DEMOCRATISING TECHNOLOGY: THE CONFLUENCE OF MAKERS AND GRASSROOT INNOVATORS

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ABSTRACT:

The global "Maker Movement" is a trend toward the democratization of technology by means of do-it-yourself culture, open-source sharing, and small scale manufacturing. Related initiatives include community workshops such as makerspaces and Fab Labs, giant Maker Faire festivals worldwide, and support for new inventions (and their inventors) through entrepreneurial competitions and activities. This movement has attracted significant media attention and interest from educators, multinational corporations, and national governments.

Although informal sector activities often overlap with do-it-yourself culture, our research indicates that many "Maker" initiatives in developing countries have ignored existing grassroots innovators– often in favour of top-down policies that supplant existing initiatives while attempting to target similar users. This paper discusses how the present lack of integration between Maker initiatives and the informal sector can be a form of neo-colonialism; in addition, the popularity of creating new community workshops detracts from the support available for existing grassroots facilities and industrial clusters. Due to the lack of cross-sector collaboration, contributions from grassroot artisans to the global Maker discussion remain limited and underappreciated.

This paper details how the global Maker Movement attracts elite actors, who ironically celebrate the methods and frugal creativity of grassroots innovators while ignoring the informal sector. There lacks a collaborative effort to incorporate grassroots innovators in spurring local technological development and creating opportunities for bottom-up innovation. This would require targeted initiatives to tap into the local skill and expertise from the informal sector, in addition to their deep understanding of the local markets for the goods and services that they provide.

The paper identifies successful international collaborations with the informal sector, with a particular focus on the Ghana Intermediate Technology Transfer Unit in the 1980s. The authors use exploratory and case study research methods to discuss how these interventions succeeded and provide recommendations for future Maker initiatives that embrace grassroots innovators. The paper concludes that further connections between Makers and grassroot artisans would provide new employment opportunities for the grassroots while validating those in the Maker Movement who possess globally-relevant technologies but lack the socio-political background necessary for impact.

Keywords: Community-based workshops; digital fabrication; grassroots; inclusivity; informal sector; innovation; job creation; education; Africa.

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Introduction

Globally, the "Maker Movement" has attracted significant media attention and interest from educators, national governments, and multinational corporations (including GE, Intel, Cognizant, Microsoft, and Godrej Group) who hope to stay ahead of what has often been termed the "new industrial revolution" (Anderson, 2012). The idea of a "Maker Movement" was popularized by the United States-based platform Maker Media, and refers to a rapidly-growing trend toward the "democratization of design, engineering, fabrication and education" (Artisans Asylum, 2014) by means of do-it-yourself culture, open-source sharing, and small-scale manufacturing and production. "Maker" initiatives include community workshops, events such as Maker Faires and similar festivals worldwide, and support for new inventions (and their inventors) through entrepreneurial competitions and activities; Lipson and Kurman (2013) name several topics involved in the Maker ethos: "community, creativity, social change, and problem solving."

We use the generic term "makerspace" to describe all community workspaces, including hackerspaces, fab labs, invention labs, and tech hubs that incorporate some aspect of new technology; we use the term Maker to signify anyone who participates in either physical or virtual makerspace communities. We employ the general definition by Maker Media and the Artisan's Asylum makerspace in Boston, USA (2014): "Makerspaces combine manufacturing equipment, community, and education for the purposes of enabling community members to design, prototype and create manufactured works that wouldn't be possible to create with the resources available to individuals working alone."

Officially, "Fab Labs" are a brand of makerspaces affiliated with the Massachusetts Institute of Technology and consisting of 440 spaces across over 60 countries (Fab Lab Network, 2014). All formally-recognized Fab Labs fulfil the following criteria (Fab Foundation, 2013):

1. *A Fab Lab must be open to the public for free or in-kind service/barter*
2. *Fab Labs support and subscribe to the Fab Lab charter.*
3. *Fab Labs share a common set of tools and processes... [at minimum] a laser cutter for 3D design and fabrication, a high precision milling machine for making circuits and moulds for casting, a vinyl cutter for making flexible circuits and crafts, a fairly sophisticated electronics workbench for prototyping circuits and programming microcontrollers*
4. *Fab Labs must participate in the larger, global Fab Lab network.*
5. *Fab Labs must be verified by a well-established fab lab before joining the network.*

Figure 1: typical fab lab in Vestmannaeyjar, Iceland (Fab Lab Network, 2014)

This paper explores interactions between the global Maker Movement and grassroot artisans with a focus on Kenya, Uganda, and Ghana, drawing upon exploratory and case study research methods in addition to the authors' extensive personal experience among both Makers and grassroot artisans. We discuss how makerspaces tend to attract elite actors, who ironically celebrate the methods and frugal creativity of grassroots innovators while ignoring the actual informal sector, and finally we offer recommendations for future collaborations.

The authors are all participants within the modern Maker and/or Appropriate Technology communities, and information gathered from our original research comes from events and conferences as well as informal discussions with our peers.

