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Crafting public space: Findings from an interdisciplinary outdoor workshop on 3D printing

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Abstract:
3D printing is touted as a coming revolution in the manufacture of consumer goods. However, its use remains limited to a homogeneous group of early adopters. We discuss this mismatch between the rhetoric and reality of 3D printing in light of findings from a co-creation workshop incorporating audience engagement activities. During the workshop art and design students collaborated with craftspeople to create 3D printed objects for an outdoor exhibition. The workshop enhanced participants' confidence in 3D modelling and printing. Claims about 3D printing are best examined through hands-on experimentation by people with a diverse range of backgrounds and experiences. Moving 3D printed objects out of the lab into outdoor public spaces can add new perspectives on this rapidly developing medium. Strategies and barriers to achieving this are discussed.

Keywords: 3D printing, hacking, crafting, public space, co-creation.

Introduction

There is no lack of vision for what the future of manufacturing using 3D printing entails (*cf.* Anderson, 2010; Berman, 2012). This family of technologies has sparked the imagination of pundits and received massive media coverage, not the least for the manufacturing of gun parts (Hultin, 2013). According to magazines such as *Makezine* and Dezeen's *Print Shift*, 3D printing technologies are set to revolutionise fashion, architecture, design, food, healthcare, pharmaceuticals and many other application areas.

Furthermore 3D printing is argued to be at a tipping point and may soon enjoy widespread consumer adoption (Manyika *et al.*, 2013: 8). Information and communication technologies are increasing the level of participation in technology. Many DIY communities and user groups are experimenting, making, crafting, prototyping, fabricating and hacking

on 3D printers. Notable online communities include Makerbot Thingiverse[1], Shapeways[2], Autodesk 123D[3], Instructables[4] and the RepRap project.[5] The exchange of digital models through online services such as Thingiverse and Shapeways could alter the way products are distributed and encourage derivative objects to be created from a blueprint. There are also off-line activities organised through networks of organisations such as FabLabs, MakLabs, HackLabs and Maker Fairs that involve 3D printing.

Many members of online 3D printing communities subscribe to open source principles and openly share ideas, software and hardware. However, physical access to 3D printers remains severely restricted. Although 3D printers have been commercially available for several years, many people have never used or seen one. Surveys of online maker communities (Moilanen, 2012a; Moilanen, 2012b) suggest adoption of 3D printing is still limited to a small homogeneous group of early adopters (Rogers, 2003). These are typically white, male, middle aged and well educated. To ensure the benefits of 3D printing become more widely realised it is important to increase the diversity of the groups who can experiment with the technology. In this spirit of *democratising technology* the authors organised a workshop where people with little previous experience of 3D printing were invited to take part.

Workshop for engaging new audiences in 3D printing

The main rationale for the workshop was to encourage a diverse audience to learn about and engage with 3D printing technology. During the three days of the workshop, seven postgraduate students from disciplines such as sound design, film studies, architecture and product design collaborated with a jeweller, a stonemason and a ceramist to create a series of 3D printed objects. Apart from a product design student, none of the participants had any previous experience of 3D printing.

As a creative frame, attendees were asked to make use of outdoor public space as both a source of inspiration for design and as an informal venue for bringing 3D printed objects to new audiences. On the first day of the workshop, participants explored Edinburgh's city centre on foot to generate ideas for designs, identify exhibition locations and capture physical object geometries through photogrammetry, a technique which consists of taking a number of images of a geometry that are then stitched together to generate a digital 3D model (*cf.* Opitz *et al.*, 2012). Having been introduced to Sculptris[6], an easy-to-use 3D modelling software, alongside non-digital media such as modelling clay, participants created digital 3D models over the course of the second day. The objects were then 3D printed overnight. During the last day, the printed objects were given to their creators to remove any residual support material (a by-product of the 3D printing process). Participants were then asked to think of ways they could share their creations with a wider audience. After lively discussions, the group decided to photograph the objects in different outdoor public locations.

Drawing on the experience gained from running and participating in the workshop, we will discuss three research questions. Firstly, to what extent was the workshop effective

in introducing new audiences to the medium of 3D printing and in building their confidence in the use of this technology? Secondly, drawing on contemporary craft perspectives, how did participants see 3D printing technology impacting on their creative practices? Finally, to what extent did the use of outdoor public spaces, for both digital capture and exhibition of 3D printed objects, enable wider engagement with this emerging medium?

Contextual review

Additive manufacturing and 3D printing

3D printing is an additive manufacturing process that is currently undergoing high levels of research and development. In subtractive manufacturing processes, such as Computer Numeric Control (CNC) routing, material is carved away from a starting block. In contrast, in additive manufacturing processes objects are produced from the ground up by joining, solidifying or depositing material through techniques such as selective laser sintering, stereolithography using photopolymerising (light-curing) resins (e.g. Formlabs, 2013), adhesive particle sprays (e.g. Kulik *et al.,* 2012) and fused filament fabrication (e.g. Jones *et al.,* 2011). These are some of the main methods that fall under the heading of 3D printing, and the more general rubrics of rapid prototyping and digital fabrication (Pham and Gault, 1998).

