The changing role of the designer in new business models based around 3D printing technologies

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<a>INTRODUCTION: CONNECTING TECHNOLOGICAL INNOVATION TO THE DESIGNER’S ROLE

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Since the advent of the internet economy and the development of web-based companies, the question of which business model would best be able to capture and exploit internet-related opportunities has been the subject of much academic and practitioner debate. However, the role of the designer within such disruptive value-capturing structures has rarely been examined.

Because of the revolutionary effect of the internet and mobile technologies, many industries have been forced to develop new strategies and business models to meet the changing business requirements of an altered market environment. Manufacturing industries are being pushed into creating new business models inspired not only by the internet and the possibilities of connective technologies, but also because of the new ways of creating, prototyping and manufacturing goods that have been made possible by the development of 3D printing technology. These business model changes are not simply addressed at accommodating new technologies but also at dealing with increasingly important social changes like the share economy and the desire for personalization of goods. This means that those manufacturers that are able to create the right organizational infrastructure and strategy for using new technologies are also rewriting the role of the designer.

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The designer's role is no longer just to produce physical products; they are to build new sorts of processes, services, IT-powered interactions, entertainments and ways of communicating and collaborating – exactly the kinds of human-centred activities in which designers excel.

Thanks to technological innovations in additive manufacturing, that is, 3D printing, the consumer can be involved in the creation of the final product. Potential faults in a design can be iterated quickly, making it easier to adjust and solve problems. In other words, 3D printing supports improved product life cycle management, although this is not its only strength. Increasingly cheap and tiny processors, new software and cheap sensors, as well as 3D printing technology itself, have allowed designers to build products that would have seemed impossible a decade ago. Sensor technology that was originally created to track nuclear material now is used to enhance experiences like at Disney World where new Magic Bands, a technological bracelet, guides the visitor to the park. Joris Laarman, (www.jorislaarman.com) lets algorithms make crucial design decisions for 3D printed chairs in that cells in the chair can be packed closer together or farther apart depending on where they fall in the 3D printer's structure. This cellular approach to design transforms traditional production, which relies on assembling premade components.

As Cliff Kuang said in an article in *Wired* (October, 2014) we are approaching a new era, 'the era of Silicon Modern' when technological innovations become commonplace and designers become a competitive advantage. As the designer's activities are not easy to copy, in this new era designers are strengthening their competitive role. On the one hand, the designer becomes an important intermediary in the creation of breakthrough ideas aided by a deep understanding of consumers' lives and skills in using innovative technologies and materials. This allows them to innovate and build new value into the output. On the other hand, organizations now need to compete to recruit and retain designers who are able to develop and evolve their roles in this new context. The result is a virtuous cycle that can produce better products.

Rather than asking designers to make an already developed idea more attractive to consumers, companies are now asking them to create innovative ideas that meet consumers’ needs and desires in order to create not only products but new experiences. The former role is tactical, and results in limited value creation; the latter is strategic, and leads to new forms of value. In this framework designers interact with 3D printing not just as a prototyping technology, as was the case in the past, but as an inspiring, creative manufacturing technology that requires a different way of thinking about and approaching design issues.

In this chapter we investigate three cases where the use of 3D-based technologies are creating a new professional profile for those designers able to inspire, ideate and implement innovation. In these contexts the design profession is both disrupting and being disrupted by the exigencies of new manufacturing business models.

<a>FROM RAPID PROTOTYPING TO RAPID MANUFACTURING

3D printing technology first emerged in 1977 when W.K. Swainson suggested a method, very similar to the modern Stereolitography (SLA), of creating 3D objects directly by using two electromagnetic radiation beams and a sensitive polymer that solidifies in the presence of the beam (Campbell et al., 2011). Others claim that Chuck Hull was really its inventor: his company, 3D

Systems, sold the first commercial 3D printing machine in 1986. The same year that Chuck Hull commercialized SLA technology, Carl Deckard filed for a patent on Selective Laser Sintering (SLS). However, the first published account of a printed solid model was made in 1981 by Hideo Kodama of Nagoya Municipal Industrial Research Institute (Bogue, 2013). Subsequently, many publications and articles have been written on the technology: Holmström and colleagues (2010) and Lipson and Kurman (2013) detailed 3D printing's current and future advantages and benefits (Table 3.1).

