Make anything, anywhere

Can everyone use technology creatively? Engineers at the Massachusetts Institute of Technology think so and have launched 'Fab Labs' around the world to prove it. Apoorva Mandavilli reports.

Neil Gershenfeld has been teaching a class called "How to make (almost) anything" to some of the brightest young adults in the United States for years. But it took an eight-year-old girl in a small village in Ghana to show that anyone, anywhere, really can make just about anything.

One evening in June 2004 — the day after Gershenfeld had left Ghana having taught a week-long version of his class in the village — little Valentina Kwofie began cobbling together a circuit board.

Hours passed. Several times Kwofie's parents stopped by the lab Gershenfeld had set up, imploring, "Valentina, let's go home, let's have dinner, let's go to bed." It was the first time anyone in the village, Takoradi, had made a circuit board: people crowded around, watching her nimble fingers manoeuvre parts half the size of a grain of rice. Finally, long past her bedtime, she crafted a board that worked.

Gershenfeld, director of the Center for Bits and Atoms at the Massachusetts Institute of Technology (MIT), hadn't known what to expect when he put the fabrication laboratory, or 'Fab Lab', technology that he worked with at MIT into the context of rural Africa. What he got was inspiration. "This eight-year-old girl in Ghana was making microcontroller circuit boards for the love of it, for the joy of discovery," he recalls. "That ordinary people can do it and want to do it was very surprising."

The Fab Lab in which Kwofie made her circuit has been followed by others around the world, each equipped with the same key machines. Today, there are ten Fab Labs — above the Arctic Circle in Norway, in Costa Rica, India and South Africa — and within the next year, fifteen others are planned, of which five will be in Africa.

Together, these labs are showing that giving people the ability to make things for themselves can be the fastest way to solve their problems, particularly in communities with little access to education or technology.

It began in Boston

Gershenfeld began teaching "How to make (almost) anything" at MIT in 1998 as part of an outreach requirement attached to his centre's grant from the US National Science Foundation (NSF). It quickly became the most popular class he taught. Students with no prior technical skills, he says, created the "most wildly expressive things": a web browser for bored parrots, for instance; a container for screams; even a 'defensible dress' that sprouts wires when someone invades its wearer's personal space.

Watching the students' passion for teaching others what they had learned, Gershenfeld toyed with the idea of starting a lab somewhere that was far removed from MIT in its expectations about technology. So he opened a Fab Lab in working-class South Boston. Heartened by this experience, he decided to start going far afield geographically as well.

He put together a collection of industrial machines, including a laser cutter that makes two-dimensional and three-dimensional objects from non-metal materials, a vinyl cutter that can make flexible antennas, among other things, and a high-resolution milling machine for circuit boards. All are run by simple computers using open-source software written by MIT scientists. This kit today costs about $25,000; materials cost another $10,000. The first labs, like the class that inspired them, were funded by the NSF grant.

> **"This eight-year-old girl was making microcontroller circuit boards for the love of it, for the joy of discovery."**
> **— Neil Gershenfeld**

"Technical empowerment, problem-solving, invention — that wasn't at all the agenda," he says of the first few labs. "At my end, it wasn't much deeper than curiosity about what would happen."

One of the things that happened was that each new lab took on a character of its own. Whereas the MIT students made fanciful gadgets, many of the developing-world communities seized the opportunity to implement practical ideas they already had but had not been able to realize.

In Ghana, for example, villagers built large 'collectors' to harness solar energy and made machines to grind cassava into fufu powder. In Pabal, India, farmers created sensors, based on a design developed by MIT staff, to meas-

Fabulous stuff: the 'fabrication laboratories' have been set up in places as far apart as Maharashtra in India (left) and Lyngen in Norway.

Valentina Kwofie, electronics pioneer.

ure the fat content in milk and help them get a fair price. Farmers in Norway created wireless radios to help them track sheep.

Some labs are on the verge of spinning off small businesses. "Fabs are now moving from experiments to becoming serious tools in addressing developing nations' problems," says Sushil Borde, executive director of the non-profit Fab Foundation, who has helped launch Fab Labs in both India and South Africa.