The 3D printers available to workshop participants were two professional *Dimension SST 768* printers and an entry-level *Makerbot Cupcake* printer. Like the majority of available 3D printers, both of these devices work on the principle of plastic filament extrusion. Firstly, a 3D computer model is created, using modelling software, laser scanning or by downloading an existing model from one of the many online repositories. Special 'slicing' software then converts the geometry of the digital 3D model into machine instructions. During printing, molten plastics (thermoplastics) are extruded through a fine nozzle onto a building platform. The machine code is executed to control the relative positioning of the nozzle and platform. This allows precise control over where plastic is deposited. The plastic is deposited as thin strands which cool and solidify instantly. The strands form layers, which are stacked one upon the other, until the whole object is completely printed. Scaffolding, also known as support material, is used to build complex protruding geometries. Consumer-level 3D printers allow material to be deposited with sub-millimetre accuracy, allowing intricate objects to be produced. Nevertheless, the process is slow and somehow unreliable, and requires careful configuration for optimal result.

Craft in the digital age

Craft is sometimes understood as a trade or an activity dependent on the transfer of skills from one generation to the next. This is a simplistic view, and current discussions emphasise different aspects of craft as the product, the practise and process, or even the attributes of the practitioner. For example, Malcolm McCullough suggests that the product must be

unique: '[craft] is not about standardized artifacts, however. It is not industrial design. It remains about the individually prepared artifact' (McCullough, 1998: 21). Moreover, he emphasises the expertise and skill that the craftsperson commands, but highlights that this is not necessarily limited to manual dexterity (McCullough, 1998: 21).

David Pye suggests that there are two approaches to production: the 'workmanship of certainty' and the 'workmanship of risk' (Pye, 1968: 24). In the 'workmanship of certainty' one would be working under tight time and quality constraints, such as on an automated production line, where low error rates, consistent output and high efficiency are valued. Whereas in the 'workmanship of risk', the kind of approach that a crafter is likely to adopt, learning by trial and error is encouraged. For instance by experimenting with different processes and materials. At a cognitive level, Pye argues that *to craft* is to demonstrate the highest level of commitment to a skilled task (Pye, 1968: 79). This is echoed in McCullough's view that 'to craft is to care' (McCullough, 1998: 21).

These examples hint at the complexity underlying the word *craft*. What is important is that contemporary approaches are moving away from traditional definitions of craft (McCullough, 1998: 22). For the purposes of this paper, we are concerned with the somewhat contrary interlinkage between craft and mastery of digital technologies. Indeed digital technologies could be viewed as intimately related to craft:

> Tools and technologies have both assisted and opposed the hand throughout history; the relation is not necessarily adversarial. […] consider the example of a skilled computer graphics artisan [...] His or her hands are performing a sophisticated and unprecedented set of actions. These motions are quick, small and repetitive, as in much traditional handwork [...] the actions have a practical component, and the skill may be practiced for a livelihood and a trade identity. If we test this description against Diderot's description of craft, almost every word fits in. (McCullough, 1998: 19-20).

If one takes this view to its extreme, a computer hacker could be said to share many of the attributes of a craftsperson. Digital manufacturing techniques, such as 3D printing, challenge the uniqueness of the crafted object. The creation of the unique artefact is no longer, if it ever was, the sole domain of *traditional* craft. 3D printing allows potentially anyone to design, share, manufacture and consume one-off objects. When anyone with a computer can design and manufacture unique products, the role of the crafter, designer, consumer, and manufacturer begin to merge.

The concept the 'prosumer' (Toffler, 1980; Ritzer & Jurgenson, 2010), captures the notion of a consumer who produces. Already in the 1970s, Alvin Toffler argued in *Future Shock* that the world had entered a 'super-industrialised' society where manufacturing technologies are diversifying product choices (Toffler, 1970: 264). Using the example of the Ford Mustang car, Toffler argued the buyer is 'designing the car when deciding between the

vast configuration options, such as body, engine, transmission, modifications, upholstery, colour and equipment' (Toffler, 1970: 266).

This customisation of a standardised product like a car hardly meets traditional definitions of craft or design. Yet contemporary craft practice is increasingly about interdisciplinary approaches and exploring boundaries through new ways of working. For example, students at the Eindhoven's Design Academy approach industrial design from a craft perspective. They reject being considered as craftspeople even when many of their products are completely handmade. This combination of traditional methods and industrial manufacturing is referred by the acclaimed design curator Murray Moss as 'industrial craft' (Fairs, 2007).

One could argue that it is more appropriate to talk about craft as a spectrum, going from more *traditional* definitions to novel use of digital design and manufacturing processes. In some circles, labels like craftsperson and designer are being replaced by new terms with less historical baggage. These include maker, designer-maker, hacker and do-it-yourself. This breaking down of traditional boundaries around craft appears especially important among younger practitioners. The craft collective *We Work in a Fragile Material*[7] aims to broaden the perception of contemporary craft. They engage the public in the creative process in order to challenge the image of the final product as a precious object (Veiteverg, 2010). This brings us to the role of public participation.

