The End of Fashion: Clothing and dress in the age of globalization

Edited by Adam Geczy and Vicki Karaminas

Chapter 8

Sustainability and Digitalizaton

Professor Sandy Black, Centre for Sustainable Fashion, London College of Fashion, University of the Arts London

s.black@fashion.arts.ac.uk

Introduction

 'Fashion is often very old-fashioned' said Ines Haag, of avant-garde design duo Bless when I interviewed her and partner Desiree Heiss in 2011 for *The Sustainable Fashion Handbook*[1]. She was particularly referring to how conventional the teaching of fashion was in colleges, where innovation should be paramount. The sentiment that fashion is old fashioned has been repeated more often recently by influential people in fashion, including designer Stella McCartney, speaking on issues of sustainability at London College of Fashion (LCF)[2] , trend forecasting guru Li Edelkoort reaffirming her 2015 Anti-Fashion Manifesto in London[3], and by designer Prabal Gurung at the 2017 Copenhagen Fashion Summit of industry leaders[4]. Whilst clearly making good journalistic copy, this sentiment also highlights the paradoxical nature of fashion – its ethos is predicated on speed and novelty, yet the industry itself has been slow to change and develop from the practices and schedules established in the mid 20th century, especially in relation to both sustainability and digital technologies.

Contradictions abound, particularly when the complexity of contemporary globalized fashion supply chains and issues of sustainability are factored in[5]. Fashion is the craftsmanship of couture and bespoke set against high volume cheap fashion;

---

[1] Sandy Black, "Fashion is often very old-fashioned" in *The Sustainable Fashion Handbook* ed. Sandy Black (London: Thames & Hudson, 2012), 116.

[2] Stella McCartney in conversation with Lucy Siegle, London College of Fashion, 14th Nov 2016

[3] Robert Cordero 'Li Edelkoort: Fashion is old fashioned'. VOICES London conference. Business of Fashion 5th Dec 2016, available at www.businessoffashion.com

[4] Designer Prabal Gurung speaking at Copenhagen Fashion Summit, Denmark 11May 2017, focused on accelerating action towards sustainability in fashion.

[5] Sandy Black, *Eco Chic: the Fashion Paradox* (London: Black Dog Publishing, 2008); Kate Fletcher, *Sustainable Fashion and Textiles. Design Journeys* (London: Earthscan, 2008)

the luxury of New York's Fifth Avenue or London's Bond Street contrasted with the poverty of many producer communities; the inherently wasteful cycles of seasonal change, that also sustain livelihoods and generate crucial income; an obsession with the new coexisting with the valorization of vintage. The rise of ubiquitous mobile phone technology, has stimulated e-commerce in the fashion space[6], and the desire for faster access to fashions has fueled recent disruptive initiatives such as the "See now, buy now" trend to monetize the catwalk by selling direct to the public, pioneered by brands such as Burberry and Tommy Hilfiger. The realization has grown within the industry that the established fashion system - based on bi-annual seasonal designer presentations to wholesale buyers travelling the globe between the key fashion capitals – seems increasingly inappropriate in the 21st century digital economy. External pressures such as natural resource depletion, escalating consumption and waste, globalized, conglomerate-led markets and financial fluctuations driven by the accelerating pace of fashion cycles, coupled with high profile designer tragedies, resignations and turnover at luxury fashion brands, all strongly evidence that the current fashion system is unsustainable from the perspectives of environment, economy and now its creative leadership.

Nevertheless, the fashion industry plays a significant role in many economies around the world, including the UK. According to a 2017 fashion industry report, global apparel and footwear consumption is projected to rise by 63%, to 102 million tons in 2030[7], increasing the imperative for the industry to address its vast environmental and social footprint. There is a critical need for fashion research (both academic and industrial) to take a radical lead in shaping a more economically, socially and environmentally sustainable fashion industry based on alternative paradigms and business models that harness new ways of creating and producing fashion, and engaging with consumers through co-creation and novel experiences.

Research commissioned by the British Fashion Council (BFC) in 2009 (updated in 2016), shows the continuing economic significance of the fashion industry to the UK – valued at £28 billion to GDP, an increase from the 2009 figure

---

[6] 29% of total spending online is on clothing and footwear, up from 13% in 2011 (Mintel Market Report 2015)
[7] Global Fashion Agenda and Boston Consulting Group 2017 *The Pulse of the Fashion Industry* report p10. Available at www.copenhagenfashionsummit.com/pulsereport

of £21billion and more than double the value of the automotive industry[8]. According to business research organization Mintel, £27billion worth of womenswear ready-to-wear was sold in the UK in 2015, predicted to grow 23% by 2020 to £32billion[9]. The UK designer fashion sector (excluding retail), recognized as a creative engine of inspiration and innovation for the wider UK and global industry, is comprised of a high proportion of innovative micro and small businesses[10]. These design-led businesses have the capability to be highly agile utilizing local and novel smaller-scale production methods and practices to meet changing demand efficiently and respond to consumer needs, but often struggle to survive[11]. With their ability to maintain control of their entire supply chain, these micro and small businesses are often pioneers, testing novel business models and design practices that also work towards full transparency in environmental and ethical practices.

Since the turn of the millennium, a dramatic shift has taken place towards a digital economy, resulting in significant disruption in many sectors of commerce including the music industry and publishing, together with the rapid development of digital visualization stimulated by the fast-growing gaming sector and film production. However, fashion deals in physical products as its core practice and has been slower to take up the digital challenge and opportunities beyond marketing and retail, and especially in design and manufacturing.

As Normann predicted in 2001, the digital economy has liberated us from the constraints of:

- Time, when things can be done,

- Place, where things can be done,

- Actor, who can do what (human and non-human)

---

[8] worth £28 billion (including retail) according to figures released by the British Fashion Council and Oxford Economics in February 2017, up from £21bn in 2009, and £26billion in 2013. http://www.britishfashioncouncil.org.uk/pressreleases/London-Fashion-Week-February-2017-Facts-and-Figures.

[9] Mintel 2016 *Clothing Retailing – UK*. October 2016 report.

[10] DCMS, *Creative Industries Mapping Document*. (London: UK Government Department of Culture, Media and Sport, 1998); Centre for Fashion Enterprise. *The UK Designer Fashion Economy. Value relationships- identifying barriers and creating opportunities for business growth.* Report commissioned by NESTA (London: CFE, 2008); British Fashion Council (BFC) and Oxford Economics, *The Value of the UK Fashion Industry: economic considerations for growth* (London: BFC, 2010).

[11] Christopher, M., R. Lowson and H. Peck, "Creating agile supply chains in the fashion industry." *International Journal of Retail & Distribution Management*, 32:8 (2004); Wendy Malem, "Fashion designers as business: London". *Journal of Fashion Marketing and Management,* 12:3 (2008).

- Constellation, with whom it can be done.

