

The FAB LAB Network

A Global Platform for Digital Invention, Education and Entrepreneurship

Can small manufacturing labs, with the tools and computing power to make almost anything, infuse new ideas and possibilities into global solution networks and give a boost to local entrepreneurship and job creation? That's exactly what a network of "Fab Labs" is aspiring to do by providing access to powerful manufacturing tools—including laser cutters, milling machines, and 3-D printers—to an increasingly broad range of users at educational institutions and local community centers around the world. Incubated at the MIT Center for Bits and Atoms (CBA), the Fab Lab Network now consists of 270 independent manufacturing centers in 70 countries around the world.

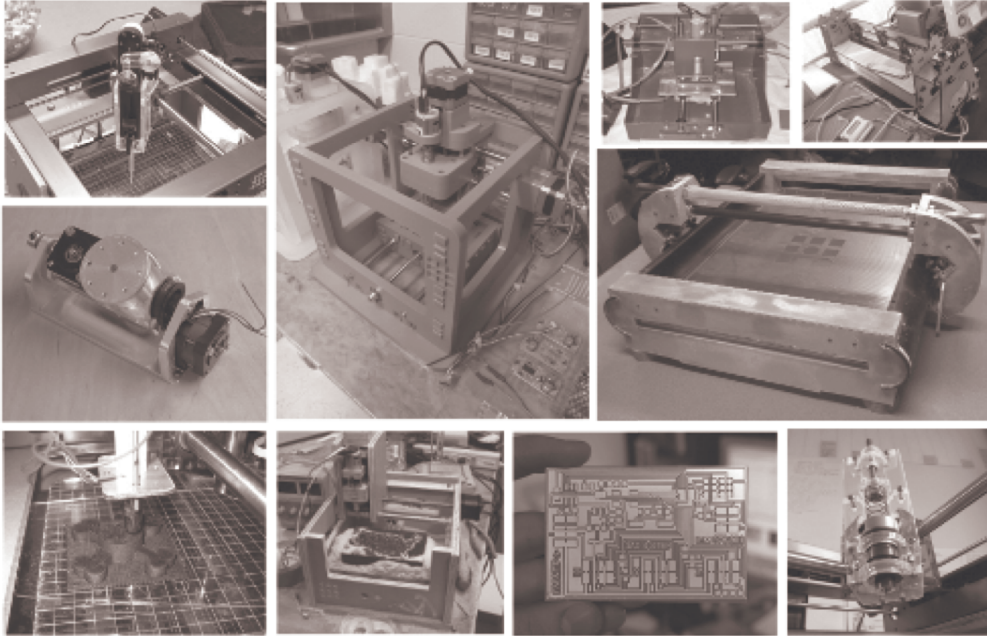
IDEA IN BRIEF

Fab Labs is a growing global network of over 200 small manufacturing workshops that are bringing together computing power and relatively simple tools to make nearly anything. Individual Fab Labs are open to a wider array of users than has traditionally been the case in industrial design or even DIY communities, allowing for a mix of entrepreneurial, research, and educational activities. By sharing a core set of capabilities, projects started in one Fab Lab can be continued and modified in others.

Fab Labs can be used to give entrepreneurs a low-cost space for designing and building prototypes. They can be spaces where students engage in design and technology education. And they can be centers of community-driven innovation, where problems that governments and corporations have not addressed can be solved using local materials—and those solutions can later be shared with similar communities around the world.

Although it is a technology-driven platform network (as defined by the Global Solution Networks Taxonomy), governance of Fab Labs is still extremely loose.¹

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Some of the tools that make up a Fab Lab

Source: <http://cba.mit.edu/media/pictures.html>

Achieving its full potential may require facilitating collaboration across different labs and types of users.

A DISTRIBUTED ENTREPRENEURSHIP REVOLUTION

It is now more than five years since the 2008-2009 economic crisis, which triggered a global recession. The recovery—especially in Europe and most especially for young people—has not been encouraging. Some of the effects—uncertainty in the labor market and worsening outcomes for low-skilled workers—reflect trends that have been developing over the past few decades, such as skill-based technological change, an increasingly global labor market, etc. These are structural changes in the economy. We have entered a more entrepreneurial world that moves at an accelerating pace, and no industry or region can be sheltered from the vicissitudes of creative destruction brought on by technology and globalization.