"I really feel that the deepest form of aid that you can give a country is to allow them to design and make their own things," says Hod Lipson, a mechanical aerospace engineer at Cornell University in Ithaca, New York. "You're letting them choose what to make. That's an amazing empowerment."

A machine that can make anything

Lipson and Gershenfeld are collaborating on the Fab@home project. Their aim is to create a cheaper and more accessible version of existing Fab Labs by scaling things down to just one machine that can make all sorts of things. This machine will fill space with droplets of matter as an inkjet printer fills a page with droplets of colour: a Fab Lab-in-a-box.

This sort of equipment, mostly used for prototyping, is not new and has become steadily cheaper. Most versions work with only one material, however, so Lipson and others are working on printers that can make complex objects from an array of polymers. They have already made simple items, including a battery, from five different materials.

The Fab Lab in Pretoria, South Africa, is the first to have one of the single-polymer '3D printers', but the goal is to make more of them for other Fab Labs, for schools and homes. "One of the nice things about this printer is that you can make it entirely in a Fab Lab, so it's really scalable," notes Lipson — although a printer alone couldn't make another printer.

The self-replicating Fab Lab has yet to materialize, but Gershenfeld and Lipson dream of the day such personal fabricators are as common as a personal computer. Others are not so sure. "It's hard to believe that everybody would want one," says Paul Wright, chief scientist at the Center for Information Technology Research in the Interests of Society at the University of California, Berkeley.

Wright teaches a class similar to Gershenfeld's, and his students too have been creative — making, among other things, a pillow alarm clock that can rouse the sleeper without waking a partner or roommate. But, says Wright, "not everyone wants to build things. One has to be realistic." More likely, he says, is that high schools or community groups would want personal fabricators.

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From Norway to South Africa

MIT fields almost daily requests to build new Fab Labs. The ones that make the cut are inevitably driven by passionate local champions. The Norway lab, for example, is led by Haakon Karlsen, a charismatic chief herder, who helped it grow from a room in a barn to a beautiful 11-building Fab Village that has had 4,000 visitors since it opened last year. The village has support from the Norwegian government and local industrialists, and is set to launch a few local businesses.

One of the newest labs is in Soshanguve, a poor township about 45 kilometres north of Pretoria, and is run by a local group, the Bright Youth Council. When the MIT researchers arrived in Pretoria in September 2005, they found that the Soshanguve group already had its own printing centre to help community members with their resumés. The group had pooled money to buy a computer and those who knew how to use it taught everyone else.

Convinced by the council's enthusiasm, Amy Sun, a graduate student at MIT, set up a Fab Lab between the printing centre and the health clinic with support from South Africa's Department of Science and Technology. Many who come to the clinic stop by out of curiosity.

When I visited the lab on a warm afternoon in mid-February, just two weeks after it had opened, it was humming with nearly 20 people. About a dozen Youth Council members, with an average age of 25, work there. Because of the demand, the day is organized into two-hour slots allotted to different age groups — and that doesn't mean just boys and men. One participant was a pregnant 18-year-old high-school dropout. Another was a 40-year-old housewife who had never seen a computer before the lab opened but is now using one to design decorative cutout designs.

People at the Soshanguve lab have made a light switch controlled by a cellphone, a motion-sensor light and an alarm system — useful devices in the many unsafe neighbourhoods in the area. Some choices are surprising. "There

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Rich variety: Haakon Karlsen holds a radio-tracked sheep, and Neil Gershenfeld presents pre-teen research.

are boys there at 1 a.m. stringing beads cut on the laser cutter and really liking it," Sun says.

A lab can be up and running within a week of delivery, but the tough part is helping people make things. Sun spends much of her time teaching physics and electronics to people with no knowledge of either who don't speak English. "Pointing helps," she says, "I show by example." In places such as South Africa, where there are 11 languages and a severe teacher shortage, the labs rely heavily on students to show the next set how to use machines. "That turns out to be a really powerful tool for Fab Labs," she says.