This new paradigm of time-place-actor-constellation has particularly impacted the dissemination of fashion through imagery – now instantly available globally from live streamed catwalk presentations, and arguably more significant than the products themselves. Even before the current digital revolution, McRobbie's 1998 sociological study of British fashion designers highlighted the power and significance of fashion imagery disseminated through media channels – at that time predominantly printed fashion magazines.

> Is designer fashion, as the respondent suggests, really about spectacle and the production of images, a kind of service sector to the high street fashion retailers and to the wider mass media? [12]

After a slow start, digital marketing and e-commerce have now gained significant traction in the fashion industry, overcoming the initial skepticism that consumers would not buy clothing or accessories that they could not touch, feel and try on. Recent statistics show 68% of UK internet users buy clothing and footwear online and 29% of total spending online is on clothing and footwear, up from 13% in 2011[13] and global e-commerce luxury fashion sales are predicted to increase fourfold from 3% in 2010 to 12% by 2020[14]. Many consumers now shop using multiple channels and combine physical browsing with online purchasing or vice versa. The growing acceptance of online sales platforms has led to an increasing number of initiatives to create virtual try-on systems online and in retail stores, such as Fits Me (http://fits.me)[15]. Experiments with virtual reality (VR) and augmented reality(AR) consumer visualization systems are prevalent, with predictions of an important future for this technology as a new marketing channel that can bridge the physical and digital. For example, Top Shop in London, and Tommy Hilfiger in the US staged simultaneous in-store VR presentations of their 2015 catwalk shows via immersive headsets, and in 2016 London designer Martine Jarlgaard invited buyers to a virtual

---

[12] Angela McRobbie, *British Fashion Design. Rag Trade or Image Industry?* (London: Routledge, 1998), 69.

[13] £12.4billion spent on fashion online in the UK in 2015, up 16% from £10.7billion in 2014 (Mintel 2015); cited by BFC Press Release 10 February 2017

[14] McKinsey and Business of Fashion report, *The State of Fashion*, (London, 2017), 10.

[15] Luciano Batista, *New Business Models Enabled by Digital Technologies. A perspective from the fashion sector.* A report to NEMODE, (2012); Black, *Sustainable Fashion Handbook*, pp 292-3.

showroom to experience a novel mixed reality fashion presentation using holograms superimposed into the space that could be experienced in the round by wearing the headset[16] (Fig. 1).

However, despite advances in presentation and marketing, many design and production aspects of the fashion industry are still comprised of fundamentally craft–based practices: designers creating by draping cloth on a dress stand, or using tailoring techniques, couture-level sewing or embellishment and pattern cutting. Most importantly, garments are still produced by skillful individuals using manually operated sewing machines, a practice found in factories around the globe at every market level of manufacturing including the high volume markets. Although aspects of the design and mass production of clothing such as bulk fabric cutting and industrial knitting have been largely automated and computerized in developed countries, this is not the case in many emerging producer nations such as Vietnam and Bangladesh.

It is also not the case within the small creative enterprises comprising the majority of the UK designer fashion sector - often micro businesses set up by designer-entrepreneurs shortly after graduating from one of the UK's many higher education fashion courses, especially those in London. In common with current UK trends, where 95% of all businesses are classed as micro enterprises[17], the designer fashion sector consists largely of businesses with under 10 employees, many being start-ups in their first few years of trading. Around 80% of the designer fashion businesses in Britain (estimated at 400 by Centre for Fashion Enterprise[18]) are located in the London area because of its status as a fashion and media city. Due to the fast cycle of seasonal fashion, designers operate in an extremely time-sensitive and high-intensity system leaving little time and resources for strategic development. However, a number of innovators are developing alternative business models that harness digital technology for creative purposes in addition to marketing and e-commerce, demonstrating the potential for such businesses to be both more environmentally and economically sustainable. This chapter discusses findings from research with micro and small designer fashion enterprises, investigating their knowledge of digital

---

[16] Brooke Roberts-Islam, "Martine Jarlgaard's Mixed Reality Show At London Fashion Week - A World First." *Huffington Post.* 16th Sept 2016.
http://www.huffingtonpost.co.uk/brooke-robertsislam/martine-jarlgaards-mixed-_b_11919578.html
[17] Lord Young, *Growing Your Business*. A report to HM Government, (London: HMSO, 2013.
[18] CFE, *UK Designer Fashion.*

technology and process innovation in the context of sustainability, and presents case studies of businesses that challenge the current paradigms and create new models for future fashion.

Digital Fashion and the fashion designer in the UK

The UK is renowned for its creative industries, first defined in a 1998 government report from the Department of Culture Media and Sport (DCMS 1998), and including designer fashion as an identified sector alongside product design, graphic design and architecture. A later updated report (DCMS 2001) identified designer fashion as including four areas: a) couture, b) international brand designated by a single name, c) diffusion –collaboration with high street retailers, and d) high fashion- up and coming, usually endorsed by celebrities, based on categories used by Mintel. The report also identified the UK fashion sector as highly populated by small businesses, in contrast to US, France and Italy. In a 2003 report to the UK Department of Trade and Industry, Newbury defined the designer fashion sector as comprising "individuals or teams that combine creativity and originality to create collections that have a specific or 'signature' identity and are exemplified by businesses that participate in international trade shows such as London Fashion Week." This is still the dominant model of wholesale trading that many designer fashion enterprises operate today, but which is beginning to see serious disruption. A 2008 report by the Centre for Fashion Enterprise (CFE) *The UK Designer Fashion Economy* identified a typology of business operations in the designer fashion sector from micro to SMEs and mapped a range of business relationships, from the individual artisan or creative partnership, to designers with licensing, manufacturing or investor partnerships. I offer here an alternative definition of designer fashion enterprises as foregrounding innovation, creating impact through innovative forms, fabrication techniques or methods of engagement with users, and sometimes creating radical conceptual fashion that disrupts the established codes and norms.

Much of the attention to digital economy developments in the fashion industry has focused on emerging paradigm-shifting advances in marketing and retail, including virtual and augmented reality presentations, mentioned above[19]. At the same time, awareness and acceptance of 3D printing technology has grown

---

[19] Batista, *Business Models*

exponentially, as it transferred from the engineering and product design sectors to mainstream consumer markets via strong media promotion. In tandem, the FabLabs (fabrication laboratories) and maker spaces movement originating at Massachusetts Institute of Technology (MIT) in the US in 2001 has developed to support communities and small scale designers to access a range of digital processes for product design such as 3D printing, laser cutting and CNC milling, enabling product prototyping and small batch production. In contrast, resources available for fashion designers largely consist of sewing machines and tailor's body forms, with some access to programmable industrial textile facilities (weaving, printing, knitting and embroidery) within arts universities and large companies, where proprietary computer-aided design (CAD) software and systems for design visualization, pattern preparation or lay planning require significant budgets to install.

