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Build your own smart devices to take over the world*

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HELEN STEER

On unicorns, making, and why millennials need to embrace creativity

DIGITAL BLACKSMITHS

How 3D printers are recycling African waste

SPHERIFICATION **LASER CUT GEARS** ERASERS **UPCYCLING**

FEATURE

DIGITAL BLACKSMITHS NETWORK

Changing the future of manufacturing in the developing world

Cameron Norris

@cameronsnorris

Cameron is a technology and communications specialist, passionate about the use of open-source hardware for social innovation.

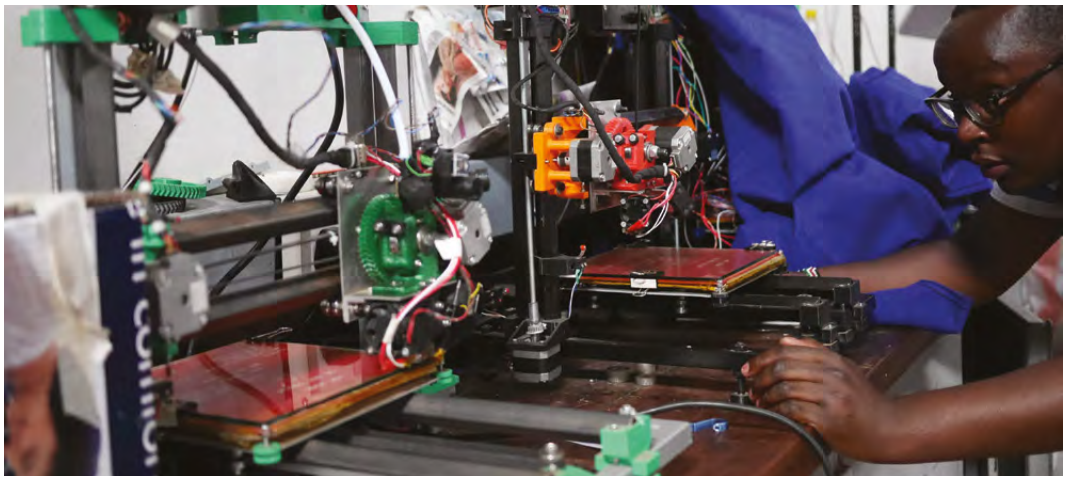
Through TechforTrade, thousands of tonnes of e-waste and discarded plastic that would otherwise end up in landfill is being transformed into a commercial and design opportunity for people in developing economies using open-source 3D printing technology.

TechforTrade is building a global 'Digital Blacksmiths Network' with the goal of alleviating poverty and pushing for economic growth through open-source product development, while ensuring that network members have access to the technology and training they need to provide 3D-printed products to their local communities.

TechforTrade's CEO William Hoyle has been working to alleviate poverty in developing countries through technology and entrepreneurship. TechforTrade is a leading UK charity specifically focused on bridging the divide between innovative new technologies, global trade, and economic development. Based in London but with impact in communities around the globe, TechforTrade has initiated a number of projects using 3D printing for international development.

DIGITAL FABRICATION

William and the TechforTrade team believe that global access to 3D printing technology is a vital step



Right ◈
Putting the Retr3D printers to work

towards the democratisation of manufacturing. It has the potential to eliminate the need for distribution by transporting physical products 'electronically', as digital designs. By lowering costs and barriers to entry, William believes 3D printing has the potential to create opportunities for micro-businesses to enter new markets by producing 3D-printed products.

TechforTrade launched the Retr3D project with the goal of providing affordable 3D printing equipment for developing economies using the 41 million metric tonnes of e-waste that is discarded globally each year.

The open-source Retr3D software enables anyone to build 3D printers using different components from discarded inkjet printers and photocopiers, and inputting the dimensions of procured e-waste components to generate a unique 3D printer design.

Matt Rogge, TechforTrade's technical director, believes 3D printing can be as transformative in developing economies as the mobile phone, and that by introducing 3D printing at a community level, jobs can be created through local manufacturing: "With a 3D printer people can gain access to a wide variety of educational, medical, and mechanical materials that would otherwise have been inaccessible."