Much of this is to be celebrated, of course, as technological improvements allow us all to do more with less, and rapid economic growth in emerging markets has lifted hundreds of millions of people from poverty.² Even for those individuals and communities that have been dislocated by economic and technological change, there are glimmers of hope and opportunity. Indeed, some of the same forces currently buffeting labor markets—such as technological change in manufacturing and communications—also offer new possibilities to ameliorate the neg-

ative impacts of technology and globalization. Fab Labs is one such example: a global network of manufacturing laboratories, outfitted with tools that provide manufacturing capabilities, which a generation ago would have taken a whole factory to house, and several kinds of engineering expertise to operate. A Fab Labs tool set includes a laser cutter, a numerically controlled milling machine, a sign cutter, a 3-D printer, and programming tools selected for relative ease of use—as opposed to the most advanced technology. Fab Labs seek to combine entrepreneurial innovation, research, and education under a single roof.³

One application for Fab Labs is providing the tools for entrepreneurs (in both developed and developing nations) to prototype their ideas at radically reduced costs. While the Fab Lab facilities cannot produce at the scale that might eventually be optimal to satisfy demand, the advantage to entrepreneurs is in nimble adaptability and simplicity. The collaborative and open-source ethos of Fab Labs is meant to ensure that, while creators can retain rights to the inventions, as much of the process as possible is shared so that others can build on and learn from the work.

With openness and collaboration in education as part of their mandate, Fab Labs also create new possibilities in STEM (science, technology, engineering, and math) education in diverse contexts—from universities, high schools and libraries, to grassroots community-driven labs. In doing so, another significant structural economic challenge is addressed: the fact that 21st century jobs require new skills and often continual upgrading of skills by experienced workers.

FAB LABS AS A GLOBAL SOLUTION NETWORK

The 270 Fab Labs around the world are representative of a surge in distributed manufacturing capability with such obvious and tremendous potential that attempts to evaluate it are bound to appear narrow.⁴ The network is a hybrid. As a model for personal manufacturing labs, it offers a platform, and it is also a knowledge network (in that it builds on shared learning) and an operational and delivery network (in that education has been part of its work since its inception).

Fab Labs are individually useful, but what makes them a promising Global Solution Network is that their capabilities—and ultimately their impact on individuals, communities, and companies—are multiplied by collaboration and shared innovation. Projects initiated at one Fab Lab can be adopted, modified for local conditions, and improved upon by other nodes in the network. One such example is the work that the House of Natural Fiber (HONF), a collaborative arts space in Yogyakarta, Indonesia, is undertaking with Fab Lab Amsterdam. HONF has worked for over a decade doing arts and empowerment workshops with rehabilitation patients. Through this work, the need for lower cost leg prosthetics among poor communities was identified. Representatives from Fab Lab Amsterdam visited HONF for an international media art fair that was held in 2008, and the idea of collaborating on low-cost prosthetics using locally available materials (in this case, bamboo) was initiated.⁵ A Fab Lab specifically oriented to



HONF low-cost prosthesis

Source: <http://waag.org/en/project/fablab-yogyakarta-indonesia>

prosthetics was established at HONF and the resulting project has combined knowledge from HONF's rehab clients, designers in both Yogyakarta and Amsterdam, and Kamerorthopdie, a Dutch prosthetics manufacturer.⁶

While the 270 individual Fab Labs have considerable autonomy, the Fab Foundation at MIT plays a coordinating role and provides services that the independent Fab Labs cannot obtain or afford on their own. For example, the Fab Foundation provides training to practitioners and helps with the set-up of new labs. It also helps source hard-to-find manufacturing materials and maintains a list of standards that individual Fab Labs are expected to meet in order to be included in the network. These requirements are fairly minimal: a common core set of capabilities, public access to the facility, following and signing the Fab Lab Charter, and participating in the knowledge-sharing community of the global Fab Lab network in some fashion (e.g., collaborating on projects with other labs or attending the annual Fab Lab Meeting).⁷

The Fab Foundation grew out of the MIT CBA—the site of the original Fab Lab, and is closely tied to the people who helped the first Fab Lab branch out from MIT. As the number of grassroots Fab Labs grows, centrally coordinating their efforts becomes more difficult but may occasionally be necessary. There does not yet seem to be a consensus about how to strike the balance between top-down uniformity and anarchic diversity.