Participation in public space

Whilst the general public may have heard of 3D printers through the media, they are unlikely to actually have seen or used one. 3D printers are still mostly found in places like universities, hacking spaces and rapid prototyping companies. Following Lyn H. Lofland's definition of public space, these locations could be viewed as 'private clubs' (Lofland, 1973: 19):

> [Public spaces are] those areas of a city to which, in the main, all persons have legal access. I refer to the city's street, its parks, its places of public accommodation. I refer to its public buildings or to the "public sectors" of its private buildings. Public space may be distinguished from private space in that access to the latter may be legally restricted. A private club may deny access to all but its members and invited guests. A home owner or tenant may legally lock his door to the unwanted visitor. But a city may not restrict entrance to a public street. (Lofland, 1973 p.19)

Universities in the UK are government funded public bodies. Although their facilities can sometimes be open to the public, such as libraries or exhibition space, they could equally be regarded as private clubs. Increasingly participation in higher education is conditioned by economic circumstances which follow classic patterns of social exclusion, such as race and socioeconomic class (Pennell & West, 2005). Similarly, communities and spaces dedicated to

hacking are often committed to diversity and public access. However, hacking culture has a very strong male bias. For example, studies of open source projects show that women are severely under-represented and alienated by the dominating male culture (e.g. Nafus, 2012). The mainstreaming of on-demand 3D printing services allows consumers to design and print 3D objects more easily. However, as these services are usually not dependent on location and user access to technology, the 3D printing process remains a black box to the user.

This begs the question of how a broader group of people can learn about, critique and shape the future development of 3D printing. This question echoes Marxist art critique of avant-garde art of the 1970s: who should participate in the making, interpretation and evaluation of art? (Gablic, 1984) Art critic Richard Cork argued that wider participation in art could take place through the use of public spaces:

> One of Cork's exhibitions, entitled "Art for whom?" and held in at the Serpentine Gallery in London in the spring of 1978, investigated the possibilities for artists of working within more "egalitarian" contexts than are available through galleries and the dealership system. Factories, hospitals, schools, libraries, pubs, football clubs, bingo halls, street corners, and town halls, according to Cork, are some of the options open to an artist [...] willing to make art for ordinary people instead of other artists. (Gablik, 1984: 27-28)

Following this line of argumentation, we expect that digital manufacturing methods could be practised and presented in public spaces. However, in the 1990s, actions to boost the market value of public space through artworks were camouflaged under the false banner of 'democratising art' by bringing it outside of the established institutions (Miles, 2011). Like Malcolm Miles, we argue that 'the real order of a city cannot be imposed by plan, but is woven in the repeated acts of its inhabitants' (Miles, 2011: 185). The display of 3D printed objects in outdoor spaces could act as a way of weaving creative practices and technology into the public space of the city.

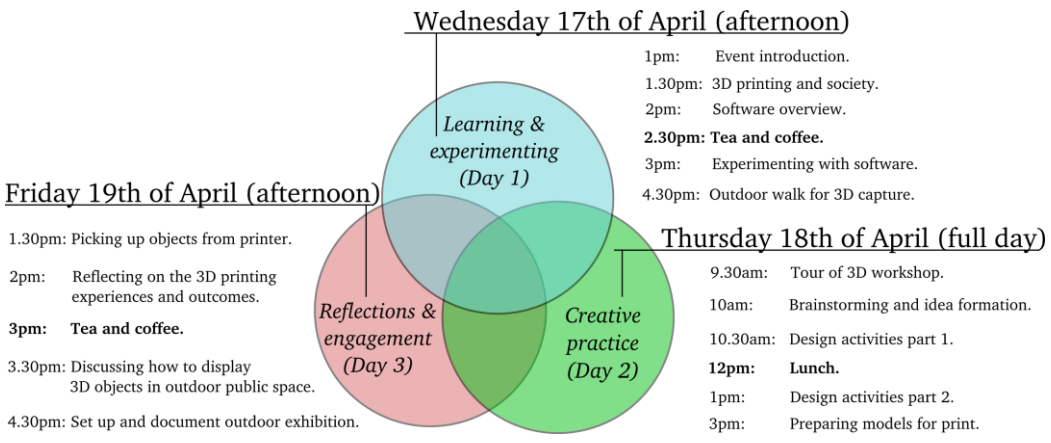


Figure 1: Workshop schedule, detailing activities and the main theme of each day.

Methods

Workshop design

Pedagogical rationale and design of activities

We anticipated that workshop attendees would have diverse backgrounds and varying levels of experience in digital modelling. Hence the two-way exchange of knowledge between facilitators and participants was a key concern. We aimed to support this through three themes: learning and experimenting, making and reflecting (see Figure 1). To ensure a minimal level of knowledge, on the first day we outlined what 3D printing is, how 3D modelling works and how outdoor public space could be used creatively. Participants were guided through the 3D printing workshop, invited to handle sample 3D printed objects and ask questions directly to the technicians running the machines. The second day was dedicated to idea generation, prototyping, modelling and printing. The last day involved reflecting on the workshop and preparing the outdoor exhibition.