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Table 3.1 The benefits of 3D printing technology

No tooling is needed, significantly reducing production ramp-up time and expense
No assembly required
Manufacturing complexity and variety are free
Small production batches are feasible and economical
Possibility to quickly change design
Allows product to be optimized for function (for example, optimized cooling channels)
Allows economical custom products (batch of one)
Less waste by-product
Potential for simple supply chains; shorter lead times, lower inventories
Zero skill manufacturing since a 3D printer gets most of its guidance from a design file
Design customization and precise physical replication: 3D printing will extend the digital

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precision of a digital music file to the world of physical objects
Unlimited design space
Compact, portable manufacturing: per volume of production space, a 3D printer has more manufacturing capacity than a traditional manufacturing machine
Infinite shades of materials: combining different raw materials into a single product is difficult using today’s manufacturing machines; as multi-materials 3D printing develops, we will gain the capacity to blend and mix different raw materials

<fo>Now, after four decades of development and use, principally as a rapid prototyping technique, 3D printing is rapidly transforming manufacturing-focused enterprises and creating new business models around its use. Cohen et al. (2014) suggest that 3D printing (also known as Additive Manufacturing (AM) technology) is causing significant disruption to the conventional way of designing and producing products. This provides the underlying motivation for this chapter in investigating the phenomenon in terms of a firm’s value creation and business model viewpoint. A number of research articles on the AM process and associated 3D technologies have been published, but the majority of these studies cover the issue from a technical perspective or examine how AM technology is implemented in various industries. Few have looked at the impact of the technology on how business is done, and none that we are aware of has examined the potentially transformational role of design in this new technological environment.

<a>ADDITIVE MANUFACTURING APPLICATIONS

3D printing technology enables small quantities of customized goods to be produced at relatively low cost, and nowadays, a diverse range of AM systems are being used to fabricate products ranging from sporting goods, jewellery and fashion items to aerospace components, automotive tooling and medical implants. In this section we describe some of the cases where 3D printing is starting to become a normal part of the manufacturing business model.

<b>Clothing

Shapeways is a company that has developed 3D printed nylon clothing that is shaped to the exact body dimensions of the person ordering it. Their first 3D printed clothing line is the N12 bikini, made from Nylon 12. The entire design is based on a body scan (www.shapeways.com/n12_bikini). Another firm, SeamBot, has also developed the ability to 3D print clothing and fabric. It combines existing design and measurement technologies with proprietary sewing automation technology to enable in-store production of custom made-to-measure clothing (www.seambot.com).

<b>Guitars

Traditionally, guitars are made out of wood (and more recently plastic) using a subtractive method. In contrast to AM processes that create pieces by fusing layers of material together to build the part from a zero base, subtractive manufacturing starts with a block of material and removes unnecessary excess until only the desired shape remains. It is now possible to create a near-perfect acoustic guitar with 3D technology; aguitar printed by Scott Summi was the first of its kind. Every part of it was 3D printed except the neck and the strings, and it took about two hours to complete (http://3dprinting.com). A guitar made using traditional methods can take anything from a few days to several months (www.acousticguitarforum.com/forums/archive/index.php/t-249907.html).

<b>Houses

Behrokh Khoshnevis, an engineering professor, described in 2014 how a full-sized house could be 3D printed in less than 20 hours. The Villa Asserbo project by the Danish Eentileen Arkitektur uses 3D printing to achieve sustainable building practices, a system that could be used to replace slum areas with affordable housing or provide quick housing for victims of natural disasters (http://facit-homes.com/).

<b>Camera Lens

It is now possible to 3D print camera lenses, although they are not yet of the same quality as traditionally made lenses. Open source design portals such as Thingiverse (www.thingiverse.com) contain examples of 3D printed camera lens blueprints uploaded by designers who allow others to download them for free and improve upon them. Some 3D printers are already capable of printing glass objects, and standards are improving rapidly.