Broadly, there are two main areas where Fab Labs has the potential to solve global problems. First, it provides access to spaces, tools, and expertise for entre-



Fab Labs Amsterdam

Source: Waag Society, Arne Kuilman, 2012

preneurs to learn new techniques, collaboratively design, and quickly prototype innovations. In many cases the problems that Fab Labs focuses on are in fact highly localized and address needs that governments or markets have overlooked. Once developed, however, they are often adaptable to markets and communities around the globe. By sharing information across the network, tinkerers and users around the world can adapt these innovations to their own local circumstances. For example, Fab Labs located in Norway, Afghanistan, and Kenya contributed to the development of a powerful open source tool for amplifying the reach of Wi-Fi networks in developing countries.

Second, as the importance of having STEM-related (sometimes including “arts” to make STEAM-related) human capital grows, Fab Labs represent a new possibility for letting learners of all ages hone their technological skills. The ability to turn ideas into useful goods is going to expand and deepen in the next few decades, and Fab Labs allow a head start on these opportunities, encouraging people who might never have thought of themselves as tinkerers or makers before.

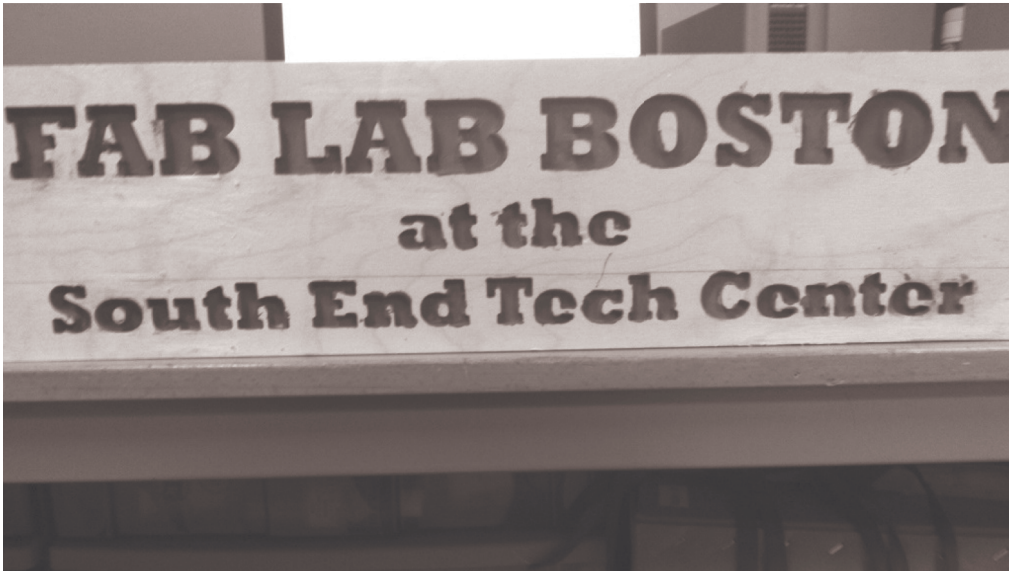
These two functions are overlapping and mutually reinforcing. Young people who receive training in what personal fabrication can do are the most likely to continue experimenting as they grow older. We examine these principle strengths and the interactions between them in greater detail below.

BITS AND ATOMS:
THE DIVIDE BETWEEN SHOP CLASS AND MATH CLASS

MIT Professor Neil Gershenfeld never felt comfortable with the division of labor in secondary and postsecondary education systems. He describes his experience of being pushed away from shop class toward math classes in high school because he was obviously intellectually gifted. “By the time I went to school, college-bound kids like me had to sit in rather sterile classrooms, while the kids taking up trades got to go to a vocational school that had all the cool stuff.”⁸ Writing about the rise of personal manufacturing leading to Fab Labs, he suggests that as far back as the Renaissance, the educational world has been trapped in a rigid dichotomy between the academic liberal arts and what might be called the “illiberal” arts of tinkering and manufacturing.⁹ He thinks this division has been perpetuated at specific modern historical junctures, such as the birth of computer science as an academic discipline in the 1950s, which trapped computer programming in the precise world of software, distant from the messiness of reality. When Gershenfeld founded MIT’s CBA in 2001, it was his intention to muddy the waters between software, information, and bits, on the one hand, and hardware, manufacturing, and atoms, on the other.