And why not? There is little else for these students to do. In many African countries, there are not many jobs for people with these mid-level skills. At one of Rwanda's few technical schools, for example, secondary-level students — about a third of whom are orphans of the 1994 genocide — earn a three-year diploma in topics such as automotive mechanics, electronics or construction. But of the 105 students at the Gitarama school who graduated last year, says the principal, Mark O'Kane, only 20 have found jobs, and 8 of those are with the school.

School officials are now talking to Rwandan companies to try to train more employable students. Gershenfeld has something similar in mind. A virtual Fab Academy could equip students with skills that would make them more attractive to local companies, he says, particularly in countries with growing technology sectors such as India and South Africa. Local companies interested in employees with certain skills could also sponsor a lab. A handful of companies, including Honeywell India's training centre at Madurai in Tamil Nadu, and Neuron Bio of Pune, Maharashtra, are negotiating support for new labs there.

Raising funds to maintain the labs will be the project's biggest test. Infrastructure challenges occur at every level, says Sun, from renting a truck to move the machines and keeping the labs stocked with consumables, to ensuring electricity or Internet access, and providing technical support if a machine breaks down.

Lab staff are usually either volunteers — akin to a "technology peace corps", says Gershenfeld — or shared with other community projects. But each lab still costs as much to run as a small business in the host country. So far they have been supported by a mixture of funds from MIT, local governments and grassroots groups. But as the number of labs grows, Gershenfeld has struggled to convince traditional development agencies to finance them.

He now has interest from several private donors, however, and is launching the Fab Foundation to match these donors to labs and coordinate the growing network so that existing labs can learn from each other and new ones can grow more easily. It's already possible, he points out enthusiastically, for a Fab Lab to make buildings and furniture, and so "we're at the point of physically making the lab in a Fab Lab," although new machines would still have to be shipped from MIT.

"We are clever people wherever we live. You see that we can do anything." — Haakon Karlsen

Into business

After much debate, the Fab Labs have together decided that anything made in one lab should be available to the others. In this way, the focus is less on intellectual property — which is hard to protect in many developing nations — and more on making the business model suit the people doing the work, the invention and the lab's location. In theory, an invention from one lab could be made by several others, essentially creating a global collection of local businesses. Gershenfeld hopes to help by providing small amounts of capital from a 'Fab Fund'. The main expectation, he says, is that there is a return for the community.

The defence of personal space inspired one US student's work.

But ensuring that return is the tricky bit. Even when they have good ideas, "taking them to the next level takes a lot of business understanding", notes Behrokh Khoshnevis, director of the Center for Rapid Automated Fabrication Technologies at the University of Southern California in Los Angeles. "Competing with industry is a big, big challenge." Khoshnevis says that for the Fab Labs, "the focus should be on education more than anything else".

Kohshnevis can appreciate their value better than most in the West: as a nine-year-old in Iran, he couldn't afford fancy toys and built himself a four-storey polystyrene building equipped with a working elevator the size of a cigarette box, complete with doors and lights. If there had been a Fab Lab to teach him, he says, his inventions could have matched his imagination.

So far the labs have excelled at recreating the outreach experiment that got them started. The Fab Village in Norway has been so successful at engaging the community that there are plans to start others in Iceland, Sweden, Finland and Russia. The lab in Ghana is similarly set to help launch labs in Kenya and Rwanda.

There is more to this story than philanthropy, though: the innovatory echoes of the outreach project have bounced back to MIT. Again, it was an eight-year-old girl who showed the way: Gershenfeld's daughter, Grace. Last year Gershenfeld was showing her how to use a laser cutter in the MIT lab, but Grace thought the shapes he was cutting out were boring. Instead she made a cardboard 'Lego kit' of two-dimensional pieces that snap together to form three-dimensional objects.

Playing with it, Gershenfeld realized the flat shapes let him build space-filling parts, "That hadn't occurred to us as a way to make stuff at MIT." He and his colleagues are now testing ways to scale this approach up or down, by using parts of various sizes and in different materials. "There are now up to four grad students developing the work of an eight-year-old kid," says Gershenfeld. As Karlsen says, "We are clever people wherever we live. You see that we can do anything." ■

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