Empowering Disabled People with Digital Fabrication: Insights from the *In the Making* Project

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Introduction

What if in 1986, we had made a concerted effort to involve disabled people in the emerging home computing trend? Through the 1990s, we would have likely seen huge benefits for the disabled community in terms of opportunities for employment and entrepreneurship. While ICTs certainly created new opportunities for disabled people, putting them at the forefront of this revolution would have been truly transformational.

In 2016, we are on the cusp of another digital revolution. This time, digital fabrication is poised to revolutionise the way that we manufacture goods by opening up manufacturing to everybody and disrupting economic barriers that prevent innovators from bringing products to market. As these technologies become increasingly widespread, we have an opportunity to ensure that disabled people reap the benefits of this revolution.

In this report, based on the findings of the AHRC-funded *In the Making* project,[1,2] we offer evidence that digital fabrication can support the government in closing the disability employment gap in the following ways:

- Digital fabrication technologies and facilities offer opportunities to create skills amongst the disabled community that might support them in finding work or in becoming entrepreneurs.
- Engaging in digital fabrication has major inclusion and wellbeing benefits for disabled people that can also support them in joining the workforce.

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[1] *In the Making* project website. http://www.inthemaking.org.uk
[2] RCUK Gateway to Research. http://gtr.rcuk.ac.uk/projects?ref=AH/M006026/1

- Digital fabrication can also support disabled people in creating or modifying their own assistive technologies, which can further support them in playing a productive role in society.

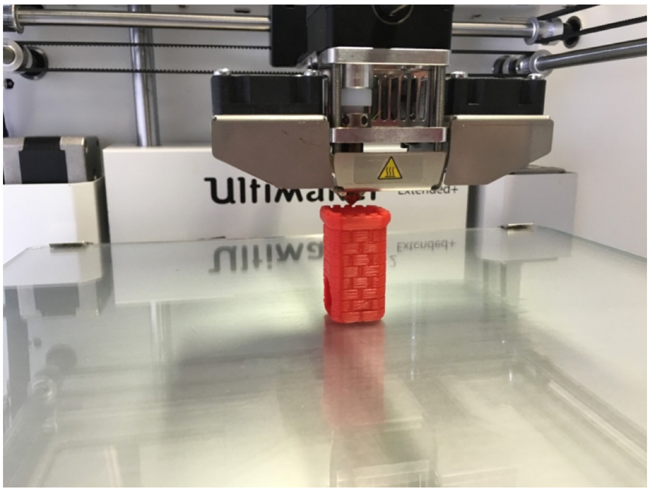
Background

Digital Fabrication

Digital fabrication refers to a family of technologies that allow physical objects to be created or modified based on computer generated designs. While these technologies are not new—such machinery has been used in industrial manufacturing for some time—the cost of such devices is now reaching the point that amateur enthusiasts can realistically afford to own their own equipment.

The main digital fabrication technologies include:

- **3D printers** capable of creating plastic objects from digital models by building up many layers of melted plastic, much like icing a cake. They are one of the best known digital fabrication technologies, and can even be found in many schools.



3D printing in action.

- **Laser cutters** are capable of cutting or etching wood or plastic in a pattern defined on a computer. This allows a level of precision that few people are capable of achieving with traditional tools.
- **CNC routers** use a computer controlled cutting tool to whittle away at a material to create an object defined on a computer. These are effectively the opposite of 3D printers, working by removing material rather than building it up.

Where these technologies are truly revolutionary is in defying economies of scale. While traditional manufacturing techniques have high setup costs requiring high volume production to recoup costs, each object created by digital fabrication device costs the same as the last. As such, they are highly suitable for businesses creating small batches of products or entrepreneurs developing prototypes.

The Maker Movement

Digital fabrication technologies alone are only part of the story. Alongside these developments is an emerging **maker movement**: a worldwide movement of individuals using a mix of digital fabrication, open hardware, software hacking and traditional crafts to innovate for themselves, underpinned by an ethos of openness and skill sharing rather than commercial benefit.[3] While often attracting an audience with engineering backgrounds, maker culture is increasingly reaching people from all backgrounds and embraces skills that vary wildly from those technical skills with which is it most closely associated.