In order to improve knowledge of the needs of small-scale entrepreneurial fashion design businesses, we developed research at London College of Fashion (LCF), University of the Arts London, focused on increasing understanding of the perceptions and practices of fashion designers and their innovation processes by working directly with designer businesses to catalyze knowledge exchange. Before entering education, I was designer and director of my own namesake knitwear brand, a small business selling internationally via the fashion circuit of wholesale trade shows in London, Milan, New York and Tokyo. It is pertinent to note that although technology and communications have changed dramatically in the intervening decades, the issues of survival facing a small fashion business have not. These include financing the production of experimental prototypes, sample collections, trade fairs, marketing and bulk production - all months in advance of any income being received. In addition, gaining access to key technical resources could be difficult as a very small player competing for the same manufacturing resources as larger fashion and retail businesses.

Experimenting with applications of technology developments in the context of sustainable production and consumption, the project Considerate Design for Personalized Fashion[20] examined the use of body scanning technology and 3D

---

[20] Sandy Black et al. "Considerate Design for Personalised Fashion." in *Designing for the 21st Century: Interdisciplinary Methods & Findings,* ed. Tom Inns, (Aldershot: Gower, 2009). The Considerate Design project was jointly funded by two UK research councils, Engineering and Physical Sciences, and Arts and Humanities: Designing for the 21st Century initiative, 2007-2009.

printing for personalized product development processes, including seamless industrial knitwear, a 3D printed flexible glove form and bespoke ergonomically shaped handcrafted bags (Fig. 2). The aim was to create products that engage and delight the consumer for longer through personalization utilising novel processes.

In the knowledge exchange project FIREup (Fashion, Innovation, Research and Enterprise)[21] we took an action research approach to support innovation in product development and communication, by pairing fashion academics and researchers with London-based designer fashion businesses over a six-month period. FIREup funded four small catalyst projects, two of which involved the use of digital technologies for product development and potential production, discussed here. The first project worked with accessories designer and maker Michelle Lowe-Holder, a micro business operating since 2010, to introduce her to 3D printing technology and computer-based digital design, in contrast to her usual craft- and materials-based approach. Working in collaboration with 3D virtual fashion researcher Thomas Makryniotis she was able to develop prototypes for a clutch bag design, and went on to develop further prototypes independently with a London 3D printing bureau. Lowe-Holder's aim was to use 3D printing to create structures that could not easily be realized in small numbers by traditional methods of metal forming, then work with these as a modular base for a range of designs. (Fig. 3) Lowe Holder's perception of this computer-based design and production process was that "3D print has to be looked at as a modern process to help bring about small scale design possibilities creating samples previously not possible economically for a small designer like myself. " The second catalyst project involved upcycling pioneers Worn Again and academic researcher Kate Goldsworthy, and developed new prototypes for Goldsworthy's ongoing Laserline project, working with polyester textiles and zero waste garment design, combining laser welding of seams and laser surface decoration techniques together. This one-step garment creation process has potential for reduction of resources and waste, utilising a polyester fiber, that can play a key role in circular systems of material use within the appropriate system infrastructure[22]. (Fig. 4) By catalyzing a collaborative research process, significant benefits to the partners

---

[21] Funded by the UK Arts and Humanities Research Council, Creative Economy Knowledge Exchange scheme, 2013-2014.
[22] see www.fire-fashion.uk for links to films about these projects.

were gained in experimental testing of new concepts. For example, Worn Again commented "there is now a proof of concept with tangible samples to take the conversation with industry to the next level"[23]. These two catalyst projects, although small in scale, demonstrated through targeted research the potential of digital processes within a fashion design and production context to create a new work flow and innovative product development with sustainability gains.

What's digital about fashion design? Mapping the landscape

Results from the FIREup project, including a survey of 56 fashion enterprises, found there was little understanding of university level research or the potential benefits of collaboration, to move research beyond the inspiration and sourcing of ideas for the next collection. These findings stimulated a further project specifically focused on the impact and integration of digital technology into designers' creative and studio processes, as opposed to retail and consumer facing applications. In collaboration with research consultancy AAM Associates, the FIRE team at London College of Fashion devised a project aiming to explore how technology was (or was not) being used within the designer fashion community.[24] Although new sales channels have disrupted and changed other sectors as discussed earlier, and despite more clothing being sold online, designer fashion businesses are still working mainly to a wholesale model of sales and production. We wanted to identify if and how traditional fashion design is being transformed by digital technology, and to see how willing designers are to adopt new digital methods and models. The first task was desk research to map current and emerging digital technologies onto the fashion design and production cycle. Key stages of the fashion cycle were identified as :

- Design inspiration and concept development,
- Prototyping and sample product development,
- Sales (wholesale and business to business),
- Bulk production and delivery to retailers,
- Retail sales and promotion through stores and/or online,
- Bespoke and customized sales direct to consumer .

---

[23] Quote taken from FIREup project internal reports 2014.

[24] Funded by Research Councils UK under the NEMODE Network+ scheme – New Economic Models in the Digital Economy. 2015 www.nemode.ac.uk https://vimeo.com/147929711

These stages are not discrete, as design for the next collection will overlap with production and delivery of the previous one, creating pressures on resources –both financial and human.
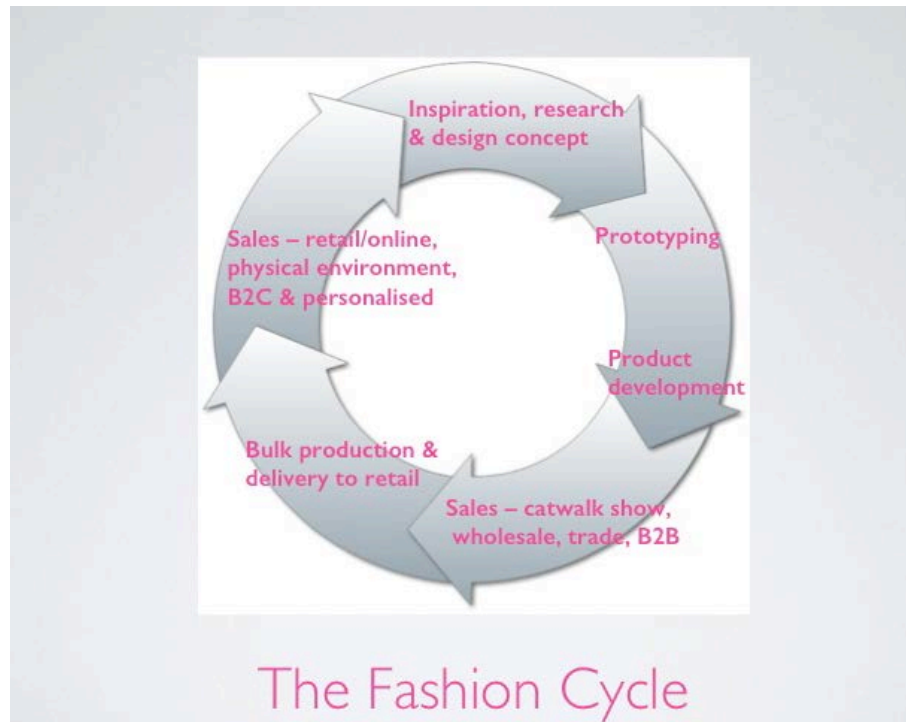

Fig. 5. Diagram showing stages of the fashion cycle. Source: FIRE project team.