<b>**Prosthetics**

Robohand is an IndieGogo crowdfunding campaign established in 2011 (www.robohand.blogspot.it/) after its creator, Richard van As, lost four fingers on his right hand in a woodworking accident. Faced with the sum of $10,000 for a mechanical prosthetic, he decided to build his own prosthetic hand instead. Using a 3D printer, he did this at home. Robohand is an open source idea, and the file is available for download from Thingiverse. Robohand has now been fitted to a number of children worldwide who have lost their hands (www.indiegogo.com/projects/robohand#/story).

<b>Body Parts

In 2014, a custom 3D printed prosthesis developed by NOVAX DMA (http://novaxdma.com/) was implanted in a patient with a dangerous fracture and large defect in the skull. This used the Trabecular Titanium system, a multi-planar structure based on hexagonal cells that resembles the porous structure of the trabecular bone.

Finally, Modern Meadow invented a tissue engineering technique based on bioprinting, the 3D assembly of tissues driven by computer-controlled processes (www.modernmeadow.com/). Similarly, Organovo, a San Diego-based research company, has printed human liver tissue capable of performing the normal functions of a liver (www.organovo.com/).

<a>THE CHANGING ROLE OF THE DESIGNER

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As described in the previous section, 3D printing technologies are increasing being used in a range of different industries. In each of these cases the designer plays an important role through:

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- Building relationships with customers: designers can interact with customers in order to create a tailored product that can be customized for each individual. Although understanding customers is second nature to designers, the use of 3D printing brings the relationship that much closer, and brings in the interaction with technology to a greater extent. In this context, the designers need to understand not only customers' need but every nuance of our everyday activities and human behaviour. The prosthesis is an example of extreme customization in which the role of the designer is vital in terms of understanding and translating their particular needs. In another example, the Michelangelo Hand built by Advanced Arm Dynamics, after having formulated a set of design requirements the design process began with brainstorming between designers and customers followed by rough pencil sketches and finally detailed computer-aided design work using CAD software (Wired, 2014).

- Building relationships with the organization's manufacturing/prototyping functions: after interacting with customers, designers know how to interact with prototyping and manufacturing. Using the prosthesis example again, as the mechanical design progressed both electrical and mechanical components were sourced and integrated into the design, which was continually updated with new iterations each day until it was optimized enough for manufacturing purposes.

- Using different resources: using 3D technologies forces the designer to learn how to use new materials as well as how to use the new technology itself. This applies not only to 3D printing but all technologies linked to fast prototyping, such as scanning, laser cutting, conversion software and the innovative materials that are used with them. This means that the quality of the finished product, in addition to the manufacturability, can be designed into the product specifications.
- Developing and applying different competences: faced with the need to solve new problems, in new industries and technologies, designers' 'design thinking' and expertise in methodologies, such as immersion in customers' behaviour, allow designers to apply novel design techniques and approaches to different fields, different technologies and subjects.
- Approaching new problems: designers are experts in solving new previously unencountered problems. One example is in the personalizing of prosthetics. Traditional sockets are hard shells custom-tailored to fit a stump, but the leg volume can fluctuate more than 10 per cent over time, making walking uncomfortable. The 'infinite socket' from LIM Innovations seeks to fix that problem by replacing the hard shell with an adjustable endoskeleton. Using a 3D scan of a user's leg and stump, the designers curve carbon fibre struts and shape them with a computer numerical control (CNC) router (Wired, 2014).</bl>

The new role of the designer has implications for organizations' value creation. The 3D printed solution arrives in the form of a customized product or service where all the functions of the organization can be connected around customers. Companies are now better able to explore and exploit new opportunities, overcoming old technological and material problems far from their core competences, and using the designer's ability to identify customers' needs and solve them through orchestration of external resources. In order to exploit new value generated by the development of 3D printing technologies, new business models are emerging in which designers have new, and increasingly important, roles. We discuss these in relation to three 3D printing companies in the next section.