Much of this activity takes place in **makerspaces**—also referred to as hackerspaces and Fab Labs—which provide communal fabrication facilities in an openly accessible space. Makerspaces dramatically lower barriers to entry, enabling anyone to access digital fabrication equipment cheaply. Initially emerging from universities, makerspaces are now found everywhere from industrial estates to high streets, schools, museums and libraries. These spaces range from grassroots spaces organised by small groups of friends, through to large social enterprises like Scotland's MAKLab who are capable of leveraging significant funding to undertake outreach activities and make their facilities available to as wide an audience as possible.

The *In the Making* Project

In the Making was a pilot project funded by the Arts and Humanities Research Council to explore how digital fabrication could be used to support disabled people, anticipating that there would be major benefits in terms of entrepreneurship and employment, but also in terms of self-expression and wellbeing. The project was a collaboration between the Universities of Salford and Dundee, and Disability Rights UK.

In the first stage of the project, researchers surveyed fifteen makerspaces across the UK to understand if and how disabled people were already making use of these facilities and to map out the barriers—both physical and otherwise—that might prevent greater usage. We also sought to understand the different opportunities presented by makerspaces (e.g. supporting small businesses) and the outreach activities they were undertaken with various excluded communities with a view to exploring how these same activities could be applied to the disabled community.

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[3] Kuznetsov, S. and Paulos, E. 2010. Rise of the expert amateur: DIY projects, communities, and cultures. In *Proceedings of the 6th Nordic Conference on Human–Computer Interaction* (NordiCHI '10), 295–304. http://doi.org/10.1145/1868914.1868950

The second stage of the project organised a series of six two-day workshops in various communities across Salford, mostly based in Gateway Centres that provided a variety of local council and NHS services. Within these workshops, participants worked with a product designer and with professional facilitators to learn about 3D printing and develop their own designs, leaving with objects ranging from expressions of individuality to simple assistive devices. The evidence in this report is based on findings from across both stages of this project.

Digital Fabrication and Assistive Technologies

The devices and aids used by disabled people are often expensive and may also be difficult and slow to acquire. They are also normally mass-produced, meaning they cannot respond to the unique and shifting needs of the user. By the time a device is acquired, it may already be unfit for purpose, leading to high abandonment rates for assistive technologies.[4,5] This is both frustrating for the user and a strain on resources, but also means that disabled people who might be capable of working with the correct assistive technologies are unable to do so.

One of the most promising examples of making and digital fabrication supporting disabled people is in **DIY Assistive Technologies** (DIY-AT). Because digital fabrication allows products to be rapidly customised at little cost, there is huge potential for the customisation of existing assistive technologies or even the creation of entirely new assistive devices.[4,6,7] Examples might be anything from a small device to help open jars, to modifications to a wheelchair, or even prosthetic limbs. If it breaks, or your requirements change, you can easily make another one.

A further benefit of digital fabrication is that the digital files used to create designs are often shared freely online. These designs can then be downloaded and created by anybody with the right equipment, anywhere in the world. The designs can also be modified, meaning

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[4] Hurst, A. and Tobias, J. 2011. Empowering individuals with Do-It-Yourself assistive technology. In *Proceedings of the 3rd International ACM SIGACCESS Conference on Computers and Accessibility* (ASSETS '11), 11–18. http://doi.org/10.1145/2049536.2049541