Impact of the Maker Movement

Makers worldwide are starting new cottage industries to sell their wares at a grassroots level; their products generally consist of artisanal crafts, household gadgets, and/or tools for other Makers. Crowdfunding and online marketplaces provide essential services to the maker movement, by allowing inventors to rapidly raise funds from their peers for small-scale production (Deloitte and Maker Media, 2014). In 2013, the world's crowdfunding sites reached close to $5 billion in transactions (Drake, 2013). Etsy.com is a marketplace for Makers to sell their creations, and its user base now consists of 15 million artisans across more than 150 countries, with 690,000 new members joining each month (Atmel, 2014). The scale of the global Maker Movement amounts to millions of (mostly part-time) Makers across tens of thousands of makerspaces and household workshops. Popular Maker technologies include the low-cost desktop 3D printer, of which 56,507 units were sold worldwide in 2013, and the programmable microprocessor Arduino, of which over a million boards have been sold worldwide (Atmel, 2014).

Today's global Maker Movement bears similarities to both the early 20th-century Arts and Crafts movement in the United States (Morozov, 2014) and the international Appropriate Technology movement in the 1970's, which was heavily inspired by Mahatma Gandhi's philosophy of independent, self-sufficient communities. The modern Maker Movement has been bolstered by technological advances in digital fabrication that make advanced manufacturing affordable to grassroots actors, and the popularity of Maker Faires has grown at an exponential rate for the past decade (Deloitte and Maker Media, 2014). The United States government held a White House Maker Faire in March, and national Maker policies are also being discussed by government officials in Kerala (India), Barcelona (Spain), the United Kingdom, Russia, Nigeria, South Africa, Peru, Iceland, Taiwan, and Shanghai (China), among others (Fab Lab Network, 2014). Barcelona will become the world's first Fab City, with a prospective fab lab in each of its 10 districts. Iceland considers itself the world's first "Fab Country," with one fab lab per every 75,000 citizens (FAB10 Barcelona, 2014).

Maker Faire Africa is a separate entity from the U.S.-based Maker Faire franchise, which celebrates boldness and local, relevant invention in its Maker Manifesto (Maker Faire Africa, 2012):

1. *We will wait for no one.*
2. *We will make the things Africa needs.*
3. *We will see challenges as an opportunity to invent, and invention as a means to proving African ingenuity*

   ...

10. *We will remake Africa with our own hands.*

The World Bank, United Nations Development Programme, and several government-sponsored aid organizations (including USAID, JICA, European Union, and DFID) have adopted aspects of the Maker Movement into their international development policies. The World Bank issued a report (2013) advising the creation of fab labs throughout Bulgaria, claiming that this network "could have a catalytic impact on Bulgaria's development by spurring innovation and creating synergies among innovators." The report continues, "The global revolution in digital manufacturing has dramatically expanded access to industrial-grade digital fabrication technology, and is transforming the landscape of business models, value chains, and cross-border trade" (World Bank, 2013).

Revolutions in production and manufacturing are inherently politically-charged, a fact often ignored by those promoting the Maker Movement as a tool for industrial development. Morozov (2014) critiques Makers for their failure to politicize, citing this shortcoming as the downfall of the U.S. Arts and Crafts movement in the early 20th century. Smith (2014) comes to a similar conclusion, analysing a network of Appropriate Technology workshops in England in the 1980s: "A key lesson from this history is that radical aspirations invested in workshops, such as democratising technology, will need to connect to wider social mobilisations capable of bringing about reinforcing political, economic and institutional change. Otherwise, as we see in the case of Technology Networks, diminished versions of these ideas and practices will become captured and co-opted by incumbents."

maxigas and Troxler (2014) provide an even more critical perspective of the current Maker Movement, given its lack of coherent socio-political action and inflated rhetoric: "Of the four possible interpretations of Fab Lab and maker culture – bourgeois pass-time, innovation in education on technology, new renaissance reconciling liberal arts with science and engineering in a contemporary and playful way, and new industrial revolution– the practice appears to swither between the former two, while the latter two rhetorically complement the former, either romantically or rebelliously according to taste."

Our paper explores a historical precedent for an initiative toward the democratization of technology in Ghana (as part of a global Appropriate Technology movement), and we discuss the practical challenges of incorporating Maker technologies into grassroot artisanal communities. We agree that the Maker Movement has not lived up to its revolutionary hype among media and policy-makers. Yet, we conclude that further connections between Makers and grassroot artisans would provide new employment opportunities while validating those in the Maker Movement who possess globally-relevant technologies but lack the socio-political background necessary for impact.

Makers: Grassroot Innovators or Bourgeois Hobbyists?

The lack of formal or centralized operations within the Maker Movement is similar to the global grassroots industrial sector, which is defined by its lack of connection to established industries, corporations, and knowledge institutions. There is a growing trend among Makers to seek full-time employment or provide others with employment opportunities, which would increase the similarities and potential linkages between groups. Informal sector business provide around 72 per cent of all employment in Sub-Saharan Africa, 65 per cent in Asia, and 51 per cent in Latin America (ILO, 2002). This amounts to several billion people, although only a small fraction work with technology on a regular basis and, unlike Makers, very few grassroot artisans take advantage of modern electronic technologies.

Both the Maker and grassroot technological communities value economical "do-it-yourself" solutions, also known as "adhocism" or "hacking," which rely on available resources/expertise and employ pragmatic efficiency rather than extensive planning and professional quality. Maker advocates also emphasize that innovation can come from anyone, regardless of one's background, age, or level of education; Maker Faires profess to be meritocratic and all makerspaces are publicly-accessible. The Honeybee Network's Ahmedabad Declaration (2013) similarly recognizes ideas from the grassroots as worthwhile contributions: "Incubation of grassroots innovations and outstanding traditional knowledge in a distributed, decentralised and social democratic manner provides an opportunity to address global concern for providing solutions to persistent social problems."

