Creating prosthetic limbs out of recycled plastic

1. Summary of impact

3D printing is a kind of modern-day alchemy.

Creating automotive components, jewellery and even body parts by ‘printing’ them from designs readily available online has become, if not exactly child’s play, then certainly an enthusiastic hobbyist’s dream.

“Almost anyone can use the technology. It’s irrelevant who they are and what technical background they have – you can buy a printer now for under $500,” says Kate Leone, a mechatronic engineer at UTS’s Rapido Social and recipient of $10,000 in 2019 Social Impact Grant funding.

This potential for everyday use means 3D printing has applications beyond creating cheaper, lighter components for industry – it can also help us to think in new ways about recycling plastics and how they can be used, according to Kate.

Rapido Social, which utilises cutting-edge engineering and new technologies for maximum social benefit, was also interested in what products could ultimately be produced out of the recycled plastic.

“For the Social Impact Grant project, we worked with Bernie Craven, CEO of Waste Free Systems and an ex-hairdresser, who noticed an abundance of waste in salons – the majority of shampoo and conditioner bottles are made from HDPE,” says Rapido Social’s social impact manager, Sophie Ritchie. “But we also built a relationship with the not-for-profit e-NABLE who release open source designs online so that 3D-printed prostheses are more accessible.”

2. The problem

“This project was an exciting opportunity because it enabled us to explore solutions for two difficult social issues at once – the excess of waste plastic globally, and the cost-barriers to purchasing prosthetic limbs,” explains Sophie.

Every year the world produces over 380 million metric tonnes of plastic waste, a whopping 91 per cent of which isn’t recycled. Of this, 51 million metric tonnes are high-density polyethylene (HDPE).

“If recycling can’t readily be incorporated into manufacturing as an intrinsic part of the production process, it risks being out-sourced to already overburdened local government recycling services and ultimately ending up in landfill,” says Kate.

Reusing not-toxic waste plastic in the 3D printing process could also have benefits beyond the obvious environmental ones. At between $5000 and $50,000 each, prosthetic limbs are beyond the means of many who most need them. While open-source plans to guide 3D printing of prostheses exist online, these can have limitations when it comes to meeting the specific needs of individual recipients.

3. Beneficiaries

The families of kids who need prosthetic limbs but are unable to afford them are the immediate beneficiaries of the project – specifically Haley and Connor, two young Queenslanders who are set to receive tailored prosthetic hands with improved wrist mobility as part of the project.

Longer term, the benefits from improvements in 3D printing technology which increase plastic recycling are likely to have a much larger effect environmentally – potentially benefiting us all.

4. Approach to impact

HDPE is used for everything from shampoo bottles to milk crates and has the benefit of being approved for medical use by the US Food and Drug Administration (FDA). For

these reasons, it was an obvious material for the team to experiment with when it came to creating recycled plastic prosthetics.

HDPE (old shampoo bottles) was cleaned, shredded then melted down into long 'spools' of filament to feed into the 3D printers at UTS. The team particularly experimented with the filament consistency and print variables to create a more uniform thickness, reducing shrinking and resultant warping in printed end products.

They also built up relationships with two not-for-profits – Waste Free Systems (based in Queensland) and e-NABLE (an online prosthetic design platform based in the US). This meant that their research was guided by real-world conditions – the functional needs and cost requirements of prosthetic users, and the availability of waste plastic from hair salons.

5. What has changed as a result of this work?

5.1 The outcomes

While recycled HDPE is medically safe, it is renowned for being temperamental when heated to and extruded into layers on a printer bed – it shrinks as it cools and has a hard time sticking (and thus layering) in one spot.

Yet the project team were able to achieve some remarkable results. From an initial shrinkage rate of about 12 per cent, which resulted in warped and unusable objects, they were able achieve shrinkage of less than 0.5 per cent in test cubes, paving the way for future research to increase recycled HDPE use in 3D printing.

The team also contributed to the open-source prosthetics space, redesigning a 3D-printed hand to improve its mobility. The new design enables users of the hand to orient their fingers in ways not previously possible – pivoting from a mechanical wrist to change from the vertical position needed to hold a pen to the horizontal one required to hold onto a bike's handlebars without having to change prosthesis.

"The team donated prostheses to two Queensland teenagers – Connor and Haley," says Kate. "When the cost of an artificial limb can be anywhere between $5000 and $50,000, this is a real game changer for these families. It's really satisfying."

5.2 Impact

Longer term, Kate is excited by the potential environmental benefits of the research. She argues it could improve the efficiency of recycling in Australia – if materials can be re-used in 3D printing, it transforms who can recycle and on what scale.

"Making recycling more accessible to the everyday person is the big thing. If this research were to be developed further, it could create a viable solution for even larger scale companies to recycle their plastics as a standard part of the manufacturing process," she says.

For Sophie, the ongoing relationship that Rapido Social has built with Enabling the Future is also a possible path to further impact.

"We'd like to work with them to use our high-end 3D printers at UTS, the ultimate aim being to contribute to the iterations of their open source designs, or even set up an assembly line for high-end prostheses for kids around the world."

While COVID-19 has put paid to this particular goal for the time being, it's something that the team may well pursue in future.

6. What has helped you accomplish this work?

Working with Waste Free Systems and e-NABLE meant that the team's research was designed to provide practical benefits in the real world from the beginning.

The Social Impact Grant was also vital.

"It's likely that without this grant the work would not have happened – meaningful resources wouldn't have been available for allocation toward a project of this nature," says Sophie.

7. Challenges

The COVID-19 outbreak has had unexpected consequences for the project team – e-NABLE is based in the US and so have pivoted towards developing much needed Personal Protective Equipment (PPE) for the time being. Further progress towards the project's social impact objectives depends on the ongoing and unpredictable effects of the virus, both on e-NABLE, and on the global manufacturing industry.