Matt first became involved in 3D printing after working as a volunteer building rural water systems in Panama; here he first heard about 3D printing and saw an opportunity to help the local community.

However, Matt soon discovered that the number of specialised or proprietary parts required to keep conventional 3D printers functioning in rural communities was far too high: the price of imported parts and printers was often double or even triple the original cost due to shipping and customs charges.

While working in Mexico, Matt had the idea of creating 3D printer design software that could automate the design changes and modifications required to make and maintain a 3D printer using the lowest cost, local source of parts possible: e-waste.

Matt Rogge

"A retread is a type of tyre made so that the surface can be replaced when it wears out. William Hoyle came up with the name Retr3D because the printers are a way of giving new life to the still usable components found in obsolete electronics"

Initial testing of the designs generated by his Retr3D software showed that many printers were sensitive to transportation on rough roads. Loss of calibration and damage was commonplace. However, by adopting a design with a welded steel frame, which could be outsourced to local welding shops, the 3D printers proved to be much more durable.

Also, by ensuring that everything could be built locally, replacement parts could be easily obtained and someone with the skills needed to make repairs was never far away. By releasing the software and designs as open-source, TechforTrade enabled anyone wanting to build a Retr3D printer to access the information needed to keep it running and make improvements.

Open-source electronics have helped to reduce the printer's cost and improve its maintainability. The popularity of RAMPS 1.4 controller boards, commonly used with RepRap-style printers, has helped to make them low cost and widely available. The electronics on a Retr3D printer cost less than £25 and, thanks to the modular design of RAMPS, damaged components can be replaced for far less. The total cost of making a Retr3D printer is only around £100, which includes the labour cost of welding the steel frame.

"The best part of this project has been the opportunity to work with such amazing people," says Matt. "I have seen nothing but awesome creativity and dedication to making something great happen. I love to see people who have become involved in the project talk about their goals and how they see 3D printing as a way to achieve them." →

Above
Matt Rogge (right) and the Digital Blacksmiths team at the University of Nairobi, Kenya Image: TechforTrade

Below
The assembly line of Retr3D printers at AB3D

RECLAMATION

The idea for 'e-waste 3D printers' was pioneered by West African inventor Kodjo Afate Gnikou, who built the first 3D printer produced from e-waste in his workshop in Togo.

FEATURE

THE THUNDERHEAD FILAMENT EXTRUDER

In developing countries without established transport or supply networks, the local cost of 1 kg of 3D printer filament can go up to as much as £60. In turn, this prevents those interested in using 3D printers from accessing the supplies necessary to utilise their machines at a reasonable price. To tackle this problem, TechforTrade developed the open-source Thunderhead filament extruder, a small-scale extruder designed to recycle PET plastic bottle flake directly into 3D printing filament. Nearly all low-cost 3D printers are fused-filament fabrication machines, which use 3 mm or 1.75 mm diameter plastic filament as their raw material. This filament is typically produced on an industrial scale before it is imported into developing countries where the market is quite small. This importation can be costly and time-consuming and often leads to unpredictability in filament supply, which reduces the viability of running a successful 3D printing-based business in these areas.

Below
The Chopper deconstructing a plastic bottle into even flake

The Thunderhead Filament Extruder provides a low-cost, small-scale means of locally producing 3D printer filament from post-consumer polyethylene terephthalate (PET) bottle flake. Waste PET is available in nearly every location on earth, which not only helps to reduce the challenges of import duties and unpredictable supply chains, but also allows for value to be added to the waste plastic close to the site of collection. PET is an ideal plastic for 3D printing, as it has a low amount of shrink like PLA, and yet is tough like ABS.

PET SOUNDS

Furthermore, small communities in developing economies often lack access to recycling facilities, and without a local means for size reduction or compaction, it is frequently too costly to transport high-volume, low-mass plastic bottles to a centralised processing centre. Instead, a low-cost, small-scale recycling system such as the Thunderhead could be a viable means for small communities to handle problematic plastic waste, while also gaining access to 3D printer filament.