Despite the similarities between movements, there have been few successful collaborations; as discussed here, the recent Maker Movement attracts predominantly well-educated hobbyists, whereas grassroots artisans tend to be informally educated and rely upon their artisanal practice as a primary source of income. Smith (2013) identifies "cultural tension" in a shared community workshop in London, United Kingdom in the 1980s "between professional and codified technical knowledge and the tacit knowledge and experiential expertise of community participants."

Participants portray the Maker Movement as inclusive, citing a popular quote from Maker Faire organizers, "everyone is a maker and our world is what we make it" (Maker Media, 2013); however, research indicated that the Maker Movement attracts mostly privileged participants. Buechley (2013) analysed every cover on the U.S.-based MAKE magazine since its first issue in 2005 and found that photos portrayed a "very narrow definition" of activities including electronics, hobbyist vehicles, and robots which would all be unfamiliar to grassroot artisans. Buechley also found that 85% of the people featured on MAKE's cover images were men and boys, and nearly all were Caucasian. Among attendees at the 2012 Bay Area and New York Maker Faires in the United States, 66% were male, the median household income was US$117,000, and 87% had tertiary degrees (Maker Media, 2012).

Similarly, the vast majority of participants among dozens of makerspaces visited by the authors and our peers across the Americas, Europe, Africa, and Asia (with the notable exceptions of several deliberately inclusive spaces in low-income areas) are male, upper or middle-class, and possess at least a secondary school education. Hielscher and Smith (2014) analyse recent surveys of makerspaces and determine "most of the members are technically interested and well educated and therefore represent a particular fraction of society." Hielscher and Smith (2013) also determine that "creating an object from an idea to a digital drawing to the finished thing is not a straightforward process"; this contrasts with the ideal of anyone being able to walk into a makerspace and start creating some product immediately. Author Waldman-Brown visited a secondary school makerspace in Boston, U.S. with a predominantly low-income African-American and Latino student body, where the director of the space actively rejects the term "Maker" due to perceived connotations of exclusivity and privilege.

Waldman-Brown et al. (2013) conclude that despite ideological similarities, neither Kenya's ARO Fab Lab (founded in 2009) nor the Ghana Fab Lab (founded in 2004) has contributed significantly to local grassroot artisans over the course of its lifetime: "While informal artisans are understandably focused on immediate functionality and their own potential for future employment, those in the fab lab are often more concerned with industrial projects or furthering the education of students by focusing on interesting rather than practical problems."

Although the Maker Movement rhetorically supports "production by the masses" over mass production, cottage industries in practice are faced with a dilemma. Schumacher (1973) discusses these two possibilities, following Gandhi's ideas of "swaraj" and critique of industrialization.

Table 1: Localized versus Mass Production (Schumacher, 1973)

Scalable Local Production *Ex: beehives in Ghana*	**Mass Production** *Ex: modern electronics*	**Boutique Artisanship** *Ex: crafts featured on Etsy.com*
Numerous cottage industries making the same product across hundreds of factories	Few industrial-scale factories	One cottage industry making a handful of unique, labour-intensive products
Entire simple product manufactured and/or assembled in one facility	One complex product often made across multiple specialized, assembly-line factories	Entire simple or complex product made in one facility
Trade secrets are difficult to protect	Trade secrets are heavily guarded	Trade secrets often irrelevant for handicrafts
Decentralized control structures	Centralized company control	Individually-owned shops
Products are often easy to repair locally; producers can more readily make new parts	Repairs are often too costly or too difficult	Products are often easy to repair locally and may be customized to taste
Expensive, slow-paced production; local manufacturing could save on distribution/marketing costs	Economies of scale lead to much cheaper production	Expensive, slow-paced production; handcrafted qualities may add value
Insufficient frameworks for enforcing environmental and safety regulations	Frameworks exist for environmental and safety regulations, but large factories may be more dangerous for workers	Insufficient frameworks for enforcing environmental and safety regulations
Better quality of life for local workers, high level of self-determination	Workers forced into crowded urban settings, lower quality of life	Better quality of life for local workers, high level of self-determination and creativity
Can be urban or rural, depending on supply chains; minimal infrastructure required	Urban factory settings only; extensive infrastructure required	Can be urban or rural, depending on supply chains; very minimal infrastructure

7.

Better supported by socialist policies	Better supported by capitalist policies	Equally supported by socialist and capitalist policies
Leads to demand-driven markets, where demand may exceed supply of product	Leads to supply-driven markets, where supply may exceed demand for product	Leads to demand-driven markets, where demand may exceed supply of product

Among Makers, the mode of production is often predetermined based on the technology and economics of the product in question, especially as related to local policies. Given the popularity of open hardware such as Italy's Arduino and China's Seeed Studio and the rapid proliferation of digital fabrication technology, hybrid models of production may take root; this could allow cottage industries to expand production in more sustainable ways while maintaining profitable businesses. In addition, mass manufacturers can now incorporate artisanal qualities including bespoke product design. Further research is needed on this topic, especially around intellectual property rights and the economics of small-scale production. There are few studies related to sustainable employment generated by the Maker Movement, and the mass media tends to falsely conflate Scalable Local Production with Boutique Artisanship.

