particular, finding solutions in storage and distribution to match the dynamism of on-demand manufacturing for entrepreneurs remains a substantial challenge. For users who choose to create for pleasure, and who take pride in craftsmanship, tools and platforms may need to support productivity in different ways than they would in professional contexts. Efficiency and power may not be the most important concerns, with users seeking out tools that are pleasant to use and foster a connection with their materials.

Design for Pleasure, Utility, and Expressiveness

From our discussion of democratized practice, we can distill several core concerns behind peoples' engagement with DIY and craft. In the practices of playfulness and material engagement, we can find an underlying concern with *pleasure*. With the increased participation of small businesses in Maker events, and the discourse around DIY in developing nations, we foreground *utility*. Lastly, the personalization of consumer products, and the critiques and imaginings embedded in many crafted artifacts, point to the importance of *expressiveness* in Maker practices. Maker practice often addresses these concerns simultaneously, questioning widespread understandings of the dichotomy between work and leisure. We will find ourselves designing more for this expanding demographic who wish to do more than just consume; who wish to personalize and design themselves. In so doing, we should consider these core goals of pleasure, utility, and expressiveness, seeking to understand the ways that they may augment and detract from one another. Each individual and group will ultimately decide how to balance these three concerns.

Design for Mixed Manufacture

Excellent designs are concerned not only with their ultimate use, but also with their whole supply chain: how they will be manufactured, stored, and distributed, which materials will go into making them. Known for creating classic chairs that still appeal decades after they were designed, Charles and Ray Eames thought carefully about industrial capabilities to shape molded plywood, manufacturing chairs that not only fit human bodies, but also stacked well. With the democratization of abilities to manufacture and create, such as 3D printing, CNC milling, sensor networks, programming, and interactive hardware, we are now faced with the opportunity to design for entirely new ways of making and distributing our technologies. We can now consider, carefully, what mass production buys us (e.g. uniformity, economies of scale, reliability) against the benefits and drawbacks of batch and personal production (e.g. local manufacturing that is more in touch with end users, personalization, unpredictability, lower transport costs). We should design to take advantage of the means of production that best suit our design goals and realize that different parts of even the same project or artifact may be best produced in very different ways.

Democratized Technological Practice and HCI

In this paper we have marshaled data and observations from a wide range of sources to advance the understanding of DIY and Maker practices as a form of revolutionary democratic material culture. Democratized technological practice entails, for designers, a new set of strategies to facilitate creativity and support pleasurable, useful, and expressive engagement with technology. We have observed the emergence of democratized practices within vernacular communities of hackers, crafters, Steampunks, hobbyists, and entrepreneurs. We have approached these communities not just as HCI researchers but as fellow practitioners. The innovation and critical engagement with technology that we have observed and participated in within these communities are not so different from the practices encountered in a contemporary HCI laboratory. Critical explorations of Maker communities can shine a light on our own formal scholarly practices, revealing that our research is also situated within a context of values, ethics, and politics. Moving forward, HCI research cannot ignore the social and critical implications of technology and design research, but must engage in the questions raised by democratized technological practice. What are the aesthetic consequences of a technology? How does a design reflect a position on materiality or sustainability? How do we express ourselves through technology? How is the lifecycle of a technology implicated in larger social and political systems? These types of questions invite us to embrace the humanist implications of human computer interaction, and to look outside our laboratories for the future of the field.

REFERENCES

1. . *Expert Villiage*.Retrieved from http://www.youtube.com/user/expertvillage on September 14, 2012
2. . *Reprap*.Retrieved from http://reprap.org/wiki/RepRap on January 13, 2013
3. Anderson, C. (2010). In the Next Industrial Revolution, Atoms Are the New Bits. *Wired*, 18, 2.
4. Anderson, N. (1961). *Work and Leisure*. Routledge, London.
5. Bardzell, S., Rosner, D. K. and Bardzell, J. (2012). Crafting Quality in Design. *Proc. DIS'12* 11-20
6. Bilton, N. and Markoff, J. (2012). *A Hardware Renaissance in Silicon Valley*.Retrieved from http://www.nytimes.com/2012/08/26/technology/silicon-valleys-hardware-renaissance.html on September 14, 2012
7. Bleeker, J. (2009). *Design Fiction*.Retrieved from http://www.nearfuturelaboratory.com/2009/03/17/design-fiction-a-short-essay-on-design-science-fact-and-fiction/ on September 2, 2011
8. Bogost, I. (2006). *Wii's Revolution Is in the Past*.Retrieved from http://seriousgamessource.com/features/feature_112806_wii_1.php on July 22, 2008
9. Bojin, N. (2008). The Way Wii Were: A Blogosphere Retrospective. *Loading - The Journal of the Canadian Games Studies Association*, 1, 2.