A critical decision was how to structure the activities to allow people from different disciplines to learn and enjoy the workshop. In particular, we anticipated that the digital workflow might hamper those that normally work directly with physical materials, as frustrations increase when creators lack haptic feedback (Shillito *et al.*, 2001). Thus, we decided to provide pressure sensitive tablets as well as clay and other modelling materials for prototyping.

Recruiting participants

The workshop was advertised through the University of Edinburgh College of Art mailing lists. We received thirty applications from students who had an interest in the topic. However, we wanted to recruit a balanced mix of workshop participants in terms of gender, age, discipline and technical experience. This meant going outside of the university network. We decided to invite local craftspeople as this was a group who had previously expressed an interest in 3D printing, but have little access to the technology. Although we collaborated with some of the local hacker community, we did not invite them specifically as they already had access to the technology and could have dominated the workshop.

Data collection and analysis

Statements pertaining to 3D printing, craft and outdoor public space were put to participants in pre- and post-questionnaires (see Table 1). This was to track how perceptions about these topics changed over the course of the workshop. The answers were recorded using Likert scales with five intervals and analysed using descriptive statistics. During the last day of the workshop, the survey questions were followed up in an informal two-hour focus group discussion. It aimed to capture how participants felt about the objects' physical properties, the experience of the design process, and how one might encourage a wider

audience to engage with the objects in outdoor public spaces. The discussions were recorded, transcribed and analysed using thematic analysis. The answers complement and contextualise the results from the pre- and post- questionnaires.

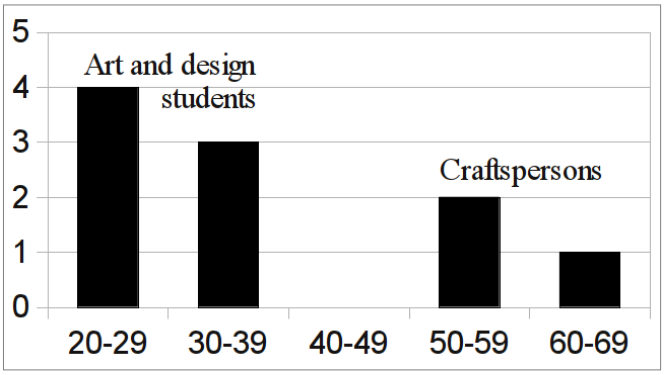
Prior to data collection, participants were given information about the research, how their answers would be used and then asked to indicate their informed consent to participate in the research. The data is reported anonymously.

1. How confident are you on the following tasks?
Using computer software to model 3D objects.
Making physical objects with a 3D printer.
Creating artwork for outdoor public exhibition.
2. Please rate the following statements about 3D printing
Working physically with the material is important to me.
My creative practice lends itself well to experimenting with 3D printing.
I have soon incorporated 3D printing into my creative work.
Modelling and printing 3D objects can be considered a form of craft.
Unique machine-made objects threaten the status of *traditional* craft.
It is easier to get emotionally attached to an object made by hand, than one made by a machine.
3. Please rate the following statements about outdoor public spaces
Exhibitions in public outdoor spaces are a valuable method for engaging new audiences.
Art should be available in public outdoor spaces, and not only in galleries/museums.
I want to share my own art by making it available in public outdoor spaces.

Table 1: Questions put to participants before and after the workshop.

Results and discussion

Although there were fifteen participants at one point during the workshop, not everyone attended all days and only ten participated in the study (five women and five men). The age distribution of respondents is shown in **Graph 1**. It is notable that the craftspeople and the students fall into two age clusters, as age is an important predictor of digital literacy (e.g. Loges & Jung, 2001).

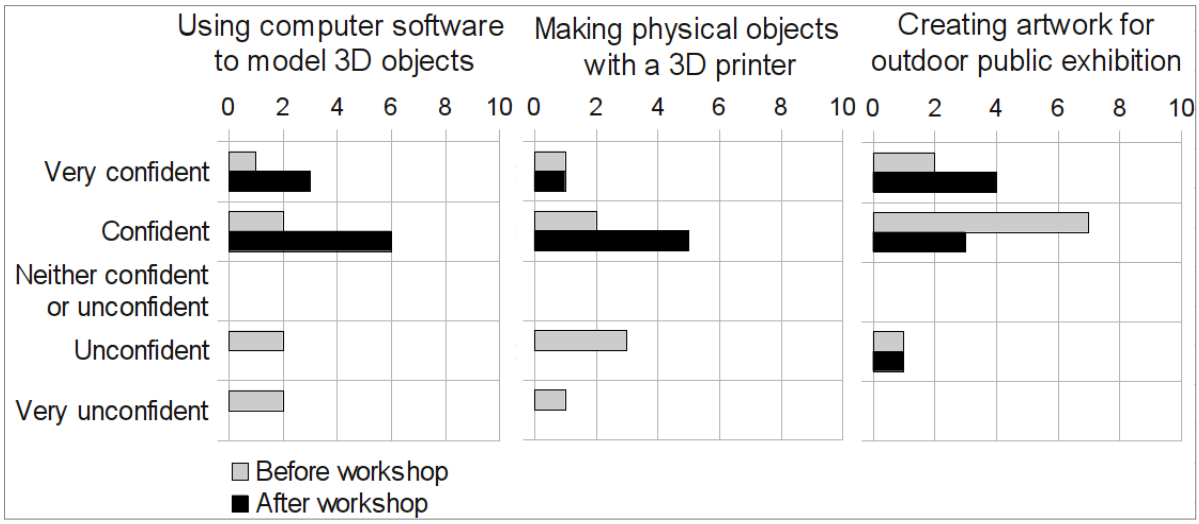


Graph 1: Age distribution of participants.