The Maker Movement's most significant contribution over the past decade is likely *not* the promotion of technologies, but rather the empowerment of people to engage with and create technological communities. Maker Faire Africa: Lagos deliberately positioned grassroot artisans who are developing agricultural processing equipment alongside university roboticists, to break down cultural perceptions around invention as an exclusive act. Through intensive study of one United States hackerspace, Toombs et al. (2014) find 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… can be usefully applied to other situations, particularly those that involve individuals who have not traditionally felt empowered." The promotion of this "creative sensibility" as it relates to international development is the primary research subject of a new academic group at the Massachusetts Institute of Technology D-Lab (Development, Dissemination, and Design Lab).

As the Honeybee Network has been successful in discovering and then sharing new innovations from the Indian grassroots through platforms such as Techpedia.in and innovation competitions (ICCIG, 2012), the Maker Movement has likewise shared inventions from individuals who would not otherwise be recognized. Although Maker Faire's English-language publicity mostly highlights North American and European makers, other online platforms, competitions, and media outlets publicize international Makers among a global audience; this may lead to press coverage and support for particularly inventive projects. Crowdfunding platforms also enable Makers to raise funds and amass support, especially when inventors can frame a compelling story about their creativity to garner media attention. The existence of a semi-coherent Maker

Movement allows the media and potential supporters to more readily identify valuable grassroot inventions, and to celebrate the existing creativity of informal artisans in a new context.

Case Studies

How can Makers interact with the grassroots in mutually beneficial ways? We present several case studies detailing initiatives to upgrade the capabilities of grassroot artisans through the democratization of technology. Most of these cases do not directly involve the Maker Movement, but rather represent potential routes for future collaborations.

Ghana Intermediate Technology Transfer Unit in 1980's

In 1980, at the height of the Appropriate Technology movement, the Kwame Nkrumah University of Science in Technology in Kumasi, Ghana erected the Intermediate Technology Transfer Unit (ITTU) to provide both technology-based and knowledge-based support and encourage a shift from repair to manufacturing. Like modern makerspaces, the ITTU and similar spaces in London (Smith, 2014) provided community access to improved technologies for small-scale prototyping and manufacturing in the 1980s. These Appropriate or Intermediate Technology facilities had a strong emphasis on job creation, following Gandhi and Schumacher's (1973) ethos of localized production and sustainability which optimized for jobs created rather than economies of scale. Although modern makerspaces similarly encourage education and prototyping services, most hardware start-ups emerging from the Maker Movement have no explicit directive to support localized over mass production.

Ghanaian and English mechanical engineering professors built the ITTU in the heart of Ghana's largest informal industrial cluster, Suame Magazine, which mostly deals in automechanical and agricultural processing equipment. Today, the ITTU is best known among Suame artisans for selling some of the first electric machining tools to artisans on hire-purchase terms, and for training apprentices and leading workshops to introduce new methods and technologies. The ITTU introduced a machining tool called the capstan lathe, which was ten times faster and more reliable than the centre lathes that were currently in operation, and brought automobile technicians from Canada to train local artisans in modern auto-repair techniques. The ITTU continues to host an exchange programme for KNUST engineering students to gain practical experience by apprenticing themselves to Suame artisans for several months.

Overall, the ITTU facilitated the growth of Suame Magazine's innovation capabilities by introducing new technologies, as discussed by Waldman-Brown et al. (2013):

Table 2: Impact of machining tools upon Suame artisans

Tools Introduced	**Knowledge Introduced**	**Volume Introduced**	**Impact**

Metal fabrication tools (lathe, drill-press, milling machine, etc.)	Manufacture of agricultural processing tools, engine re-boring, customized gears...	Over 100 machining tools	Customized manufacturing and precision work
Small-scale iron foundries and aluminium-spinning	Making of nuts/bolts, tools, millstones...	Currently over 100 small-scale foundries in Kumasi, trained through workshops	Customized manufacturing, improved compatibility of repair tools, introduced scrap-metal collection for iron recycling
Record-keeping	Basic accounting skills, literacy	Dozens of workshops for interested artisans	Improved customer relations, advertising, business transactions (primarily big businesses)

Due in large part to the efforts of the ITTU, the stock of machine tools in Suame Magazine grew from 6 in 1971 to over 100 in 1987 (Intermediate Technology Ghana, 1996). By working with the government and establishing a precedent for the importation of used equipment, the ITTU also helped pave the way for unaffiliated artisans within Suame to import their own machining tools, as shown in Figure 2:

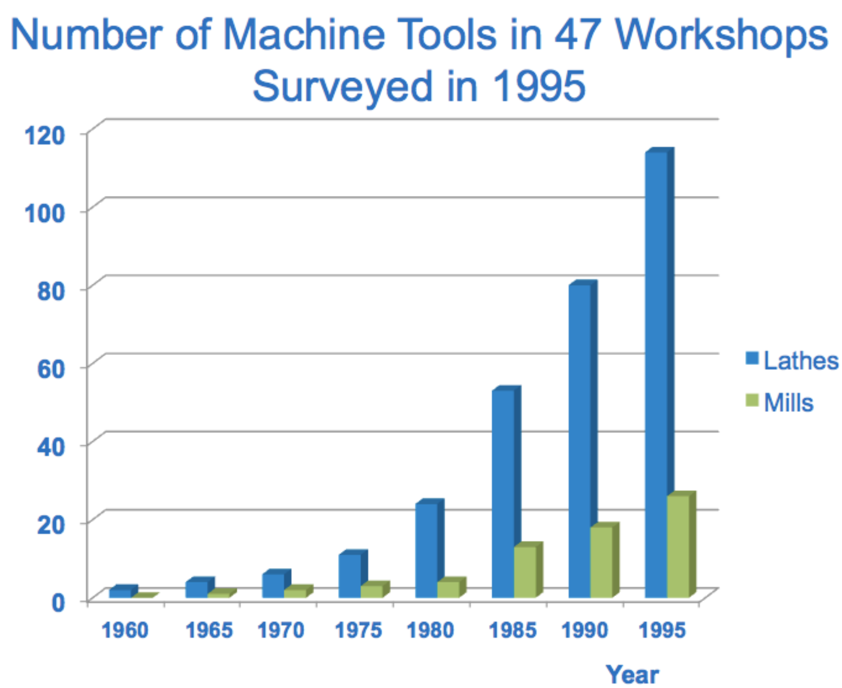

Figure 2: Growth in Numbers of Machine Tools in Ghanaian Grassroots Industries (Intermediate Technology Ghana, 1996). KNUST's appropriate technology department started supplying machine tools in 1979, and the Suame ITTU opened in August 1980. Many machine tools were sold to firms other than the 47 surveyed in 1995, and so are not included.

By introducing equipment that could be used for the local manufacturing and processing of raw materials, the ITTU's activities helped stimulate the nation's economy and produced a cascade effect of new manufacturing industries (Powell, 1990), as shown by the introduction of beekeeping:

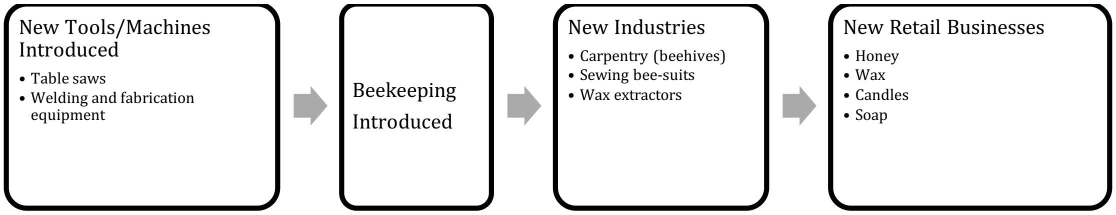

Figure 3: Cascade effect of new industries, as enabled by the introduction of beekeeping technologies in Ghana in the 1980s (Waldman-Brown et al., 2013)

Although Ghanaians had historically harvested honey and wax from wild bees, the ITTU's collaboration with beekeepers in Kenya brought the first domestic beehives into Ghana. While honey was rare and of inferior quality prior to the ITTU's intervention, it is widely available throughout Ghana today.

Due to the success of this first ITTU, Ghana's Ministry of Trade and Industry established 9 more Appropriate Technology centres throughout the country. Although there are no exact statistics available, Waldman-Brown et al. (2013) and Powell (1995) estimate that this programme's activities from 1980-1995 created tens of thousands (if not hundreds of thousands) of new jobs and introduced hundreds of new industries to grassroot artisans in the region. Despite its success, the ITTU (now called the Ghana Regional Appropriate Technology Information Service) failed to keep up-to-date with modern technologies; their network of spaces lost considerable support and funding in the late 90's, as Ghana moved away from socialist policies and aid organizations shifted focus from mechanical to digital technologies.

Fab Lab interactions with grassroot artisans

In their discussion of Fab Labs in Latin America, Herrera and Juárez (2013) claim that makerspaces have much to offer local artisans: "digital fabrication can optimize the mechanical processes and provide more time to the artisan/producer to invest in creative processes, directly affecting the value of the product and improving their quality of life." Globally, our findings indicate that this potential has not been realized by the Maker Movement.

We estimate that the roughly 150 Fab Labs in the developing world have only led to tens of new jobs, not counting occupations created for Fab Lab staff members. Vigyan Ashram Fab Lab in Pune, India may have had better success, although their centre began as an appropriate technology institution which added a fab lab during the modernization of their workshop. In addition to initiating the first local manufacture of tractor frames, Vigyan Ashram students and staff have sold over 5000 units of homemade LED lights, and one entrepreneur started a company to manufacture and sell a pedal-powered charger designed at the fab lab (Kulkarni, 2013). The Ghana Fab Lab supports numerous part-time businesses including bespoke solar lamp manufacturing, screen-printing, and etching/engraving services provided by the laser cutter, and Ghana Fab Lab staff helped a local speaker manufacturer to purchase a new CNC machine for rapid production. Yet there is little information on whether these and other products invented by Makers can be manufactured and/or assembled locally in hundreds of different grassroot workshops rather than through mass production. Unlike Appropriate Technology proponents, the Fab Lab community has not identified localized production or entrepreneurship as a primary ambition; further research is needed on the effectiveness of Fab Labs for job creation. Fab Labs support a variety of activities including education and prototyping services, and the main focus of any individual lab is dependent upon its context.