As expected, although few independent designer fashion businesses had set up transactional websites for direct to consumer sales, research showed a far greater number of digital technologies and systems on offer at the consumer-facing marketing and retail stages than others, working across both physical and online retail contexts.[25] These include combinations such as so-called "magic mirror" visualization systems of augmented reality in stores where clothes and cosmetics can be virtually tried on. Since the concept of mass customization was first posited in the 1990s[26], "aiming to produce goods and services catering to individual customers'

---

[25] A selective survey listing of digital tools and processes is available at
https://docs.google.com/spreadsheets/d/1TGeAVXPp-XLh7qLZ1Ga2TCsL0oL-
9U9OwgX9wYcL8b0/edit?pli=1#gid=796169669&vpid=A1
[26] Joseph Pine II, *Mass Customization: The New Frontier in Business Competition.* (Boston: Harvard Business School Press, 1993)

needs with near mass production efficiency" [27], personalization and customization of goods has been something of a holy grail in retail sales[28]. Accurate garment fit and sizing is another major retail issue, and technologies such as body scanning and foot scanning systems that produce accurate 3D body images have the potential to enable individually sized garments to be created in a personalized service. However, despite early retail efforts by the company Bodymetrics, a spin-out from the 2004 UK Sizing Survey[29] to provide bespoke designer jeans with Selfridges and Harrods stores in London and later Bloomingdales in the US, body scanning technologies have yet to be seamlessly integrated into the retail shopping experience, in part due to sensitivity to the accurate results of bodyscanning technology[30]. Alternatively, virtual try-on systems comprising interactive mirrors that capture and reflect a customer's image and overlay it with specific garments the customer browses can express rewarding body images, and link to social networks for fun shopping experiences.

In contrast to these consumer-facing marketing and social shopping approaches, the technologies most relevant to the fashion design and product development process include: digital printing and embroidery onto 2D surfaces, laser cutting and welding, 3D printing, and 2D and 3D simulation and visualization of clothing designs (with some systems such as Marvelous Designer and Optitex using virtual stitching techniques, see Makryniotis (2016) for detailed explanations). Digital printing of imagery onto fabric has already enabled a new paradigm in printed fabrics freeing up the scope for complexity of colors and imagery, scale and non-repeating placement of pattern and design. Fashion designers whose work is highly distinctive in their use of digitally printed textiles include Mary Kantranzou, Alexander McQueen and Dries van Noten. However, 3D printing has received the widest media coverage, as desktop 3D printers (e.g. Makerbot) have become available and online bureaux such as Shapeways offer 3D printing services to anyone. In fashion terms, key designers such as Iris van Herpen, Frances Bitonti and more

---

[27] Frank Piller and Mitchell Tseng, eds. *Handbook of Research in Mass Customization and Personalization,* Vols 1 & 2 (Hackensack NJ: World Scientific Publishing, 2010), 1.
[28] Jung-ha Yang, Doris H. Kincade and Jessie H. Chen-Yu, "Types of Apparel Mass Customization and Levels of Modularity and Variety: Application of the Theory of Inventive Problem Solving." *Clothing and Textiles Research Journal*, 33:3, 2015.
[29] Philip Treleaven "Sizing Us Up." *IEEE Spectrum*, 41:4, 2004, 28-31. http://doi.org/db9tqw
[30] Suzanne Loker et al., "Female Consumers' Reactions to Body Scanning." *Clothing and Textile Research Journal* 22:4, 2004, 151-160; Tasha Lewis and Suzanne Loker "Trying on the Future: Exploring Apparel Retail Employees' Perspectives on Advanced In-Store Technologies." *Fashion Practice* 9:1, 2017, 95-119.

recently Noa Raviv have taken a creative lead in the conceptual development of wearable 3D printed showpiece garments, working with architects and 3D computer design experts, and have inspired many others. Much of the output of 3D printing uses rigid nylon materials, and the challenge taken up by pioneers Freedom of Creation and university research groups has been to create a flexible textile-like surface from modular interlocking elements (Fig.6). Recently the Modeclix project has prototyped 3D printed dresses from similar structures (www.modeclix.com), moving research a step closer to the goal of comfortable and wearable 3D printed clothing.

Scanning the horizon for digital systems that will impact fashion, much research is ongoing into wearable technology including electronic textiles or e-textiles. Since the beginnings of wearable computing in the 1980s when Steve Mann and others at MIT first experimented with distributed computing functions around the body[31], there has been an exponential rise in new developments in what is now termed fashion technology or "fashtech". The prospects for this field, in which clothing becomes smarter and responsive to external stimuli, capable of monitoring vital signs, emotions, location, wellbeing and keeping us entertained, perhaps also changing color and form at will, is widely regarded as the biggest opportunity for clothing, once all the component elements have become truly compatible. Much has still to be developed but research has moved forward strongly in the last 15 years[32].

Electronic textiles that can respond to pressure, or conduct heat, have been developed and mass produced by pioneers such as Asha Peta Thomson (a weaver) and Stan Swallow (an engineer) of Intelligent Textiles, founded in 2002, who now work exclusively for military research. Since 2015, Google has invested to scale up research into electronic functional textiles with their Jacquard project, which at the time of writing awaits the release of its first commercial product – a Levis denim jacket that can help take calls and messages on the move. A novel approach to e-textiles is taken by research in the Functional Electronic Textile Technology project at

---

[31] for early history see Bradley Rhodes, *A brief history of wearable computing*. available at https://www.media.mit.edu/wearables/lizzy/timeline.html . Accessed 25 May 2017
[32] Sandy Black, "Trends in Smart Textiles." In *Smart Textiles for Medicine and Healthcare*, ed. Louiva van Langenhove, (Cambridge: Woodhead. 2007), 3-26; Joanna Berzowska, "XS Labs: Electronic Textiles and Reactive Garments as Sociocultural Interventions" in Black et al. eds. *Fashion Studies*, 456-475; Bradley Quinn, "Technology and Future Fashion: Body Technology" in Black et al., eds. *Fashion Studies,* 436-455.

Nottingham Trent and Southampton Universities that embeds miniaturized semi-conductors and LEDs directly into the structure of yarns for weaving and knitting (https://www.fett.ecs.soton.ac.uk). These initiatives will undoubtedly lead to novel garment applications for both therapeutic and general fashion use.