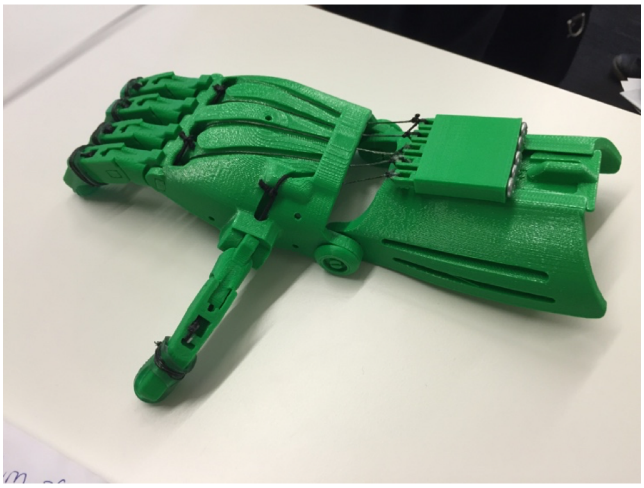
[5] Phillips, B. and Zhao, H. 1993. Predictors of assistive technology abandonment. *Assistive Technology* 5, 1, 36–45. http://doi.org/10.1080/10400435.1993.10132205

[6] Buehler, E., Hurst, A. and Hofmann, M. 2014. Coming to grips: 3D printing for accessibility. In *Proceedings of the 16th International ACM SIGACCESS Conference on Computers & Accessibility* (ASSETS '14), 291–292. http://doi.org/10.1145/2661334.2661345

[7] Hook, J., Verbaan, S., Durrant, A., Olivier, P., and Wright, P. 2014. A study of the challenges related to DIY assistive technology in the context of children with disabilities. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (DIS '14), 597–606. http://doi.org/10.1145/2598510.2598530

that it isn't necessary to start from scratch: an existing design can be downloaded and tweaked until it meets the user's needs.

Case Study: The e-Nable Network



A 3D printed prosthetic hand. Image © [John Biehler]

The e-NABLE network[8] is one of the most remarkable examples of DIY Assistive Technologies in action. It brings together people all over the world who have access to digital fabrication equipment and connects them with people who need prosthetics. A handful of ready-made designs can be downloaded and tweaked to meet the user's individual requirements, including both functional and purely aesthetic modifications. This is particularly appealing for children, who quickly outgrow costly prosthetics and who might be nonplussed by functional devices, whereas digital fabrication can cheaply and quickly create new devices as they grow and even allows cosmetic customisation.

Skills, Inclusion and Wellbeing

We believe that the use of digital fabrication to create new assistive technologies is only the tip of the iceberg in terms of potential value for disabled people. In a survey of fifteen makerspaces across the UK,[9] we found many activities amongst the maker community that supported the creation of skills, social inclusion, or personal wellbeing. We see these as ways that digital fabrication and making can help to support disabled people in increasing their employability and ability to work.

There is already a skills gap around digital fabrication—indeed, 35% of engineering jobs already require these abilities.[10] According to the UK Manufacturing Institute, most large UK manufacturing businesses have segregated skill sets, with market research, design,

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[8] E-Nable Network. http://enablingthefuture.org/

[9] Taylor, N., Hurley, U. and Connolly, P. 2016. Making community: the wider role of makerspaces in public life. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (CHI '16), 1415–1425. http://doi.org/10.1145/2858036.2858073

[10] Platt, J.R. 2015. Thirty-five percent of engineering jobs now require 3-D printing skills. *The Institute.* http://theinstitute.ieee.org/career-and-education/career-guidance/thirtyfive-percent-of-engineering-jobs-now-require-3d-printing-skills

prototyping and production situated in different individual employees. The need now is for creative individuals who encompass the whole skills package, as exemplified by FabLab practice. There is a training and consultancy need in the UK economy for individuals who can impart this knowledge to others. Now that manufacturing is concerned with mental rather than physical ability this career path is open to many disabled people if they are aware of it and choose to take it.

In our survey, we saw many examples of makerspace facilities being utilised by everyone from small local businesses (e.g. creating décor for a new café) to major industries (the makerspace in Aberdeen was frequently used by the oil industry), demonstrating the variety of ways that those with digital fabrication skills can contribute to the economy. As we have suggested previously, we can see parallels with the rise of computing in the 1980s, where skills developed amongst hobbyists working at home would eventually lead to opportunities for employment and for the creation of a generation of dot com millionaires who forged new industries.