Langevin (2011) found that the majority of potential users at the ARO Fab Lab in rural Kenya are undereducated, and they are disinclined to visit the Fab Lab because they would feel useless in a facility based on computer skills. As most grassroot artisans in Sub-Saharan Africa are computer-illiterate if not entirely illiterate, Waldman-Brown et al. (2013) conclude, "local fab labs would need to make a particular effort to make these artisans feel welcomed in their workshops. Informal artisans often work for long hours at or below the poverty line, so they have little leisure time in which to leave their workshops and attend classes; if they do not see any immediate benefit in using fab lab facilities, they will not take time to visit."

Most of the 43 Fab Labs in the Latin American Fab Lab Network were initiated by well-educated architecture or design students, and most labs are located within (often closed-off) university campuses. Herrera and Juárez (2013) report on the difficulties of promoting Maker ideals within Latin American institutions: "an entrenched culture of misguided competition sums up: 'I win, you lose.' Most public and private institutions speak of cooperation, but hardly encourage it."

However, this regional network has several burgeoning collaborations with the grassroots. In 2014, the network began work on a "Floating Fab" barge to float down the Amazon River; this project will work with indigenous communities to identify new materials and techniques for conservation and sustainable production. Fab Lab UNI in Peru works closely with Professor Walter Gonzales who teaches traditional weaving, and Gonzales invented the Digital Loom which can be manufactured with a CNC machine in 60% of a traditional loom's production time, at a similar cost (Herrera and Juárez, 2013). Although this technology has not been introduced widely among grassroot weavers, the Latin American network is optimistic that their Fab Labs will encourage further cross-sector cooperation. Herrera and Juárez (2013) praise "the spirit of social and technological convergence that occurs in [Latin American Fab Labs]: a growing culture of innovation with inclusion."

Collaborative Design Workshops

The Human-Centred Design process (akin to Design Thinking and Creative Capacity Building) is practiced and promoted by leading innovation firms such as IDEO; it is a popular tool for the development of empathetic innovations through collaborative development of relevant and locally-appropriate technologies. These processes employ rapid prototyping and frequent user-testing at various stages, and emphasize multidisciplinary approaches to collaborate with target users throughout the design process. Most Makers employ similar techniques when inventing or improving upon technologies (though they may not realize the similarities), but there are few explicit links between Human-Centred Design and the Maker Movement as a whole.

The following recent examples provide specific projects on which technically-knowledgeable Makers might collaborate with the grassroots to improve technologies used throughout the informal sector. Unfortunately, follow-up studies are not yet available for these examples. Metrics for evaluation may include jobs created, uptake of new technologies and methods, whether participants develop a new appreciation for cross-sector collaborations, and the degree to which participants take away new design and engineering skills.

Rethink Relief Workshop in Pader, Uganda
Rethink Relief is an annual design workshop hosted by the Massachusetts Institute of Technology and Caritas Uganda to create technologies for humanitarian relief that specifically addresses the gap between short-term relief and long-term sustainable development. It is an opportunity for practitioners, designers and recipients of humanitarian aid to engage and develop a holistic approach to relief that considers the transition from emergency response to post-disaster self-sufficiency as an integral part of the planning and implementation process. The 2014 conference was held in Pader, Uganda to assist the refugees in Ayilo Camp; participants came from 16 different nationalities, including the refugees themselves who worked alongside participants in understanding first-hand the situation on the ground. The participants were divided into 5 teams, each tackling a specific subject: water, light, agriculture, health and cooking. Throughout the 2-week conference, participants utilized the design thinking process to develop low cost technologies that might aid refugees in their day-to-day activities.

Ideas from teams included:
1. ‘Make Your Own Light’ kit which enables the user to create a light specific to their need
2. An alternative method for safekeeping of refugee camp medical records safe
3. Techniques for rainwater harvesting
4. New approaches to farming with limited space and resources
5. An efficient, smokeless cookstove

At the end of the conference, teams presented their prototypes at an event that drew over 100 people from the community including government officials. The feedback received was overwhelmingly positive; participants were pleased with the results and refugees reported that they gained skills which they could pass along to others, signifying a sustainable and self-reinforcing method of building creative capacity. All prototypes are posted online, so people who are interested in carrying projects further can get in touch with the inventors following the conference (Rethink Relief, 2014).

Low Cost Manufacturing Tool for 'Jua Kali' Artisans in Nairobi, Kenya
This project was carried out from the Glasgow School of Art in Scotland in collaboration with artisans from informal sector manufacturing sites in Nairobi, Kenya over a period of four months in 2013. Participants aimed to improve the quality of goods produced by grassroot "jua kali" artisans, who were using obsolete and inefficient tools.

Design ethnography was carried out as the main form of research at grassroot sites in Dagoretti, Kamukunji, and Nyamakima over a period of two weeks. The researchers had several key findings: set-up costs for production are of the highest priority to the artisans, they seek equipment that requires no training to operate, and the most highly-demanded goods are cookware.