In many developing countries, recycling systems are mostly informal, with vast numbers of waste collectors working in often dangerous conditions to make as little as £1.50 per day selling collected plastic waste at £0.10/kg. The capital investments required for setting up recycling facilities are generally high,

Left
Three forms of the same plastic, from waste to product

FROM TRASH TO TREASURE

The value chain from waste PET to 3D-printed products:

- Waste plastic bottles are valued at around £0.10/kg
- When converted to clean flake, the value rises to around £0.50/kg
- 3D printer filament produced from clean flake sells for around £20/kg
- 3D-printed parts made from recycled filament can reach £400/kg

requiring expensive equipment and lots of space in centralised locations. As with many commodities, the route to profitability is through the processing of large volumes.

Developing low-cost equipment for the small-scale production of recycled 3D printer filament keeps the value-added steps within the country of origin, and by reducing the necessary capital investment required to get started, it becomes possible for those closer to the bottom of the supply chain, including waste pickers, to benefit from the value addition process.

TechforTrade is currently working with NGOs in Kenya to employ refuse pickers in the Dandora slum, a waste site a few miles from central Nairobi, to collect, clean, and shred waste plastic ready to turn into filament. As part of this initiative, they have established the Ethical Filament Foundation, hoping to replicate for 3D printer filament what fair trade has done for coffee.

The aim is to partner with organisations that encourage the manufacture of 'ethically produced' 3D printing filament, made from recycled plastic waste, as a viable alternative to the standard virgin plastic spools. The ethical element extends not just to feeding recycled waste plastic back into the 3D printer ecosystem, but to provide a sustainable income for vulnerable waste pickers. The Ethical Filament Foundation is now working to develop a standard for ethical filaments that can be used to certify producers, who will be able to license and display its accreditation mark.

A RUBBISH INNOVATION

"After realising a gap in the market for 3D printer filament made from recycled plastic, we immediately recognised the opportunity this presents to the developing world where plastic waste is in abundance," explains William. "By making the first move into ethical filament, we hope to raise awareness about the importance of this technology and the benefits it can provide to some of the poorest people in the world."

To overcome the technical challenges in producing PET filament of sufficient quality, TechforTrade is developing a bottle washing and de-labelling station and a chopper for producing flake, to support their filament extruder, all of which are open-source. The total materials cost for the whole system is less than £1 500.

The Thunderhead filament extruder can produce 5–10 kg of filament per day, which is sufficient to supply 20–40 Retr3D 3D printers for full-time production. Based on the sale price of £20 per kg for recycled PET filament, the extruder is capable of producing £100–£200 worth of filament per day. →

Below
The Thunderhead, ready to convert plastic flake into filament

FEATURE

TREASURE MADE FROM TRASH

Right
The 3D-printed microscopes are ready for a trial in Kenyan schools

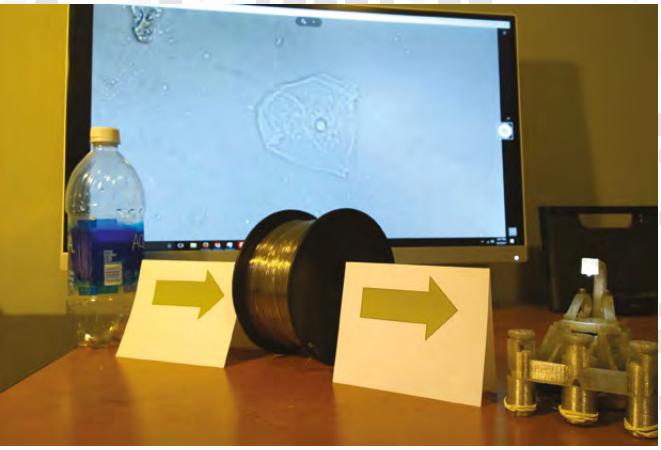
Roy Mwangi is the founder of AB3D (African Born 3D Printing), a social enterprise that manufactures Retr3D printers and 3D printer filament using the Thunderhead Filament Extruder in Kenya. Roy's first social impact project, 'Happy Feet', provides bespoke 3D-printed shoes for people with foot deformities caused by jigger sand flea infection.