On the fashion and entertainment side of the industry, Cute Circuit (fashion designer Francesca Rosella and interaction designer Ryan Genz) developed their own fabric technology and hardware components to create large LED arrays displaying color imagery across clothing. This pioneering company created its novel Hug Shirt concept in 2005, to transmit the electrical sensation of a hug to a loved one across distance, and later developed the first interactive dress that could display live messages via Twitter. In 2014 Cute Circuit repositioned their offer to launch a couture line of stylish garments with LED panels displaying moving imagery controllable by the wearer (Fig. 7) and have recently released a dress incorporating a graphene enhanced stretch sensor that captures the wearer's breathing pattern.

Further promotional projects for the catwalk, brokered by the Fashion Innovation Agency at LCF, mark out milestones in communication of fashion technology including a "digital skirt" commissioned for London Fashion Week February 2014 by Nokia, in collaboration with designers Fyodor Golan and Kin Studio. This used Nokia mobile phone technology in a literal but eye-catching way for the catwalk – ironically the very opposite of a truly wearable fashion technology garment (Fig. 8). At the other end of the spectrum, a dress project shown in London the following season, a collaboration between Disney and late designer Richard Nicoll, created a magical fashion experience using light optic fibers, realized in collaboration with another early pioneer of wearable technology Studio XO, founded by Nancy Tilbury and Ben Males (Fig.9). Their knowledge base also combines fashion, textiles and computing skills, and Studio XO have created showpieces for entertainers including Lady Gaga. Tilbury and her team are now setting up a platform for connected devices that will emotionally engage entire music audiences in a digitally enabled experience. With the emerging Internet of Things, where devices in the environment and the home are wired and connected, and accessible to our smart phones, Mark Weiser's prophetic vision of ubiquitous computing seems about to come true: "The most profound technologies are those that disappear. They weave

themselves into the fabric of everyday life until they are indistinguishable from it." [33]

It is clear from the above examples and many others that the integration of digital technologies in diverse ways is profoundly changing the fashion industry. However, a key issue to be resolved in the development of all new categories of wearable technology and functionalized electronic clothing, is the simultaneous and seemingly unwitting creation of a new waste stream of inseparable electronic and textile components. These new products of the future must be designed for disassembly from the outset, to address the considerable issues of sustainability in both the electronics and fashion industry, and also address issues of user need, privacy from potential surveillance and monitoring and user's control of personal data. Cute Circuit for example have designed their LED display panels and controllers as modules for disassembly, but these are issues which need to be widely addressed in this burgeoning industry. To this end, a collaborative EU-funded project WEAR Sustain has recently been set up to encourage sustainable innovation in wearable technology through experimental prototyping (http://wearsustain.eu).

What's digital about fashion design? Insights from an industry/academic workshop
To interrogate the question What's Digital about Fashion Design? we convened a workshop with 22 established fashion designers, industry representatives and academics to discuss how the fashion industry currently operates within the digital economy[34]. The purpose was to identify where opportunities for innovation in both product and business development lay, and three themes were established. A comment from one participant reinforced the slow changing ethos of the fashion industry: *"The fashion industry likes how it works, it has an entrenched way of operating – the seasonality is very difficult to change."*

The first theme to emerge was the Challenge to Tradition. In deconstructing the traditional fashion design cycle we questioned how the transition from wholesale to direct to consumer retail is impacting fashion design. It was agreed that whilst digital activity is mainly focused on sales, there is an unexplored opportunity to

---

[33] Mark Weiser, "The Computer for the 21st Century" *Scientific American,* Sept 1991, 94.

[34] Workshop convened as part of the NEMODE Network+ project led by Sandy Black and AAM Associates on 25th October 2015 at the Photographers Gallery London, with 22 attendees. See Sandy Black, Mary Jane Edwards and Gabrielle Miller, *What's Digital About Fashion Design?* 2015. A report to RCUK NEMODE (New Economic Models in the Digital Economy) available at   http://issuu.com/aamassociates/docs/whats_digital_about_fashion_design_/1

introduce digital technologies in the earlier stages of the design process, which could have the potential to transform both a designer's practice and business. The group acknowledged that while it was important to challenge fashion traditions, nobody wanted to see digital entirely replacing craft methodologies, but for it to be integrated in a way that would enhance a designer's practice and raison d'être: "Digital technology obviously isn't going to be a replacement for craft-based design practices, it should be more about how it can enhance what I want to achieve."

The second theme, Digital and the Design Process, challenged the potential of digital interventions to help save time and costs in day-to-day processes. It is a given that fashion designers are time-poor, working at a fast pace, and on a tight budget, and these concerns were strongly shared by workshop participants. Conversations explored how designers could potentially invest more time and money into creative research and development processes if physical overhead costs were cut and replaced with digital services. The idea of removing the physical store was just one proposed solution, and by all means not for everyone. However, by removing the high cost of company stores, designers would be able to embark on new journeys and perhaps bring in new team members such as consultants and software developers. Replacing the physical with digital would have an effect on budgets and free up spending for embedding digital into day-to-day operations. The thought of this seemed plausible and exciting to several participants: "We need to collaborate and open research - that is the only way things will change and [fashion] designers will start to define their place in the digital economy."

The group discussed how more collaborations between fashion, technology and manufacturing are needed to successfully integrate technology into both design and production processes. Participants speculated about more of a start-up culture in fashion, borrowing working practices from the entrepreneurial technology industry who, unlike fashion designers, are not wedded to the traditional fashion design cycle and are seen to be driving the development of new revenue models. Fashion designers often think of themselves as a one-man band, whereas tech startups form functional cross-disciplinary teams and are more entrepreneurial in seeking funding, a major cultural difference. The potential to house designers and technology start-ups in the same building, in incubator spaces such as Makerversity in London, might organically spark these types of collaborations and knowledge sharing .

Developing New Models was the third theme. By the end of the workshop participants considered that fashion designers were in a unique position, with specialist knowledge and understanding of design, to help shape developments in digital technology. There was a shared cautiousness about adopting digital business operations as there is a lack of available technology in fashion environments to support the transformation. Skepticism remained as to what extent digital engagement could be integrated into the entire product development lifecycle within the present fast-paced business and protracted cash flow models. Although digital was felt to be important, "Not many designers are able to invest time, energy and money in understanding what digital services would work for them. They're too busy getting ready for the next season!"

This workshop made a contribution to understanding the potential for digital technologies in fashion design, breaking down the barriers and exploring opportunities for new models of practice in this period of significant growth in the digital economy. With the rapid growth of business-to-business trade fairs such as Decoded Fashion (www.decodefashion.com) taking place in international fashion capitals, and many other meet-ups and events focused on wearable and digital technology, the fashion industry is now moving quickly into the digital space. Indeed, in 2016 the Centre for Fashion Enterprise started a three-year EU-funded initiative, to catalyse fashion and technology start-up businesses. Digital will continue to play an increasingly important part of daily life and the workshop showed the SME designer community is open to using technology to serve both the design process and product and business model development, but is in need of collaborative support to achieve this change.