These findings drove the following design phase, in which artisans at the Nyamakima site were provided with a laptop and internet access to collaborate with design students in Nairobi and Glasgow, Scotland. Various concepts for new manufacturing tools were designed and evaluated collaboratively, based on the following criteria:

1. Cost to produce and operate the tool
2. Ease to build and operate
3. Ability to produce good quality goods safely and efficiently.

The outcome of this project was the design of a low-cost, metal-forming machine that utilises the 'deep drawing' process to produce medium-sized aluminium cooking pots. The machine is of a simple design for easy construction and operation by grassroot artisans, and all resources required for producing the machine are relatively accessible locally. The final machine is designed to produce higher-quality pots at a faster rate than the current tools, enabling the artisans to increase their income and hopefully achieve higher standards of living.

Figure 4: Rendering of metal-forming machine developed with grassroot innovators

Foondi Collaborative Design Workshops in East Africa

Foondi Workshops is a product design company based in East Africa that uses collaborative design workshops to teach design thinking, product design and appropriate technologies. By working with both skilled and semi-skilled artisans as well as community leaders, Foondi nurtures a community of local problems solvers and innovators. The larger vision is to spur bottom-up innovation that is both scalable and sustainable by building localized ventures around ideas generated through these workshops, similar to the Ghana ITTU's initiatives detailed above.

Foondi held a collaborative design workshop in 2014 in a village in Mpigi, Uganda, outside Kampala; most residents of this small town are farmers who have limited or non-existent access to electricity. The most popular means of local transport is the motorcycle-taxi. Considering both the difficulty of charging mobile phones and the ready availability of motorcycles, Foondi Workshops collaborated with the Watoto Church Vocational Institute to develop motorcycle-based charging facilities for mobile phones.

Participants also developed a business model for students to build and maintain these units for motorcycle-taxi drivers, who would collect fees from passengers who wished to charge their mobile phones while in transit. This developed two value streams: one for students and grassroot artisans who would build and sell these charging units, and another for motorcycle-taxi drivers.

This proved to be a simple, viable, and scalable technology in the context of both rural and urban Uganda. After the workshop, all 16 participants expressed interest in carrying the project forward and turning it into a business venture.

Recommendations

Avoid neo-colonialist imposition of technologies through collaborative discussions
Without a reciprocal sharing of knowledge, proponents of the Maker Movement could damage grassroot communities by imposing unwanted technologies which detract attention from more important activities, and potentially minimize the support and funding available for pre-existing local initiatives. According to Warren and Cashman (1988): "Many technological solutions that have been proposed to address problems in rural communities have failed in the field because they do not take into account the local culture, particularly society's preferences, skills, and knowledge." As Troxler and maxigas (2014) state, summarizing the findings of Chan (2014), "the air-drop model of Information and Communication Technologies for Development (ICT4D) proved to be neo-colonialism driven by technological determinist imaginaries."

Instead of beginning with the technology itself, we highly recommend an empathetic design process similar to the Human-Centred Design workshops or the Ghana ITTU's preliminary investigations. This empathetic and collaborative process allows grassroot artisans to draw their own conclusions and collaborate with Makers to determine which exogenous technologies may prove useful.

Unfortunately, in many cases of technological sponsorship, corporations or governments will donate equipment in order to directly satisfy their own requirements rather than the needs of those who receive it. In the words of a rural educator in Peru who received an unasked-for shipment of One Laptop Per Child computers for his school: "when [the state] gave you the computer, it was really another duty on top of all the [routine] functions that teachers already have, and we were never trained to teach with such tools before… Without rural and intercultural priorities [around technology], we'll keep amplifying unequal divides" (Eleazar Mamani Pacho quoted in Chan, 2014). Chan (2014) explains that the burden of new laptops for rural educators in Peru was somewhat lessened by efforts to incorporate indigenous languages into the computers—thus bringing added value to both teachers and indigenous language activists who sought educational materials in their own languages.

When the technology itself is predetermined, it becomes necessary to introduce it in a locally-appropriate manner. Once grassroot artisans can familiarize themselves with the possibilities through visiting a demonstration makerspace, the Makers can provide assistance to artisans in identifying and importing their own equipment– as Ghana ITTU did with capstan lathes in the 1980s. Although Fab Labs are designed with the capabilities to "make almost anything" (Fab Foundation, 2013), this potential will not be immediately obvious to a grassroot artisan who is unfamiliar with digital manufacturing; any "air-dropped" technological facility must make a concerted effort to welcome local ideas and incorporate community members.

While conventional manufacturing equipment is often too costly and complicated for general use in the informal sector, many technologies that are popular in makerspaces provide state-of-the-art capabilities for a fraction of the cost and complexity, and communities already exist around customizing and repairing this equipment. If these Maker tools do not easily translate to informal industrial settings, Makers could work collaboratively with grassroot innovators to develop more appropriate versions. One successful example is the W.Afate 3D printer made from electronic waste by the WoeLab Fab Lab in Lomé, Togo (WoeLab, 2013), although we have yet to find compelling 3D-printable products that are directly useful for grassroot artisans, aside from printing objects to be turned into moulds for casting.