"The sand flea is a tiny insect that feeds on mammals, including humans. It burrows into the skin and destroys the surrounding tissue. People develop foot deformities, which leads to amputations or even death," Roy explains. "Many of those affected by the sand flea infection cannot wear normal shoes because of their deformities."

By creating specially made shoes, Roy aims to help sufferers remain mobile, while also lessening the chance of re-infection. Over a 20-month period in Kenya, around 50 000 students dropped out of school due to jigger infections alone, highlighting the frightening severity.

3D printing technology is widely viewed as unreachable by many Kenyans due to the pricing of the machines, but TechforTrade partnered with Roy and other social entrepreneurs in Kenya to teach them how to build e-waste 3D printers, while also providing financial support for their micro business ideas, including the Happy Feet project.

"For as long as we use petroleum products, we will always have plastic as a by-product; for now, the best thing to do is to find positive uses for it," says Roy. Alongside Happy Feet, AB3D has also begun fabricating and distributing open-source 3D-printed microscopes to help Kenyans identify bacterial contamination in places that lack access to clean water. Using a Raspberry Pi and camera module, the OpenFlexure Microscope can take high-resolution



Above
From waste to educational tools in two easy steps

time-lapse images of bacterial growth within a water sample to test for dangerous pathogens including E. coli, Listeria, and Legionella. In addition to the electronics, the design requires only around 100 g of plastic and a few nuts and bolts.

The design uses thin flexible hinges, rather than the mechanical joints that are machined from metal in conventional microscopes. This reduces the friction and vibration of the 3D-printed parts, which in turn enables the microscope to achieve steps below 100 nanometres – which is 1000 times smaller than the thickness of a human hair – when driven with miniature stepper motors.

LOOKING CLOSER

"We're on the brink of launching a microscope trial, with an aim to donate 100 3D-printed microscopes to Kenyan schools, made from recycled plastic collected locally," reveals Selam Zeru, TechforTrade's Entrepreneur in Residence and Business Lead. "Just this month, we closed a crowdfunding campaign raising almost double our target to fund this trial."

Besides checking for bacterial growth in water samples, the microscopes can also be used as an aid for interactive STEM teaching in Kenyan schools to enhance the learning experience. Selam believes that if the trial is successful, it will stimulate interest within the education sector, which will justify scaling up local production of educational tools such as microscopes and other interactive learning aids from within the Digital Blacksmiths Network, creating additional opportunity for entrepreneurs like Roy Mwangi.

LEARNING EXPERIENCE

And things are already looking promising as the Kenyan government announced in 2017 that it would shift its policy by putting more resources into promoting STEM education to increase the number of students pursuing STEM courses in higher education.

The OpenFlexure Microscopes are now being tested in Kenya by Farm Africa's SIDAI group of veterinary technicians, while a team of supporters based at the University of Nairobi work on developing curriculum-relevant content to include the microscopes in STEM education. Dr Richard Ayah, Director of the Science and Technology Park at the University of Nairobi comments, "This project seems to inspire everyone who comes across it, so we're excited to see how we can get more support to push things further and faster. The potential impact of being able to print really useful items at a fraction of the cost is massive."

Matt Rogge adds, "It's taken us nearly four years to get to the stage where we can go all the way from bottle to printed product, so we've finally hit the most exciting time for Digital Blacksmiths – Now we need to focus on how we get as many of these products into the hands of people who need them as we can."

To find out more about the Digital Blacksmiths Network visit **digitalblacksmiths.org**. □

Katherine Hughes
Fundraising and Communications Officer at TechforTrade

"We are thrilled at the enthusiasm these machines have received from around the world, but particularly in East Africa. As with so much 'new' technology, including mobile phones and mobile money, entrepreneurs in developing countries are enthusiastically adopting and adapting 3D printing technology for use in their own communities"

Below
A 3D-printed microscope made from recycled waste