Case studies of new business models

As the workshop illustrated, practices with small design-led fashion companies come from a conservative place, possibly based on previous education, which has been slow to evolve, both in terms of digital technology and in terms of sustainability. Perhaps fashion and design businesses can learn from the start-up culture of technology businesses. Two London-based start-ups are discussed below to exemplify new types of business models with digital processes at the heart of their development that potentially disrupt existing business paradigms. Both have clear sustainability benefits compared to existing business models.

UNMADE : customized knitwear

Unmade is an award-winning start-up design company, founded in 2013, that in their own words set out to "revolutionize the fashion industry". Working with the concept of fashion on demand, the company has harnessed the fundamental digital programmable capacity of industrial knitting machines to enable the creation of exclusive one-off knitwear pieces, at a unit cost similar to mass manufactured premium quality knitwear. Unmade have created an impressive interactive touch screen interface allowing anyone to customize a sweater design and then have it knitted as a unique piece. The customer manipulates a realistic visualization of the garment's patterns and color palette to create unique variations of placement, colors and scale, of any available pattern design. Having effectively 'hacked' the proprietary programming system and written their own software to directly command Stoll industrial knitting machines, Unmade has bypassed the expert programmer role to effortlessly enable designs to be created online by anyone and sent direct to the machine. The sweaters are knitted in the standard industrial manner using jacquard structures in fully fashioned (i.e. shaped) pieces, but unique knitted garments can be made for the same cost and speed as mass production, in effect mass customization[35] for graphic patterned sweaters.

Unmade was founded by three partners, interaction designer Ben Alun-Jones, fashion knitwear designer Kirsty Emery and former mechanical engineer Hal Watts, who all met at London's Royal College of Art. Their complementary expertise and new business model, focused on customer experience and digital technology, soon attracted venture capital. The company quickly grew to include software designers and developers working in the same space as people who made up the sweaters. Unmade is so called because each piece is unmade until the customer is involved; no stock is held. Their system – and the revolution they refer to – is that only goods that have been pre-ordered are produced, so overproduction is avoided together with the consequent wasted stock, an endemic issue in the fashion industry.

An Unmade pop-up store, complete with knitting machine, featured in the Selfridges London Bright Young Things installation in spring 2016, showcasing emerging businesses with a sustainability ethos. The speed of knitting technology –

---

[35] Pine II, *Mass Customization.*.

about 90 minutes to knit a sweater – meant that customers could see their piece being made, creating a direct link to the process of manufacturing their personalized design. Whilst researchers and industry players, for example Larsson and colleagues[36] in Sweden and Shima Seiki industrial knitting machine builders in Japan, have previously investigated knit-on-demand services, Unmade have achieved this long-term aim of moving from mass production to mass customization. Initially Unmade produced the knitwear themselves in their own London studio in collaboration with fashion designers, such as Christopher Raeburn, who each created distinctive graphic patterns. Unmade now classify themselves as a software design company and have shifted their goals from customer service as a brand to providing their technology platform for much larger collaborative projects with industrial manufacturers.

In the first realization of this goal, a three-way collaboration launched in November 2016 with cult brand Opening Ceremony, major e-commerce platform Farfetch and traditional knitwear manufacturers Johnston of Elgin created a limited edition collection of knitwear pieces available to a much wider audience. By integrating the Unmade technology platform with a scaled-up production process and embedding its online retail interface in an existing portal, anyone can order their customized sweater online and receive it within three weeks (Fig.10). By aligning their service with the digital disruption of 3D printing, Unmade have caught the imagination of the industry and the public – despite industrial knitting having been digital and fully programmable for decades. This has led to some confusion with journalists referring to 3D printing or print-knitting a sweater[37] - Unmade's knitwear is neither 3D printed nor 3D knitted. There are currently some limitations such as limited sizing and styles available and the focus on graphic jacquard patterns only - although an interesting elliptical sweater has been devised (Fig.11) - however Unmade have their sights on other techniques for customizations including stitch structures which is far more challenging. They also have ambitious plans to revolutionize other digital production areas including customizing digital print and embroidery processes – a revolution indeed.

---

[36] Jonas Larsson, Pia Mouwitz and Joel Peterson. "Knit on Demand – mass customisation of knitted fashion products." *The Nordic Textile Journal, Special Edition Fashion & Clothing*, 2009, 108-121.

[37] Marc Bain .5th April 2017. "Brands see the future of fashion in customized 3D knitted garments produced while you wait" Quartz Media . https://qz.com/949026/brands-including-adidas-uniqlo-and-ministry-of-supply-see-the-future-of-fashion-in-on-demand-3d-knitting/

MIXIMALISTE.COM – 3D fashion visualization and zero prototyping

A perhaps even more experimental startup company is Change of Paradigm – an ambitious name for an ambitious project. This is a business startup that designs, develops, manufactures and distributes luxury fashion capsule collections through its own online e-commerce platform with an entirely new business model for the creation and selling of fashion virtually. This is based on zero prototyping – that is, no actual sample garments are made but virtual patterns and photo-realistic simulations are created as 3D models using a suite of 3D CAD software packages to develop highly sophisticated renderings of designer fashion styles.

After three years' development and successfully seeking investment, the platform launched in October 2016 under the new brand name MIXIMALISTE. A series of exclusive capsule collections are designed and developed in collaboration with well-recognized London-based independent fashion designers such as Boudicca, Fyodor Golan and Teatum Jones, and available on their e-commerce platform www.miximaliste.com for a limited period of three weeks. All the fashion outfits are displayed as 3D simulations on 3D mannequins using sophisticated software. By collaborating with recognized independent fashion designers, collections with identifiable signature style are created utilising the designers' own fabrics which physically exist and are realistically rendered. From a hand-drawn sketch, the fashion designer and the company's 3D specialist, together with the creative director, work together to develop the virtual patterns from the designs – using CAD programmes including Marvelous Designer and/or Clo3D (for more detail see Makryniotis 2016). These pattern pieces are then virtually stitched together in 3D and rendered onto 3D mannequins. Significantly, the outfits are shown highly realistically not only in static form (back, front and side views), but also as moving garments in a video sequence changing in 3D display between front and side views, illustrating how a customer might actually wear the piece and how the fabric looks, moves and drapes around the body (Fig 12).

It is worth reiterating that there is no physical garment, pattern, model or even photograph in this system, all is virtual computer-generated imagery and data, only the fabrics are real, based on scanned information. The innovative online visualizations are super-realistic with much attention clearly having been paid to creating lifelike fabric and body movements working together. Like Unmade, the designs are available for pre-order – nothing is made until ordered and a 50% deposit

paid.   Unusually, only one designer at a time is featured, within a visual setting developed as part of the creative collaboration between the designer and MIXIMALISTE's 3D virtual design team.