<a>NEW 3D-RELATED BUSINESS MODELS: QUIRKY, I.MATERIALISE AND FAB LABS

<fo><b>Business Model 1: The Design Orchestrator

<fo>Quirky is a maker of consumer products that turns crowdsourced invention into retail products with a manufacturing process based on 3D printing technology. Since its launch in 2009, Quirky has attempted to change the way the world perceives product development. Their process, which goes from an idea to a final product, involves a plethora of actors of different types. Each week new ideas are submitted by dozens of amateurs including kitchen workers, technology experts and jewellers. Then, hundreds of online community members (or 'Quirks') – mainly made up of hobby inventors, students, retirees and product design enthusiasts – weigh in on the products and vote for their favourite submissions. The two most popular ideas are sent to an in-house team of engineers/designers to research, render and prototype. Kaufman (Quirky's founder) and his team

cull the results, sort out potential patent conflicts or production problems, and then make the final call on the week's winner.

Quirky's manufacturing process involves a small factory with 3D printers, a laser cutter, milling machines, a spray-painting booth and other bits of equipment. Its product development team makes a prototype. Users review this online and contribute towards its final design, packaging and marketing, and help set a price for it. At every stage – design, colours, naming, logo development – the community contributes. The best suggestions are incorporated. However, even if a product gets community approval, it will only make it to market if enough web surfers pre-order it to cover production costs. According to Kaufman, this is where the company finds out if a good idea is a good product. By using its community as a sounding board, Quirky can quickly establish if there is a market for a product and set the right price before committing itself to making it in large quantities. Quirky then looks for suitable manufacturers. The product is sold on the Quirky website and, if demand grows, by retail chains. In fact, less than a third of Quirky's products are actually produced in the end. However, it claims to bring three brand new consumer products to the market each week

Using its community, Quirky collects the wide range of multi-disciplinary skills needed to turn an idea into something tangible. A background in design, electrical engineering, marketing, fund raising and access to retailers and manufacturers are all required skills that can be found inside the sourcing community in order to complete and sell a product. Kaufman calls this process 'social product development'. However, the company has a number of experienced in-house staff and describes the product development process as 'enabling a fluid conversation between a global community and Quirky's expert product design staff" (The Economist, 2012). Thanks to 3D printing technology, the speed with which Quirky turns designs into products is much quicker than normal product development processes. As the founder suggests: ‘The amount of creativity that happens when you are standing next to a machine that’s making hundreds of thousands of things is much greater than when you are working 4,000 miles away … your mind is spinning as to what else you can design for the machine to make’ (The Economist, 2012).

Quirky shares its revenue directly with the people who helped them make successful decisions, earning ‘secondary influencers’ a portion of future sales revenue. The community members that participate in any aspects of product creation, from design to naming and coming up with a tagline for a piece (‘Protect Your Produce’ is the slogan for the Mercado farmers’ markets shopping bag, which Quirky developed) will receive a small share of the profits (https://www.quirky.com/). Quirky also handles patents and standards approvals and gives a 30 per cent share of the revenue from direct sales to the inventors and others who have helped.

In this type of business model, the impact of changes such as the rise of social media, the use of internet communities, as well as the technology itself, have meant that the designer’s role is radically different from those typically found in traditional manufacturers, whether they are located within the firm or outside it. The creative input and ideation tends to come from external, independent individuals, whether formally trained as designers or not, who have to fight within a highly competitive market place for their ideas, and any income they may achieve from their efforts. The internal designers, or design ‘adjusters’, have to be skilled at selection and improvement rather than ideation and creation on their own account. These attributes suggest they may be more on the ‘adaptive’ end of the adaption–innovation continuum (Kirton, 1984, 2004) than other designers, preferring to improve what already exists rather than challenge the status quo and create new paradigm-breaking, ideas from scratch. As this is a relatively rare attribute to find within the design community (Rieple, 2004), companies that are able to recruit such staff may have the basis for competitive advantage. They may also need to work at a much faster pace than is usual, a factor that also has implications for the selection and training of designers working within such business models.