Workshop effectiveness

The questionnaires suggest improved confidence levels in 3D modelling and making 3D printed objects after the workshop (see Graph 2). There are many factors likely to account for this result. Many participants did not witness the details of each step of the actual printing process, such as preparing the 3D printer and collecting the prints. Most respondents lacked any prior 3D printing experience, so the baseline was very low. Another important factor was the choice of 3D modelling software used in the workshop, Sculptris (see **Graph 2**). All participants managed to use this software at a basic level to create objects, despite some initial fears by participants:

> It is not as hard as it looks. [...] If I had seen that a distance, I would have thought "Oh that looks quite complex - I wouldn't be able to do that". Whereas in actual fact, it is quite simple to navigate and you can get some very interesting shapes. It has been something of a revelation. (Ceramist, female, 50-59)



Graph 2: Participants' self-reported confidence levels before and after workshop.

Compared to professional parametric modelling software such as Rhino, Sculptris is clearly intuitive, fast to learn and relatively easy to use. But it is important to remember that software packages target different kinds of uses. For example, Sculptris is more akin to clay modelling and less suitable for high precision work compared to Rhino, which is closer to computer-aided design (CAD). The uphill struggle of teaching oneself a program like Rhino is a major barrier for digital manufacturing, as the experience of the jeweller illustrates:

> Before [the workshop] I would [say to myself] "I'd like to do that" [use 3D digital modelling]. But [I wouldn't bother because] it's like I've got to learn really, really slowly, this really extensive program [Rhino]. Why does it with this [computer software], if you can do it with a piece of clay or metal? [---] Now it's not like that anymore. I can quite happily see this [Sculptris workflow] easily interrelating with my practice. (Jeweller, male, 50-59)

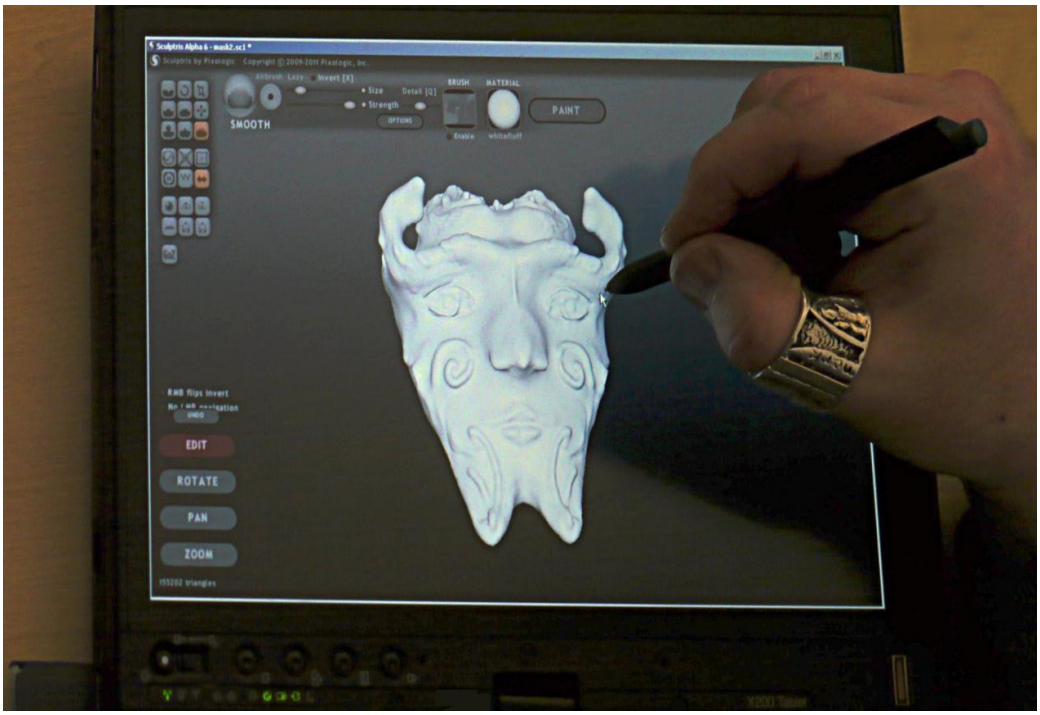
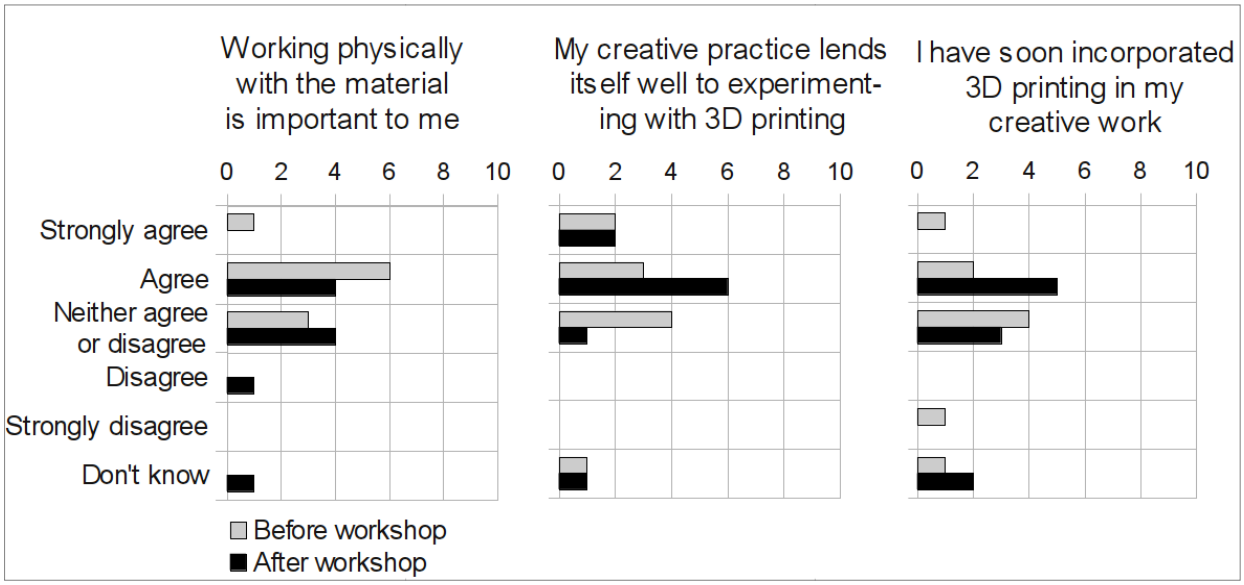