Work with policy-makers to facilitate importation of new technologies
Successful Maker implementation plans must work with policy makers to lower the costs and timeframes associated with importing new technologies; heavy custom duties and enterprise-related taxation is a hindrance for grassroot innovators and Makers who require imported materials for local production of goods. Burgeoning companies RLG (computer manufacturer) in Ghana and Kickstart (irrigation pump manufacturer) in Kenya initially hoped to assemble their products locally using imported components, but were forced to export assembly due to the importation fees imposed upon raw components. The Ghana ITTU facilitated the local growth of machining tools in part because the initiative was a collaboration with the Ministry of Trade and Industry; this meant that those involved could set a national precedent for how to import the machines.

Maker initiatives have not, to our knowledge, made a significant effort to set precedents for importation— despite the popularity of related programmes in determining government policies. Customs fees for the Nairobi Fab Lab in Kenya increase materials and equipment costs by 30% or more. Herrera and Benito (2013) estimate the acquisition of Fab Lab equipment in Latin America to be 3-8 times more expensive than in Europe or the U.S., and they report that the installation of Fab Lab Lima in Peru took 9 months, Fab Lab Addis Ababa in Ethiopia took 24 months, and the average U.S. or European Fab Lab requires only 3 months.

Promote vocational training and practicable skills
Following the successful precedent of Appropriate Technology facilities, local makerspaces should make a concerted effort to provide vocational training through collaborations with the grassroots. These trainings would have the joint advantage of allowing grassroot innovators to experience the technological possibilities of the Maker Movement and to improve their own skills. Makerspaces in Ghana and Nigeria host vocational training courses that are sponsored by corporations such as GE and petrochemical engineering firms, but these courses are primarily useful for employees involved in mass rather than localized production. Naturally, corporations are less likely to sponsor workshops for grassroot artisans unless there is some immediate benefit; support for these trainings would likely come from government or aid organizations.

To however ensure that vocational training initiatives do not fall into the common pitfalls of technology transfer, the following is suggested:

1. Grassroot innovators should determine themselves what will be taught. When the Ghana ITTU introduced beekeeping, for example, there was already a local interest in honey and beeswax. Basic principles of engineering and design should be explained in a clear and practicable way, enabling innovators to develop new and improved products through a better understanding of scientific fact.
2. Design and manufacturing tools that are popular within the global Maker Movement (such as digital fabrication software/equipment and microprocessors) should be introduced as options and not absolutes, and makerspaces must make a particular effort to reach out to grassroot artisans. Makerspaces will be seen as impractical if they have too many intricate and complex technologies to offer without any specific opportunities for grassroot artisans. Makers tend to use less robust materials such as plastics, plywood, and electronics for creating intricate products that rarely provide critical services; grassroot artisans, on the other hand, usually create functional and durable products out of metal and wood.
3. After learning basic safety precautions, grassroot artisans should be encouraged to "tinker" with Maker tools to become familiar with their operation, and instructors should be open to improvements that may come out of tinkering. "Improvement" does not necessarily require sophistication, but rather refers to the modification of tools to become more culturally relevant (which may mean added simplicity or reduced cost).
4. Instructors should have a road map by which vocational courses will eventually be taught by grassroot artisans themselves, preferably previous graduates of those courses. This models the tradition of apprenticeship often used by informal industrial firms, and proved highly successful for the Ghana ITTU to become better integrated with grassroot artisans (Powell 1995). Apprenticeship models will help drive participation and lend legitimacy to training sessions; as Warren and Cashman (1988) report, "Success in development is more likely to be achieved when local people are involved in the planning and implementation of development projects; and project officials who are familiar with indigenous knowledge are better equipped to facilitate participation by the local populations."
5. Enable open access to relevant technological information, including accessible platforms such as Techpedia.in that enable grassroot innovators to publicize their ideas and online courses / instructional videos around new or improved grassroot technologies.

Conclusion: A Call To Action

The global Maker Movement, saturated with state-of-the-art technological advances and media attention, struggles to live up to its inclusive ideals and revolutionary rhetoric; meanwhile, grassroot artisans suffer from a lack of technological and socio-political support for their methods of small-scale and localized production. Both parties would greatly benefit from a confluence of their collective efforts, including the acknowledgement of grassroot artisans as a critical and formative component of the global Maker Movement, as has been emphasized by Maker Faire Africa. Instead of making half-hearted attempts to formalize the informal industrial sector, policy-makers could recognize its vast potential for job-creation and take advantage of Maker tools to upgrade existing grassroot technologies.

Grassroot artisans worldwide have a long history of innovation and extensive networking amongst local firms (Adeya, 2008), while modern makerspaces are relatively new and “air-dropped” technologies or technical facilities have no ties to local communities. Nonetheless, policy-makers and aid organizations demonstrate a preference for creating brand new makerspaces, “tech hubs,” and even entire innovation cities (such as Kenya’s Konza Techno City) instead of investing in existing innovation communities at the grassroots. As most innovation spaces are only fully-funded for the first couple years, the proliferation of these spaces will lead to intense competition for minimal funding in the future. Furthermore, the popularity of makerspaces will likely wane within the next decade. The Appropriate Technology movement, despite its demonstrated successes, lost most of its international funding with the onset of digital technologies in the 1990's, and today’s Ghana ITTU network is severely underfunded; in fact, several sponsors that initially supported ITTU workshops now provide resources to brand new fab labs and tech hubs instead.

By incorporating grassroot artisans into the global Maker Movement and promoting cross-sector collaborations, we can better encourage the democratization of new technologies on a global scale.

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