<fo><b>**Business Model 2: The Design Adjuster**

<fo>Our second example of a new 3D-related business model is epitomized by a company, i.materialise, an online 3D printing service based in Belgium. It was formed as a spin-off from Materialise, a product development and prototyping company. i.materialise's value proposition is that it offers everybody the possibility to turn their ideas into physical reality, to develop their own individual non-standardized products. Given that many of its customers are not expert designers, it provides support in the form of 3D printing tools, software and design resources. This allows individuals and small-scale makers to become producers, and even sellers, of their own designs. Part of its business model is that individuals can not only make their own products but earn a percentage of any future sales made by i-materialise on their behalf (i.materialise.com). i.materialise provides the platform for designers to demonstrate their work and sell their products based on its worldwide distribution network, allowing potential buyers to access a collection of different products that can be 3D printed on demand.

The process starts when a customer uploads their project file to the service. A range of 3D software is used to create design files that can be uploaded to the website. Tinkercad, 3D Tin, 123 autodesk and Google Sketchup programs enable novice makers to design 3D printable products without previous expertise – the maker can just open the browser and start creating his or her own products in a relatively user-friendly and intuitive way. i.materialise supplies a range of 3D printing materials, allowing makers to choose the quality and look and feel of their product. This allows a choice of production price. The product is then manufactured in 5 to 15 days.

In this business model one disruptive effect is on the design consultancy profession, which becomes of less relevance if consumers can pick designs off the digital 'shelf' and make their own products. Instead, the designer's role is front-loaded into the development of product specifications that can be customized and digitized. The designer has to have competences in the presentation of product outlines on digital media that will attract non-expert consumers. i-materialise's own in-house staff have to have expertise in website and process design, sufficient so that the novice 'designer-maker' will feel able to understand the process.

<fo><b>Business Model 3: The Design Enabler

<fo>Our third example of a new 3D printing technology business model is not a single organization. Fab labs (fabrication laboratories) are a network of small-scale workshops offering personal digital fabrication facilities. A Fab lab is generally equipped with an array of flexible computer-controlled tools that cover several different length scales and various materials, with the aim of allowing users to make 'almost anything'. This includes technology-enabled products generally perceived as previously the province of mass production. Fab labs have empowered individuals to create smart devices for themselves.

Each Fab lab typically includes:

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- A computer-controlled laser cutter, for press-fit assembly of 3D structures from 2D parts.

- A larger (4’ x 8’) numerically controlled milling machine, for making furniture- (and house-) sized parts.
- A sign cutter, to produce printing masks, flexible circuits and antennae.
- A precision (micron resolution) milling machine to make 3D moulds and surface mount circuit boards.
- Programming tools for low-cost, high-speed embedded processors.</bl>

Many Fab labs are members of an international network of organizations across Europe, the USA and elsewhere that share knowledge and resources. One benefit of this network is the ability to diffuse education, learning and research as well as business opportunities. The networks of Fab labs share an evolving inventory of core capabilities allowing people and projects to be allocated appropriately. They have also developed courses in conjunction with universities that educate young people in the skills of making high-tech products.

Manufacturing in Fab labs is localized. For manufacturing companies there is therefore no need for expensive and/or risky outsourcing, and because of 3D’s ability to make small quantities cheaply, there is no need for expensive set-up and tooling costs. Fab labs make it possible to produce in a cheaper and faster way, allowing experimentation and relatively risk-free failures meaning that the hunt for low-cost locations becomes less necessary. The differences from the i.materialise model with which it shares similar empowerment of the novice designer is that expertise is devolved and shared.

<a>NEW 3D-LED BUSINESS MODELS

A key feature of all the business models that we describe above is that non-experts can become designers and makers of small quantities of different products. The monetization of the product design and manufacturing process, of selling small numbers to few customers, is economically viable thanks to digital platforms such as Quirky and i.materialise and the open digitization of the design process. The underpinning philosophy is based on the concept that a collaborative community outside the organization can develop an idea into a product ready to be sold or used (Chesbrough, 2006; Rieple and Pisano, 2015) The ‘dis-integration’ of the conception-conceptualization-engineering-production-sales activities chain of business processes (Porter, 1980) and the breakdown of integrated value chains (Porter, 1980) has given rise to companies specializing in micro-activities.