The realization that manufacturing labs could be useful to a surprising range of people and projects came out of a course that Gershenfeld taught at the CBA, titled provocatively, *How to Make (Almost) Anything*.¹⁰ When that course was first offered, two unexpected things happened that have been definitive for the direction that Fab Labs has taken. First, the course attracted hundreds of would-be students—far beyond the small group of researchers Gershenfeld expected would be interested in the tools at the CBA. Second, the projects people had in mind were things that Gershenfeld had never imagined. “One made an alarm clock that the groggy owner would have to wrestle with to prove that he or she was awake. Another made a dress fitted with sensors and motorized spine-like structures that could defend the wearer’s personal space.”¹¹ Taking these lessons to heart, Gershenfeld and a colleague decided to take the CBA’s tools out of the academy and into inner-city Boston. The result was the second Fab Lab, housed at the South End Technology Center (SETC, a facility run by Mel King, an activist experienced in bringing technology to youth in underserved communities). At a cost of around \$50,000 for equipment and \$20,000 for materials, they were able to deliver manufacturing capabilities that would previously have been prohibitively expensive into the hands of inner city students, who took to the machines just as enthusiastically as the grad students.

Demand and serendipity pushed the project further still. Some of the girls trained at the SETC came from Boston’s Ghanaian immigrant community. The Ghanaian families saw the possibilities inherent in a Fab Lab and, through the ties of their diaspora, pushed for a Fab Lab in Ghana.



Fab Lab Boston: Sign built by student at South End Technology Center

Source: <http://cba.mit.edu/media/pictures.html>

NEW CONTEXTS FOR SCIENCE AND TECHNOLOGY EDUCATION

As a result of the Boston inner-city experiment, the earliest Fab Labs facility outside MIT was established at the Takoradi Technical Institute in Ghana. In addition to holding classes for students of the institute, the Takoradi Fab Lab followed the principles of the Fab charter and was opened to a wide range of public users, “from street children to tribal chiefs.”¹² Amy Sun, part of the team that implemented Fab Lab in that Ghanaian location, noted that children were particularly interested in learning how to use the tools available and in making products that they had envisioned; she saw surprising significance in the children’s desire to make things as simple as fluorescent pink keychains. Despite the fact that most of the students had little ability with computers when they started, the children were dedicated to learning. “Kids aren’t afraid to be wrong. As a result, by the time I left, I had 7- and 8-year-olds cutting and stuffing circuit boards and sort of understanding assembly code and how to manipulate it.”¹³ This is illustrative of some of the educational possibilities of Fab Labs, which are being explored by primary schools, community centers, and libraries around the world.

Professor Paulo Blikstein, Stanford University, has been responsible for much of the work in bringing Fab Labs into K-12 education in the U.S., trying to make up for the deficiencies experienced by the young Gershenfeld in his frustrated learning experience. He writes that the United States National Research Council has been concerned about the disconnect between modern technology and K-12 public education in the U.S. since at least 1999.¹⁴ His work is grounded in pedagogical theory and developmental psychology dating back to the attempts by Jean

Piaget and Seymour Papert to bring the Logo programming language to school-children in the 1960s. Blikstein argues that children learn particularly well when they build things that can be shared with others, bringing ideas into a public and collaborative space—rather than privately examining them inside their own heads.¹⁵

In 2008, as the Fab Lab network was gaining momentum, Blikstein launched the FabLab@School project. Believing that schools needed to give manufacturing and design education a space on par with athletics offerings, he worked to design Fab Labs for schools that would break down preconceived notions of what and, perhaps more importantly, who was involved in the traditional shop space. Says Blikstein:

I realized that digital fabrication had the potential to be the ultimate construction kit, a disruptive place in schools where students could safely make, build, and share their creations. I designed those spaces to be inviting and gender-neutral, in order to attract both the high-end engineering types, but also students who just wanted to try a project with technology, or enhance something that they were already doing with digital fabrication.¹⁶

The lack of facilities of this sort contributes to the need for what researchers call the “STEM Pipeline.” Blikstein points out that of 3.7 million children beginning elementary school in the U.S. each year, by 7th grade only 730,000 of them are expressing an interest in science and technology, and only 67,000 go on to achieve engineering degrees.¹⁷ He cites recent studies arguing that the most important predictor of whether a student will go on to a career in a STEM field is actually declared interest in science and technology in 8th grade.¹⁸ In spite of the fact that social prestige and salaries in these fields are already very high, Blikstein says that “we are running out of incentives to make people go into those careers and one of the reasons is that it’s terribly boring to study those things.”¹⁹

Blikstein’s vision is being put into practice through the FabLab@School program, being undertaken by the Transformative Technologies Learning Lab at Stanford University.²⁰ There are now five FabLab@School sites, three in Palo Alto, one in Russia, and one in Thailand, with future schools planned for Melbourne, Australia and Mexico City.^{21 22} The schools are being used to conduct empirical studies into the relative effectiveness of the FabLab@School initiative; early studies have shown that hands-on, discovery-based learning has considerable positive effects.²³

PERSONAL MANUFACTURING AND THE POSTINDUSTRIAL ENTREPRENEUR

Peter Troxler, president of the International Fab Lab Association, thinks that Fab Labs are more important as examples of collaborative organizations than as technological bellwethers. He sees in them an explicit challenge to industrial-era hier-

archical enterprise and the emergence of a new era of collaborative entrepreneurship. Describing the decline of the industrial manufacturing model, Troxler notes the mention of trends in the opposite direction. “Suddenly the term ‘re-shoring’ is appearing in business books and lingo, companies experience that certain manufacturing activities that used to be off-shored to China, Taiwan, Korea, etc., are being moved back to the U.S., UK, and all over Europe.” Troxler sees this as connected to the “growth of very small companies consisting of only a few or only one person.”²⁴ Since Fab Labs allow people to create prototypes of inventions either on their own or in collaboration, they are a prime example of ways in which some manufacturing functions might be reclaimed for entrepreneurs by regions that have seen industrial operations come and go.

It seems particularly appropriate that a Fab Lab specifically dedicated to entrepreneurship should be located in Manchester, England—one of the cities where modern industrial manufacturing was born, and one that has struggled to find an identity as globalization has shifted large-scale manufacturing operations to lower cost locations. The Manufacturing Institute, a charity dedicated to supporting renewed manufacturing in the UK, funds the Manchester Fab Lab. They see Fab Labs as making the connection between education and entrepreneurship. Eddie Kirkby of the Manufacturing Institute describes the trajectory: “We’re trying to build a ladder that takes people from a very young age, keeps them engaged as they go through, and develops them into young entrepreneurs who can start new businesses.”²⁵ Thus far, the greatest success of Fab Lab Manchester has been the invention, manufacture, and funding (through Kickstarter) of the Nifty Minidrive, a storage device that fits into the SD slot of an Apple Laptop, adding 64 GB of capacity.²⁶

A PLATFORM ALLOWING INVENTORS TO RESPOND TO VERY LOCAL NEEDS

One of the things that surprised Gershenfeld about the initial projects undertaken by his “How to Make (Almost) Anything” students has remained consistent as Fab Labs have expanded around the world: the projects are highly individualized. What Gershenfeld describes as the “killer app” of personal manufacturing is the ability to design and build products for a market of one.²⁷ While this aspect of what Fab Labs can accomplish is unlikely to create the next billion-dollar innovation or solve a global problem on its own, it is part of an encouraging technological trend that has been growing for decades: the ability of consumers to become active participants in creating the products they use. This is something Don Tapscott and Anthony Williams addressed in their book, *Wikinomics*. They called it the rise of the “prosumer.”²⁸ The capabilities that serve a market of one can also be harnessed to serve the market of a family, a neighborhood, or a village—and meet needs that were unseen or deemed unprofitable by existing businesses.