CEO Henri Mura, says: "MIXIMALISTE goals are to enhance the entertainment value of online shopping for fashion and to promote a sustainable pre-order business model where cost savings are passed on to customers."[38] Pricing operates on a direct to consumer basis, passing reductions in overhead and prototyping costs onto the customer, based on an even split between the parties - a third each to MIXIMALISTE, the designer and the manufacturing costs. This they claim offers a competitive half price premium compared with a normal retail price markup structure of at least 300%. Mura elaborates: "The idea is to offer women an alternative to both fast fashion, which is often made with low quality materials, and can be unethically sourced, and luxury fashion with its premium price. We enable a fashion connoisseur a new entry level to designers they love." [39]

Although at the time of writing, only a small number of outfits have been sold, MIXIMALISTE.COM is open for business - albeit in its beta-testing phase. The brand's journey is only part way through towards developing a fully commercial business offer and the company has plans, currently in development, to make the experience truly interactive in 3D. Soon to be launched are three different technological systems: in the first customers can visit a virtual showroom space, using VR headsets to visualize the pieces and walk around (virtual) mannequins in full 360 degrees; the second uses augmented reality applications on mobile devices to interact in the real world with the virtual collections, including customers' own living room; the third application will use holographic technology in which a 3D representation of the modeled outfit will literally "come out of the screen" . This level of 3D sophistication has already required several technology challenges to be solved including complex cloth physics (with multiple layers of cloth/body interactions), and integration with games engines to allow real-time interaction, rendering of high quality textures, and delivery of video streams in real-time (or quasi real-time) to multiple users.

---

[38] CEO Henri Mura 17 Oct 2016 Linked-in announcement.
[39] Third wave fashion Sept 2016 www.thirdwavefashion.com (accessed 28th April 2017)

MIXIMALISTE are clearly pioneers in a field which anticipates the time when the paradigm really does shift from 2D experiences of shopping online to a stage when 3D digital experiences become an everyday matter, including having 3D cameras on mobile phones as standard. As Mura says "combining online fashion shopping with a new user experience" creates interactivity by merging digital simulation with our real world experience for a mixed reality. He envisages a mixed business model where brands might offer a 3D online experience with their standard collections, together with the new preorder model for exclusive ranges[40]. Of course, the crucial commercial aim is to convert this experience to purchases, which still remains to be tested.

Conclusions

Both case studies discussed here work with a new paradigm – changing the fashion business model from Design/Make/Sell to Design/Sell/Make. This is more radical than it may seem, requiring a flexible infrastructure to be able to work with fulfilling individual orders efficiently on a modular basis, but at similar cost to traditional bulk production methods. Both Unmade and miximaliste.com businesses have harnessed the digital systems available and developed new digital processes to connect with the customer from an initial online engagement and experience through to communication of production information (knitting sequence and machine instructions for Unmade and garment pattern and sizing information for miximaliste.com).

There is widespread recognition that fashion (as we currently know it) is in a state of flux and undergoing a process of fundamental change – the "end of fashion" referred to in the title of this volume. The question remains, how can fashion businesses thrive whilst aiming to reconcile the complexity of commercial, creative, environmental and social issues in our global connected and increasingly digital economy? There is greater acceptance of and expectations for digital technology to pervade all aspects of everyday life beyond communications into services and experiences but urgent consideration must be given to the overuse and depletion of natural resources including water and the rare earth metals essential to the

---

[40] Personal communication with Henri Mura, 24 May 2017.

manufacturing and operation of electronic devices. It is imperative to align these technological advances with design for sustainability thinking i.e. whole life cycle design and circular material flows for both biological and technical systems [41].

Developing new business models for fashion to reduce consumption but increase delight, by harnessing the benefits of digital technologies could be a significant contributor to a sustainable future, including for developing countries that have deftly bypassed the need for fixed based technologies, going straight to mobile platforms, an infrastructure enabling full access to globalized online systems.

Mass customization has long been a goal of large scale businesses, and apart from the bespoke tailoring and dressmaking services still widespread in several countries, especially in Asia, digital technologies, interfaces and capabilities appear to be finally synchronizing to realise this personalization ambition for a wide community, now fueled by small, agile and innovative businesses. Sportswear brands such as Nike have been at the forefront of development of mass customization with their NikeID platform for personalizing trainers, launched in 2006. More initiatives are taking place: early in 2017, Adidas opened a pop up shop Knit for You in Berlin testing a customization platform with a small range of 3D (seamless) knitted sweaters, and similarly in Boston, Ministry of Supply launched a knit on demand store with a single seamless 3D knitted jacket. With the arrival of Amazon selling strongly in the fashion space, no doubt there will be acceleration of innovation and competition to create and maintain customers.

The workshop discussed above focused specifically on fashion designers' attitudes and requirements, and questioned to what extent digital engagement could be integrated into the entire fashion product development cycle, highlighting issues within the present business and cash flow models. Fashion designers could be in a position, with their specialist knowledge and understanding of design and its cultural as well as economic significance, to help shape developments in digital technology, especially the burgeoning wearable technology market and its relationship to the Internet of Things and to the human experience. There remain further research opportunities to interrogate how the traditional model of fashion design is and can be

---

[41] William McDonough and Michael Braungart *Cradle to Cradle: Remaking the Way we Make Things*. (New York: North Point Press. 2002); Ken Webster *The Circular Economy. A Wealth of Flows*, (Cowes: Ellen MacArthur Foundation, 2017).

transformed by digital technology, and to support the SME designer fashion community to adopt new models of engagement with manufacturers, wholesalers, retailers and consumers that can underscore the crucial sustainability agenda. Revisiting the observations of Sarah Scatturo from 2008, the following still resonates:

> If selectively and rationally embraced, technology can continue to serve the sustainable and ethical requirements of modern society, enabling ever sophisticated methods of clothing creation, consumption, and disposal[42].

References

Batista, Luciano. 2013. *New Business Models Enabled by Digital Technologies*. *A perspective from the fashion sector.* A report to the RCUK project NEMODE (New Economic Models in the Digital Economy) available at http://www.nemode.ac.uk/wp-content/uploads/2013/03/BATISTA-case-study-in-the-fashion-sector-FINAL-Report.pdf.

Berzowska, Joanna . 2013. "XS Labs: Electronic Textiles and Reactive Garments as Sociocultural Interventions." In *The Handbook of Fashion Studies,* edited by Sandy Black, Joanne Entwistle, Amy de la Haye, Agnes Rocamora, Regina Root and Helen Thomas, 456-475. London: Bloomsbury

Black, Sandy. 2007. "Trends in Smart Textiles." In *Smart Textiles for Medicine and Healthcare*, edited by Louiva van Langenhove, 3-26. Cambridge: Woodhead.