Figure 2: Jeweller working on a creation in Sculptris using a pressure sensitive tablet.

Perception of 3D printing

After the workshop, participants became more comfortable with the digital workflow, although working physically with the material remained important (see Graph 3). For example the ceramist argued that her creative practice depends heavily on working with her hands and the material:



Graph 3: Perception of material processes, 3D printing and creative practice before and after workshop.

> The thing about 3D printing that strikes me is that there's a big distance between the [physical object and] the computer. So you are completely removed from the material. There is no hand intervention at all. Whereas, with me, [my creative practice] it is all about the material. [...] It is my hand and the material together. (Ceramist)

Moreover participants agreed more strongly that their creative practice lends itself well to experimenting with 3D printing after the workshop. Experimentation is ingrained in creative practice and the concept of workmanship of risk (Pye, 1968). The following dialogue between the jeweller, the stonemason and the research student in film studies illustrates their openness to trial and error. The discussion was sparked by some faulty prints made with the Makerbot Cupcake:

> Jeweller: There are lots of things which have gone wrong and [...] come out as interesting effects rather than something that goes in the bin
>
> Stonemason (male, 60-69), replying to jeweller: You have that perspective, as somebody who works in the crafts sphere. If you like, it is all relevant. As opposed to [someone who] wants to achieve [a particular outcome and] might look upon mistakes [as something negative].
>
> Research student in film studies (female, 30-39) responding to stonemason: [Instead of] mistakes, I would like to talk in terms of experiments. [...] When cinemas were invented there were a lot of things that might be seen as

> mistakes [...] but it was the most creative period of cinema, [sowing the seeds for] a lot of things that were developed years later. With 3D printing we [...] are experimenting and mistakes can turn out to be the way forward. So it is important to create something that you might call a "safe space" [where experimentation is encouraged].

With any new technology users go through a process of domestication (Silverstone *et al.*, 1992), where they ascribe personalised meanings to the technology and develop ways of incorporating it into their daily routines. For many participants the workshop was only the beginning of this process. When asked to reflect on how 3D printing might impact their work, one of the architecture students argued that 3D printing might play a future role in his research on urban planning:

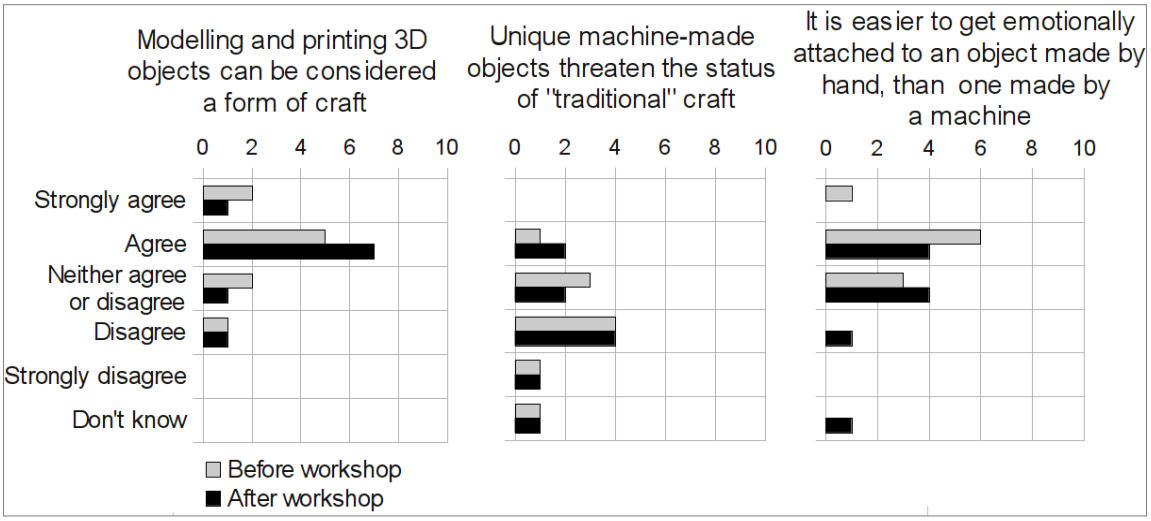
> Now I'm thinking about 3D modelling. I am considering [modelling] bioregions, mountains, the soil and geological [features]. I think this a really good tool to introduce in my research. Maybe not now, but eventually. (Architect student, male, 20-29)

Many of the craft professionals expressed a more holistic approach toward technology. To the jeweller, the ability to tinker and subvert the 3D printing process was important to his creative process:

> For me [3D printing] is just a process with potential to change. [...] Can I stop the process halfway and interfere with that process. For instance this piece here [a small 3D printed cube] looks like a natural setting for a stone. Could I stop the process and stick a diamond in there and then let the process continue? (Jeweller)

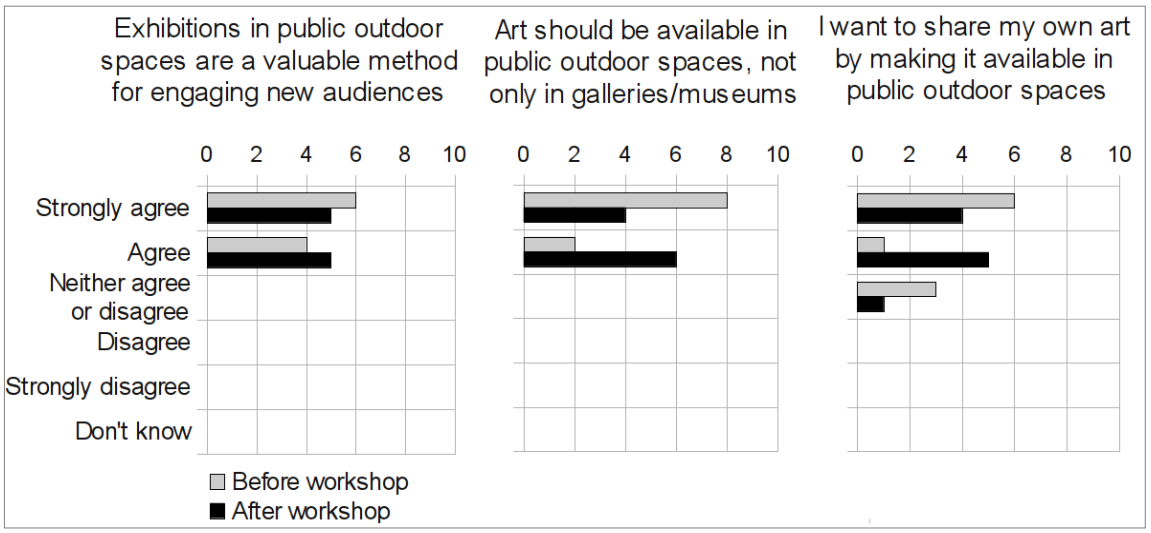
This level of experimentation could be said to amount to a form of hacking, and many participants felt that 3D modelling and printing could be considered a form of craft (see Graph 4). For example the stonemason likened it to craft because it requires a significant amount to time to master a digital workflow:

> [3D modelling] is something that is more accessible than it might appear at first sight. [...] But I think we need more time to get the most out of the tools that are there. To master a craft takes a long time to get used to the tools, and what you can actually do, what the limitations are, and how those limitations shape the direction you might go in. (Stonemason)



Graph 4: Participants' views of the status of digital 3D workflow, manufacturing and hand-crafted objects.

The ceramist, however, was less sure about whether 3D printing could be viewed as craft: 'I am not against technology at all. Every artist will need technology. [3D modelling and printing] is definitely art. But is it craft?' This perception could reflect the need of the manual craftsperson to directly touch and feel the material (Shillito *et al.,* 2001). Although, opinion was divided about whether 3D printing can have an impact on craft practice, no one felt it would replace craft. Indeed digital and manual processes can be used together to create new expressions of craft, as the work of textile designer Rachel Philpott illustrates (Philpott, 2012).



Graph 5: All participants felt art should be available to a diverse audience and in public spaces, but some felt less confident about sharing their own work in this way.