In some ways the developing world is a more receptive location for personal manufacturing than advanced economies; the divide between users, manufactur-

ers, and tinkerers has never been well established in places where throwing out and replacing broken machines was not a viable economic option. Gershenfeld tells the story of S. S. Kalbeg, a food technologist PhD from Mumbai, who founded Vigyan Ashram—a school in western India built on the principle of learning by doing—which became the site of India’s first Fab Lab. Gershenfeld notes that, for Kalbeg, growing up in a Mumbai suburb “there were no services—if his family wanted electricity, or running water, or sewers, they had to provide these things for themselves, which they did. He grew up not only learning how to build such systems but also seeing engineering in the home as an opportunity rather than an obstacle. If he didn’t like something, he fixed or improved it.”²⁹ Coincidentally, Kalbag had a similar experience to Gershenfeld’s when he began to succeed in conventional schooling—he was frustrated by the fact that he seemed to be learning more practical knowledge at home, while at school he was never allowed the chance to use his hands.

Vigyan Ashram became a proto-Fab Lab, offering private, low-cost technical education to students who had dropped out of public schools, and also a home for the businesses these same students would start as their innovations became ready for the local market. Some of their initial innovations were economically priced ground-resistance meters—admittedly designed by copying an existing product—used to find water, as well as “Mechbulls”—tractors made from spare Jeep parts.³⁰ When Gershenfeld visited the school in 2001, he found a place of bustling innovation, but one where ambition and ability were held back by a lack of access to tools. The additional capabilities Fab Lab has brought to Vigyan Ashram have been used to design products that are cheaper and more basic than what is available elsewhere, but also designed with local conditions in mind. The Fab Lab has allowed them to construct things such as a machine for extracting oil from nuts and seeds, and a machine for producing biogas from household kitchen waste.³¹ These frugal innovations, responding to local needs, can be scaled up to satisfy the needs of similar communities around the world. For example, the Pabal Dome, an easy-to-construct and earthquake-resistant bamboo geodesic house designed at Vigyan Ashram, has attracted a great deal of attention from other parts of rural India.³²

Sometimes the adaptation to local needs happens through collaborations between different Fab Labs, each seeking to solve a local problem but sharing experiences and thus contributing to the solving of problems around the globe. One example of a project that several Fab Labs have undertaken collectively is the search for low-cost Internet and Wi-Fi infrastructure. The project grew out of the Norwegian Fab Lab, which was using a system of reflectors to send radio signals around obstructing mountains—the purpose being to extend the distance at which a shepherd could track sheep using radio collars.³³ The Fab Lab in Afghanistan built on the idea of extending connectivity by reflection, now called Fab-Fi, and found a way to dramatically increase the power of Wi-Fi routers. With the Norwegian reflector design and modified store-bought routers, they can now beam Wi-Fi connectivity across several miles where it previously could only reach across a living room.



Pabal dome

Source: “In Pictures: Vigyan Ashram,” BBC News. http://news.bbc.co.uk/2/shared/spl/hi/picture_gallery/05/south_asia_vigyan_ashram_/html/3.stm

What does this have to do with the kind of small-scale manufacturing Fab Labs facilitate? The designs for adapting conventional routers and building reflectors are shared, open-source, and can be made out of a variety of materials, allowing adaptation to local conditions.³⁴ The project has since been replicated by the Fab Lab in Nairobi, Kenya, as a for-profit enterprise to deliver low-cost Wi-Fi access.³⁵ A project like this spans different kinds of users and problems—from the needs of a single shepherd, to a community, to entrepreneurs delivering a lower cost service than their competitors. In each of its iterations, it is built on the work of a slightly different problem-solving activity that preceded it.