Large firms such as IBM, eBay, Autodesk, PTC, Materialise, Stratasys and 3D system are developing platforms on which other companies will build and connect. The role of platform provider is still very much a developing competitive field:

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Platform owners will be powerful because production itself is likely to matter less over time. Already some companies are setting up contract printer farms that will effectively commoditize the making of products on demand. (D’Aveni, 2015)</quotation>

Those that control the digital ecosystem will sit in the middle of a huge volume of industrial transactions, collecting and selling valuable information. Since the first industrial revolution the power to make things at an economic scale has belonged to those who owned the means of production, which has meant big factories, big companies and the mass-market goods they were built for (Anderson, 2013).

3D printing technology will in time affect nearly all manufacturing ecosystems and value chains. Petric and Simpson (2013) describe it as a disruptive technology impacting how products are designed, built and delivered. AM technology enables local production and collaboration between various stakeholders, both within and outside the formal boundaries of the organization. Product delivery time to the end-user shortens and transportation costs decrease when an AM service provider is able to produce and deliver the product locally (Petric and Simpson, 2013). AM enables design for function instead of design for manufacturing (D'Aveni, 2013). Design for manufacturing sets limits to product forms and structures (Press and Cooper, 2003), but AM technology enables a novice to design and produce even complicated forms and structures. It changes the design into a digital format, easy to share and difficult to protect file, for example, a 3D scanning device makes it easy to reverse engineer products by analysing and defining their geometric information. Designers need to become 'smart business designers' enlarging their vision of managing, not only the design process but also incorporating other important organizational activities, for example, networking with consumers or design providers, or altering the organizational structure. As a result, some important questions need to be considered by executives, such as how, where and when products and parts are fabricated, what network of supply chain assets are put in place, what mix of old and new processes would be optimal (D'Aveni, 2015) and – critically – what role should designers have in any of these changes. Moreover, if a company becomes able to produce and sell different products from different industries, which strategic decisions will be the correct ones? And if the organization's role within the supply chain changes, what should the organization's role, asset requirements and investments be? Are new roles necessary? Could it be useful to create a design technology manager, for example?

Combining other technologies such as embedded technologies and the better known ‘internet of things’ with AM processes helps designers to better understand the needs and behaviours of clients. The result is a more customized product that enables continuous improvement and changes that can be modified each time the clients’ needs change. These new technologies will inevitably mean the reconfiguration of strategies and operations, given the myriad new options for fabricating products and parts. Transitioning to 3D equipment and design can reduce direct costs (D’Aveni, 2015), changing the manufacturing methods (for example, AM, in a more standard way or in a hybrid way) and finally modify the selling process (for example, creating a customer user interface where they can choose different product configurations). In this framework it is easy to perceive a possible change also in organization value change and company capabilities. One example is UPS that is starting to ‘customize parts to customers as needed, instead of devoting acres of shelving to vast inventories’.

<a>CONCLUSION

<fo>3D printing has the potential to change much of the manufacturing industries’ value chains and business models worldwide. This process is still in its early days, and is limited because of the limitations of materials and 3D printing capabilities, but the potential is immense given the size of the manufacturing sector (Anderson, 2006). This new era is starting to redefine the ways we design,

buy and distribute products. Normally, designers interact with customers in the development of new products at the behest of an organization, in line with customers' requests or in order to improve existing products. This can also be the case in some 3D printing business models – i-materialise, for example. However, in all three of the business models we describe the designers' role has changed to one that is much more central to the relationship between organizations and customers and even potentially offering activities, strategies and positioning in a manufacturing industry as a whole. As D'Aveni (2015) highlighted, 'companies will need to imagine how their customers could be better served in an era of additive manufacturing': designers will need to approach the design process in ways that were not possible before by providing features and benefits to individual customer requirements, but also by overcoming the restrictions and delay that are currently prevalent.

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