Outdoor public space and public engagement

All participants agreed that public outdoor spaces are important venues for engaging new audiences and that art should be made available in outdoor spaces. There were no significant changes in these attitudes after the workshop (see Graph 5).

The focus group functioned as a way of deciding how to display the 3D printed objects. After some initial hesitation, when participants started to discuss ideas for exhibiting the objects concepts started to flow. Ideas included attaching the objects to a helium balloon or to a pigeon, causing some laughter and raising ethical questions. Other ideas included projecting enlarged versions of the printed objects, creating a mobile game based on geocaching[8] or inserting objects into a bottle with a message and throw it in the sea. Some objects were created to be exhibited in specific ways. For instance, the creators of a cloud and rainbow object wanted to photograph it against the sky. Other participants suggested putting an object resembling a raindrop into an old, dry fountain. The craft practitioners all had prior experience of displaying their artwork in outdoor public locations, and offered insights into the associated challenges:

I have found from personal experience that the quality of the [outdoor public space] show has to be better than average [...]. As a gallery or museum is a definite focal point for the exhibiting of all types of specialism, they draw specific groups with a predefined interest. To draw new interest from new audiences into interacting with art by exhibiting in a public space [is more challenging.] [...] With regards to my own art, a lot of my work already operates on levels that express both a personal and social interaction in the private and public arena. (Jeweller)

Participants reflected on how to engage the wider public in 3D printing. Everyone agreed that engagement is not achieved by merely imposing a technology or an artwork on people. Rather, audiences must become actively involved in the production process, either creatively or technically:

> I think the way to engage a wider public in art, outside or inside, is to involve them. [...] If you involve people in art and decisions about their landscape, then I think that's always is going to be better than saying, "this is art, we're going to put it here and its *good"*. I don't think that is going to work. [---] [Whereas if you] help them design things [...] they get on board. (Ceramist)

This raises the question of how one might bring the 3D printing process out into the public space to make the whole experience more participative, rather than just showing the end product. That was not technically feasible during the workshop, but is worth exploring in the future. Many of the exhibition ideas were motivated by a concern that the objects were very small and therefore unlikely to capture anybody's attention, as opposed to how to engage at a deeper level with passers-by:

> With 3D [printed objects] the main constraint is the size. [For something in public space] to be noticeable it has to be quite large. The main challenge is to how to make something small visible. (Research student in film studies).

Sound design student (female, 20-29), responding:

> [We could] organise an outdoor show with a projector and big screen to show how the 3D printing process works.

In fact, the small scale caused some passers-by to stop and look at what the workshop participants were doing, crouching on the street to try to photograph the objects. Participants enjoyed the outdoor exhibition of the workshop, but the public engagement could have been stronger. Figure 3 shows photographs taken of the 3D printed objects in a variety of outdoors locations and some spectators.

Figure 3: Pictures from the outdoors exhibition of 3D printed objects. Some curious passersby stopped to look at and ask questions about the 3D printed objects. Photo: the authors.

Conclusion

Preconceived notions and perceptions of 3D printing were challenged through the workshop activities. Participants demonstrated a more realistic view of the opportunities and limitations associated with digital manufacturing, which is considered necessary in the process of domestication of technology (Silverstone *et al.,* 1992). Despite the time constraints imposed by a three-day workshop, the structure and activities were effective in enhancing self-reported confidence levels. However, it remains to be seen whether this new confidence will motivate participants to explore 3D printing further in the future.

After the workshop some participants reported that experimenting with digital modelling and 3D printing had helped to de-mystify it. The focus group discussions indicated that some people could see a way of using 3D printing in their work. This included a wide range of art, craft, architecture and manufacturing applications. The craft practitioners were excited at the possibility of interfering with the 3D printing process and replicating objects in an affordable way to reach a wider audience.

Since this was a first encounter with a new technology for most participants, they felt it was difficult to accurately estimate its impact on their creative practice. Moreover, the workshop identified several barriers. This includes the lack of learning opportunities and access to 3D printers (Moilanen, 2012a; Moilanen, 2012b), the need for safe learning spaces for experimentation (Lofland, 1973: 19), the significant amount of time it takes to master new software and digital workflows, and general issues of computer literacy. The craft practitioners who belonged to an older generation perceived greater barriers to adopting digital design processes when compared to the students, confirming the relationship between age and computer literacy (Loges & Jung 2001).

After some initial hesitation, the use of public outdoor space to exhibit objects and generate ideas worked quite well. However, the engagement with the wider public during the outdoors exhibition was rather ad hoc, as the interactions happened when curious passersby stopped to look and ask what the group was doing. The workshop would have created more interest if the very process of digital manufacturing had been brought out to the city's public spaces. This was not feasible for this event, but the rapid development of new 3D printers, applications and materials could make it easier in the future. In conclusion, 3D printing is an emerging technology that already appeals to the greater public. However, it is crucial that more people have the opportunity to discover the strengths and weaknesses of the technology first hand, rather than merely through sensationalist reporting. Carefully designed public workshops would be one form of intervention that may enable this process.

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