Fab-Fi reflector

Source: <http://cba.mit.edu/media/pictures.html>

THE CHALLENGES OF OPEN-SOURCE HARDWARE

Personal manufacturing, and especially 3-D printing, has recently been the subject of a tremendous amount of hype and an equal amount of suspicion. The idea that the tools to make (almost) anything could be placed in (almost) anyone's hands is fertile territory for both utopian and paranoid speculation. These technologies present legal challenges to areas from intellectual property to gun control. Concerns have been raised, for example, that unrestricted access to 3D printers could make it easy for individuals to freely replicate the designs of popular consumer items. But most emblematic of this concern over personal manufacturing is the furor that erupted in 2013 after University of Texas law student Cody Wilson printed and distributed blueprints for the Liberator—a functioning firearm.³⁶ Others, such as former *Wired* magazine editor-in-chief Chris Anderson, have pointed out that claims of a looming firearms crisis are somewhat beside the point in a world where guns are already widely available.³⁷ Gershenfeld points to another alarming example, two of his students made master keys to luggage padlocks without having copies of the originals, by taking x-rays of the locks.³⁸ Anderson himself acknowledges that the legal issues surrounding personal manufacturing and intellectual property will take decades to sort out.³⁹

A role that might be taken on here by the Fab Foundation or some other body is that of a policy network. Analogous to the work that Creative Commons has

done for the world of open-source software, open-source hardware needs to codify norms and establish best practices around fair use, which will protect the rights of innovators without stifling innovation. More urgently than with software, perhaps, Fab Lab users need a unified voice to represent the interests of designers and users with legislators, as there is a real danger that incumbent businesses and security zealots will join forces to unduly limit the potential for collaborative innovation. Recent history is replete with such examples. Consider, for example, how proprietary software vendors attempted to undermine open source alternatives, or the way the recording industry tried to quash MP3 audio-encoding technology in the early days of digital music distribution.

LATERAL POWER VERSUS CENTRALIZED GOVERNANCE

Though Fab Labs has its historical roots in a university—a model of industrial-era hierarchy—Gershenfeld and others at the Center for Bits and Atoms have not attempted to exercise strict executive control over the goals and techniques employed by Fab Labs. In fact, the Fab Foundation has recently loosened strictures on the need for a uniform set of machines, moving toward “an evolving inventory of core capabilities.”⁴⁰ There has been a similar relaxing of the insistence that all Fab Labs be of similar size. Instead, there is a new understanding that Fab Labs might be created with as little as \$10,000 in initial investment.⁴¹ This attitude demonstrates a level of trust and a concern for fundamentally voluntary interactions that is rare even in the world of cooperative networks.

As the number of grassroots Fab Labs—those started outside of educational or government institutions—grows, it remains to be seen what form these “center-periphery” relationships will take. On the one hand, individuals in the community have resisted attempts to impose centralized governance models, including efforts by the International Fab Lab Association created by Gershenfeld and Peter Troxler to adopt a more robust coordinating function.⁴² At present, the International Fab Lab Association, a democratic association open to anyone interested and/or involved in the Fab Labs community, mostly serves to promote personal manufacturing and provide visibility to the growing number of Fab Labs around the world. More recently, the Fab Foundation has created controversy among some of its grassroots members by accepting a \$10 million donation from Chevron.⁴³

On the other hand, there is longstanding concern among Fab Lab participants that too little of the collaborative potential of Fab Labs is being successfully exploited.^{44,45} This is a role in which both the Fab Foundation and the International Fab Lab Association could render themselves indispensable, especially given their reputational credibility to manage relationships with large donors that could help fund investments in community-building infrastructure. The continually diminishing costs of personal manufacturing mean that there is little chance of grassroots Fab Lab activity slowing down. At the same time, vigorous competition (from other personal manufacturing models, such as Makerspaces and

TechShops) will ensure that labs have the freedom to move on to other models or networks, should the Fab Foundation and the International Fab Lab Association prove to be insufficiently open to network members' concerns. In this climate, there could be considerable advantage to offering collaboration incentives to tap the true potential of the platform.