10. Brody, A. (2006). The Cleaners You Aren't Meant to See. *Antipode*, 38, 3, 534-556.
11. Buechley, L., Eisenberg, M., Catchen, J. and Crockett, A. (2008). The Lilypad Arduino. *Proc. CHI'08* 423-432
12. Buechley, L., Rosner, D. K., Paulos, E. and Williams, A. (2009). Workshop: Diy for Chi. *Proc. CHI'09 Extended Abstracts* 4823-4826.
13. Colao, J. J. (2012). *Makerbot: 3-D Printing for Your Living Room*. Forbes.Retrieved from http://www.forbes.com/sites/jjcolao/2012/06/06/makerbot-3-d-printing-for-your-living-room/ on September 13, 2012
14. Dougherty, D. (2012). *Darpa Mentor Award to Bring Making to Education*. O'Reilly.Retrieved from http://blog.makezine.com/2012/01/19/darpa-mentor-award-to-bring-making-to-education/ on September 13, 2012
15. Dougherty, D. (2012). *Makerspaces in Education and Darpa*. O'Reilly.Retrieved from http://blog.makezine.com/2012/04/04/makerspaces-in-education-and-darpa/ on September 13, 2012
16. Dourish, P. and Bell, G. (to appear). "Resistance Is Futile": Reading Science Fiction Alongside Ubiquitous Computing. *Pers. Ubiq. Comput.*
17. Dovey, J. and Kennedy, H. W. (2006). *Game Cultures*. Open University Press.
18. Downs, D. (2012). *5 Kickstarter Projects Slammed with Success*. Wired.Retrieved from http://www.wired.com/design/2012/07/st_kickstarter/?pid=695 on September 13, 2012
19. Fry, B. and Reas, C. (2012). *Processing*.Retrieved from http://processing.org/ on September 13, 2012
20. Gelber, S. (1999). *Hobbies*. Columbia University Press, New York, NY.
21. Greenberg, A. (2012). *'Wiki Weapon Project' Aims to Create a Gun Anyone Can 3-D Print at Home*. Forbes.Retrieved from http://www.forbes.com/sites/andygreenberg/2012/08/23/wiki-weapon-project-aims-to-create-a-gun-anyone-can-3d-print-at-home/ on September 14, 2012
22. Hertz, G. (2012). *Critical Making*.Retrieved from http://www.conceptlab.com/criticalmaking/ on September 13, 2012
23. Innis, H. A. (1991). *The Bias of Communication*. University of Toronto Press, Toronto, ON.
24. Ishii, H. and Ullmer, B. (1997). Tangible Bits. *Proc. CHI'97* 234-241
25. Kamkwamba, W. (2009). *The Boy Who Harnessed the Wind*. William Morrow.
26. Krahulik, M. and Holkins, J. (2006). *Penny Arcade*.Retrieved from http://www.penny-arcade.com/comic/2006/11/13/ on october 6th, 2008
27. Kushner, D. (2011). *The Making of Arduino*. IEEE.Retrieved from http://spectrum.ieee.org/geek-life/hands-on/the-making-of-arduino/0 on September 13, 2012
28. Kuznetsov, S. and Paulos, E. (2010). Rise of the Expert Amateur. *Proc. NordiCHI'10* 295-304
29. Levy, P. (1999). *Collective Intelligence*. Basic Books.
30. Lindtner, S. and Li, D. (2012). Created in China: The Makings of China's Hackerspace Community. *Interactions*, 19, 6 (November 2012), 18-22.
31. Maines, R. P. (2009). *Hedonizing Technologies*. The Johns Hopkins University Press, Baltimor, MA.
32. Make Magazine. (2012). *Special Edition: School's Out! Summer Fun Guide*. O'Reilly.Retrieved from http://www.makershed.com/category_s/214.htm on September 14, 2012
33. Mcluhan, M. and Mcluhan, E. (1992). *Laws of Media*. University of Toronto Press, Toronto, ON.
34. Mota, C. (2011). The Rise of Personal Fabrication. *Proc. C&C'11* 279-287
35. Moynihan, C. (2012). *Scores Cuffed or Cited by End of Day of Demonstrations*. The New York Times.Retrieved from http://cityroom.blogs.nytimes.com/2012/05/02/scores-cuffed-or-cited-by-end-of-day-of-demonstrations/ on September 13, 2012
36. O'reilly Media. (2012). *Maker Faire*.Retrieved from http://makerfaire.com on September 13, 2012
37. Oroza, E. (2012). Technological Disobedience. *Make Shift - A Journal of Hidden Creativity*, 1, 3, 50-53.
38. Owen, W. (2012). *Hillsboro's Girls Get It Camp Introduces Sciene, Technology, and Engineering to Girls*. The Oregonian.Retrieved from http://www.oregonlive.com/hillsboro/index.ssf/2012/07/hillsboros_girls_get_it_camp_i.html on September 13, 2012
39. Paulos, E., Honicky, R. J. and Hooker, B. (2008). *Citizen Science*.In Handbook of Research on Urban Informatics, M. Foth, eds. IGI Global, Hershey, PA
40. Ratto, M. (2011). Critical Making. *The Information Society*, 27, 4.
41. Rosner, D. K. (2012). The Material Practices of Collaboration. *Proc. CSCW'12* 1155-1164
42. Rosner, D. K. and Bean, J. (2009). Learning from Ikea Hacking. *Proc. CHI'09* 419-422
43. Scott, J. (1985). *Weapons of the Weak*. Yale University Press.
44. Tanenbaum, J., Tanenbaum, K. and Wakkary, R. (2012). Steampunk as Design Fiction. *Proc. CHI'12* 1583-1592
45. The Economist. (2012). *The Third Industrial Revolution*.Retrieved from http://www.economist.com/node/21553017 on September 13, 2012
46. Torrey, C., Churchill, E. F. and Mcdonald, D. W. (2009). Learning How. *Proc. CHI'09* 1371-1380
47. Upton, L. (2012). *Raspberry Pi*.Retrieved from http://www.raspberrypi.org/ on September 14, 2012

Wang, T. and Kaye, J. J. (2011). Inventive Leisure Practices. *Proc. CHI'11* 263-272