At the present time, schools are only just beginning to introduce pupils to digital fabrication alongside traditional Design and Technology education. While universities have been embracing these technologies for some time in engineering, design and even computing departments, there remains a lack of provision for the general population, so there is still likely to be a skills gap in the future. The premise for our work is that by moving quickly now, we can create these skills amongst the disabled community.

However, it was clear from our survey that there are many other potential benefits for the disabled community beyond just the development of skills. The makerspaces we visit typically had a strong focus on outreach and were dedicated to making the benefits of digital fabrication and other technologies available to as wide an audience as possible. In fact, in this sense the makerspaces in many ways resembled libraries. While at first glance, a sedentary library and bustling workshop might seem diametrically opposed, both are intended to make resources available to everybody regardless of their backgrounds. In recent years, libraries have diversified their offerings significantly, and have often been a point for digitally excluded people to access ICT facilities.

Moreover, the makerspaces we visited placed an emphasis on the social aspects of the space and attempted to build a community where members could learn from each other. We saw examples of disabled people, especially those with autism and other similar conditions, benefiting greatly from these social aspects, which allowed them to build confidence and engage with other people while simultaneously developing technical skills.

In this way, both the development of skills and the social inclusion brought with it can support disabled people in joining the workforce.

This brings us to the final positive aspect of makerspaces that we observed: emotional wellbeing. The value of craft as a tool for wellbeing is well-established—"when we make, repair, or create things, we feel vital and effective"[11]— so it is unsurprising to find these new digital crafts can likewise be therapeutic for those engaged in them. In our own digital fabrication workshops, many attendees joined for this reason, and while some attendees chose to try creating assistive technologies, others engaged with equipment purely for the joy of creating something. One example of this was a sculptor who was having increasing difficulty working with physical materials, and wanted to explore the possibilities of 3D printing for her craft. Like the social inclusion aspect of maker culture, we can see emotional wellbeing as an enabling factor for disabled people to enter the workforce.

Case Study: FabLab Northern Ireland

Two makerspaces in Northern Ireland present one of the most remarkable examples of digital fabrication facilities being used to support skills and social issues together. Spaces in Belfast and Derry/Londonderry were commissioned by the Northern Irish government with the explicit intention that they would contribute to the peace process. They aim to bring people together around shared creative activities regardless of their backgrounds to inspire positive ways of creating economic prosperity in the region. The facilities are located at interface areas between nationalist and unionist areas of the city and are combined with other community arts facilities, including music studios, practice rooms and other bookable spaces. These spaces offered a recognised qualification to young people who took part in a training scheme.

Case Study: Westhill Men's Shed

Westhill Men's Shed is part of an international movement that originated in Australia in response to concerns about mental health in older men, who are often reluctant to access traditional support. Like makerspaces, Men's Sheds provide a communal workspace, but also provides communal areas and have expanded their provision into other areas, such as cookery lessons. Attendees are mostly older men who may be feeling isolated following a major life event such as retirement, bereavement or a stroke. The shed provides social contact and a sense of purpose without foregrounding mental health issues. Men in the

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[11] Barron, C. and Barron A. 2013. *The Creativity Cure: How to Build Happiness with Your Own Two Hands.* New York: Scribner.

shed often work on their own projects, but they also accept jobs from local businesses and organisations (e.g. making benches for a local school), so are able to contribute to the community. The shed's organiser reported many examples of huge wellbeing improvements in members, including reduced need for medication, and a Social Return on Investment analysis found a tenfold return on investment.

Supporting Disabled People in Making

While digital fabrication presents many opportunities for disabled people, any new technology also throws up barriers that create challenges for people trying to take advantage of them. One of the aims of *In the Making* was to explore what these barriers are and to begin to understand how we can break them down.