IMPLICATIONS FOR NETWORK LEADERS

“There is nothing better than to have sophisticated users.” In an interview with economics professor and blogger Russ Roberts, venture capitalist Paul Graham gave this advice to companies wanting to leverage their user base in designing new products: “Put something out there right away. Then your users will tell you what the product should have been.”⁴⁶ Being able to engage with prosumers is of particular significance to networks built around platforms. The kinds of problem solving that your platform might enable are not strictly determined by the design of the platform itself—only users can determine those possibilities. For Fab Labs, some of the potential uses, such as spillover between educational and entrepreneurial activities, have been demonstrated in local contexts but have not yet been sufficiently explored. There is an opportunity to find soft solutions, or to use incentives in a non-coercive way to encourage collaboration across different types of users. The Fab Charter already mandates access to the public; the Fab Foundation could take this further and mandate that users dedicate time to teaching after they have reached a certain level of expertise. In the past, Gershenfeld has used his reputational capital to exhort the network to move in various directions, from starting the International Fab Lab Association to the current challenge to build houses using Fab Labs, which he has made a theme for 2014 FAB10 conference in Barcelona. Enhancing the network's capability to share and collaborate would seem a logical next step.

Give your network a narrative for the future. Neil Gershenfeld's extremely ambitious vision of where Fab Labs are going is grounded in experience that predates the Center for Bits and Atoms. Gershenfeld sees the Fab Labs as evolving in four stages, beginning with a Fab Lab as a small workshop, moving toward the moment when a Fab Lab is capable of building all the Fab Lab machines itself, and finally moving toward complete digital production, when materials will be capable of storing the blueprints for their construction within themselves.⁴⁷ Eventually, along the model of the DNA building blocks of living tissue, Gershenfeld theorizes that the differences between hardware and software will be rendered obsolete.⁴⁸ This can sound fanciful to the non-expert, but it is an extremely compelling metaphor for the problems that Gershenfeld sees in traditional manufacturing and innovation. By seeing Fab Labs as part of a larger trend toward reducing the hurdle between ideas and their realization, it becomes easier to think about the range of problems they could play a part in solving and to imagine their progress into the future.

Act as a bridge between old and new economies. Platforms typically attract a



Fab House Barcelona

Source: <http://cba.mit.edu/media/pictures.html>

plethora of users from different stakeholder groups. This can cause conflict, such as when the anarchist-tinged hacker community becomes suspicious of sharing a network with organizations funded by big oil companies. The challenge of bridging this cultural divide cannot be ignored. Networks that want to mobilize the decentralized expertise of the talented crowd need to find ways of coordinating that are not seen as threats to individual autonomy. It could be appropriate for the Fab Foundation to attempt to exercise a bit more centralized influence through incentives and soft power, without catastrophically jeopardizing grassroots participation. Peter Troxler has suggested what, alternatively, might be needed is a deepening of democratic decisionmaking. Without being able to pinpoint a single solution, Troxler acknowledges that, from a practical standpoint, the key is that decisions be made in ways that are perceived as fair.⁴⁹

Recognition by established corporate and government players is something young networks should celebrate, while remaining sensitive to the possibility of alienating the grassroots participants. It can also create opportunities by bringing the expertise of university-funded researchers to the same workshops at which children from low-income backgrounds are “playing” at meeting local needs.

Keep track of what you learn—and share it. Open-source culture is a particularly vibrant response to Joy’s Law (named for Sun Microsystems founder, Bill

Joy): “No matter who you are, most of the smartest people work for someone else.”⁵⁰ A network formed around a platform has an especially great incentive to remain porous in relation to the contributions of outsiders. Like a knowledge network in many ways, it gains strength from building on the innovations of its users and ensuring that a culture of shared expertise eliminates the need for duplication of effort across the network. The work done at any particular node could contribute to surprisingly diverse projects for other users.

Use the whole range of human motivations to harness talent. The realization that people respond to many motivators—not simply maximization of narrow economic advantage—is as old as the study of economics itself. Adam Smith’s *Theory of Moral Sentiments* includes a detailed study of how deeply human beings are affected by the values and opinions of their peers, and how diligently they strive to earn the admiration of others. Fab Labs are part of many new models of organization experimenting with people’s willingness to volunteer their time and relinquish traditional property rights over some portion of the fruits of their labor. This does not mean that standard forms of compensation are becoming obsolete. Particularly among extremely highly skilled individuals, however, additional forms of motivation, such as the chance to work on personally meaningful projects and the opportunity to display ingenuity in the company of respected peers, are proving capable of accomplishing more than was traditionally thought possible—Smith’s 250-year-old insight notwithstanding. Indeed, it is these diverse motivations that make the Fab Lab network a growing force in solving global problems.

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The FAB LAB Network

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