Many of these challenges are due to limitations in the technology. One of the major advantages of digital fabrication for people with disabilities is that it is computer controlled. This means that, with appropriate accessibility software/hardware, a disabled person can do things that they would be physically unable to do using traditional fabrication equipment.[12] However, the reality is that using the equipment remains physically involved (e.g. manually calibrating a 3D printer) and the software remains relatively complex and difficult to learn.[13] New applications are constantly becoming available, but this remains challenging in the short term.

Other limitations are more familiar cultural and accessibility challenges faced in any effort at inclusion. Problems remain in ensuring makerspaces are accessible,[14] and many of our participants had concerns about accessibility that discouraged them from making the most of this resource. It is also true that, at present, much of the maker community is homogenous in terms of their cultural background. For example, we were told about one example where a child from an immigrant family was not able to return to the makerspace because his parents did not feel that it was "for them". Although almost all of the makerspaces were very active in attempting to reach out beyond this demographic, they were hampered by a lack of resources and specialist training. These are obviously challenges that makerspaces share with many other public resources.

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[12] Hurst, A. and Kane, S. 2013. Making "making" accessible. In *Proceedings of the 12th International Conference on Interaction Design and Children* (IDC '13), 635–638. http://doi.org/10.1145/2485760.2485883
[13] Ladner, R.E. 2015. Design for user empowerment. Interactions 22, 2 (March 2015), 24–29. http://doi.org/10.1145/2723869
[14] Klipper, B. 2014. Making makerspaces work for everyone: lessons in accessibility. *Children and Libraries* 12, 3 (Fall 2014). http://doi.org/10.5860/cal.12n3.05

When attempting to engage people with disabilities, one challenge is of course the sheer diversity of disabilities that might be present and providing resources that can cater to this range. This was a major challenge in our own series of workshops held across Salford through 2015. The solution that developed across the workshops was a combination of non-digital activities (e.g. clay or poetry) to introduce creativity generally and 3D printing activities based on template files (e.g. personalised key fobs). In later workshops, the most successful approaches combined these activities by 3D scanning non-digitally created objects and modifying them in software. This minimised the use of software while still creating something that introduced these technologies and their capabilities. Our goal was to ensure that every participant left the workshop with an object that was personally meaningful to them.

Although the majority of participants attended largely out of curiosity, a smaller number arrived with specific things that they wanted to create and wanted to know how digital fabrication could help them. Our main way of supporting this was to have a product designer on hand who was able to spend a significant amount of time with each participant helping them to generate ambitious designs. Several participants were able to create prototype assistive technologies in this way. Other participants chose to attend multiple workshops over which they could develop their skills and attempt more ambitious projects.

Ultimately, one of our key goals in this project was to encourage participants to make use of nearby makerspaces. We aimed to take participants as far as we could with limited time, but primarily aimed to introduce the core concepts and possibilities and ignite enthusiasm that would lead them to pursue it further. However, the project also has its own equipment, including two 3D printers and a number of 3D scanners, that we intend to leave in the community after the project has concluded, most likely in service centres that combine libraries and other council services. Having these facilities locally, rather than on the far side of nearby Manchester, is particularly important for people with mobility problems, which was true of many of our participants.

In addition to making this equipment available, it is important to build associated skills and enthusiasm. Otherwise, the equipment will most likely remain unused. We have had some successes in creating 'pioneers' who can utilise the equipment and demonstrate to others. For example, one participant ran a charity organising activities for people with autism and attended with a number of her clients. Subsequently, she has begun attending the local makerspace with one of her clients and has taken on an unofficial 'greeter' role when she saw the difficulties new attendees could have.

Summary and Key Findings

- Digital fabrication can support the development of skills that will be useful in the workplace and act as a route for social inclusion and wellbeing to further support ability to work.
- It can also support the creation of new or customised assistive technologies that can support disabled people in being able to work.
- Makerspaces should be seen as community resources akin to libraries, with a strong focus on outreach and social inclusion.
- Placing digital fabrication facilities in accessible community spaces reduces the difficulties disabled people have in reaching these facilities.
- Pioneers should be created within the disabled community who can champion digital fabrication to others.