Black, Sandy. 2008. *Eco Chic: the Fashion Paradox*. London: Black Dog Publishing

Black, Sandy. 2012. "Fashion is often very old-fashioned". In *The Sustainable Fashion Handbook,* edited by Sandy Black, 116-119. London: Thames and Hudson.

Black, Sandy. 2013. Introduction to Section VI: Science, Technology and New Fashion. In *The Handbook of Fashion Studies,* edited by Sandy Black, Joanne

---

[42] Sarah Scatturo, "Eco-tech Fashion: Rationalizing Technology in Sustainable Fashion." *Fashion Theory,* 12:4, 2008, 469)

Entwistle, Amy de la Haye, Agnes Rocamora, Regina Root and Helen Thomas, 429-435. London: Bloomsbury.

Black, Sandy, Claudia M. Eckert, Philip Delamore, Frances Geesin, Steven Harkin , Penelope Watkins and Fatemeh Eskandarypur. 2009. "Considerate Design for Personalised Fashion." In *Designing for the 21st Century: Interdisciplinary Methods & Findings,* edited by Tom Inns, 67-86. Aldershot: Gower.

Black, Sandy, Mary Jane Edwards and Gabrielle Miller. 2015. *What's Digital About Fashion Design?* A report to RCUK NEMODE (New Economic Models in the Digital Economy) available
at http://issuu.com/aamassociates/docs/whats_digital_about_fashion_design_/1

Bocken, Nancy M.P., S.W. Short, P. Rana and Steve Evans. 2014. "A literature and practice review to develop sustainable business model archetypes." *Journal of Cleaner Production,* 65, 42-56.

British Fashion Council (BFC) and Oxford Economics. 2010. *The Value of the UK Fashion Industry: economic considerations for growth.* London: British Fashion Council

Centre for Fashion Enterprise (CFE). 2008. *The UK Designer Fashion Economy. Value relationships- identifying barriers and creating opportunities for business growth*. London. Report commissioned by NESTA (National Endowment for Science Technology and the Arts)

Christopher, M., Lowson, R., and Peck, H. 2004. "Creating agile supply chains in the fashion industry." *International Journal of Retail & Distribution Management*, 32(8), 367-376.

DCMS. 1998. *Creative Industries Mapping Document*. London: DCMS (UK Government Department of Culture, Media and Sport)
DCMS. 2001. *Creative Industries Mapping Documents 2001: Fashion*. London: DCMS (UK Government Department of Culture, Media and Sport).

Edelkoort, Lidewij 2015 Anti Fashion: a manifesto for the next decade available at Dezeen www.edelkoort.com/2015/09/anti_fashion-manifesto

Fletcher, Kate. 2008. *Sustainable Fashion and Textiles. Design Journeys*. London: Earthscan

Larsson, Jonas, Pia Mouwitz and Joel Peterson. 2009. "Knit on Demand – mass customisation of knitted fashion products." *The Nordic Textile Journal, Special Edition Fashion & Clothing*, 108-121.

Lewis, Tasha and Suzanne Loker. 2017. "Trying on the Future: Exploring Apparel Retail Employees' Perspectives on Advanced In-Store Technologies." *Fashion Practice* 9 (1), 95-119.

Loker, Suzanne, Lora Cowie, Susan Ashdown and Van Dyk Lewis. 2004. "Female Consumers' Reactions to Body Scanning." *Clothing and Textile Research Journal* 22 (4), 151-160.

Makryniotis, Thomas. 2015. *3D Fashion Design. Technique, design and visualization*. London: Batsford.

Malem, Wendy. 2008. "Fashion designers as business: London". *Journal of Fashion Marketing and Management,* 12 (3), 398-414.

McDonough, William and Michael Braungart. 2002. *Cradle to Cradle: Remaking the Way we Make Things*. New York: North Point Press.

McRobbie, Angela. 1998. *British Fashion Design. Rag Trade or Image Industry?* London: Routledge.

McRobbie, Angela. 2016. *Be Creative. Making a Living in the New Culture Industries.* Cambridge: Polity Press.

Newbery, Malcolm. 2003. *Conclusions and recommendations of a study of the UK designer fashion sector*. London: UK Government Department of Trade and Industry.

Normann, Richard. 2001.*Reframing business: When the map changes the landscape*. Wiley.

Piller, Frank and Mitchell Tseng, eds. 2010. *Handbook of Research in Mass Customization and Personalization,* Vols 1 & 2. Hackensack NJ: World Scientific Publishing.

Pine II, Joseph. 1993. *Mass Customization: The New Frontier in Business Competition.* Boston: Harvard Business School Press.

Quinn, Bradley. 2013. **"**Technology and Future Fashion: Body Technology." In *The Handbook of Fashion Studies,* edited by Sandy Black, Joanne Entwistle, Amy de la Haye, Agnes Rocamora, Regina Root and Helen Thomas, 436-455. London: Bloomsbury.

Rhodes, Bradley. n.d. *A brief history of wearable computing* . available at https://www.media.mit.edu/wearables/lizzy/timeline.html Accessed 25 May 2017

Scatturo , Sarah. 2008. "Eco-tech Fashion: Rationalizing Technology in Sustainable Fashion." *Fashion Theory,* 12(4), 469–88.

Schaltegger, Stefan, Erik G. Hansen and Florian Lüdeke-Freund. 2015. "Business Models for Sustainability: Origins, Present Research, and Future Avenues." *Organization & Environment*. Online: http://dx.doi.org/10.1177/1086026615599806.

Treleaven, Philip. 2004. Sizing Us Up. *IEEE Spectrum*, 41 (4), 28-31. http://doi.org/db9tqw

Webster, Ken. 2017. *The Circular Economy. A Wealth of Flows*. Cowes: Ellen MacArthur Foundation.

Weiser, Mark. 1991. "The Computer for the 21st Century." *Scientific American,* Sept, 94-100.

Yang, Jung-ha, Doris H. Kincade and Jessie H. Chen-Yu. 2015. "Types of Apparel Mass Customization and Levels of Modularity and Variety: Application of the Theory of Inventive Problem Solving." *Clothing and Textiles   Research Journal*, 33(3), 199-212.

Lord Young, 2013. *Growing Your Business*. A report to HM Government, London HMSO.

Shin, Eonyou and Fatma Baytar. 2013. "Apparel Fit and Size Concerns and Intentions to Use Virtual Try-On. Impacts of Body Satisfaction and Images of Models' Bodies." *Clothing and Textiles Research Journal* 32 (1), 20-33.

Acknowledgements

Biography

Sandy Black is Professor of Fashion & Textiles Design & Technology in the Centre for Sustainable Fashion, London College of Fashion, UAL, and has extensive experience in both academia and the fashion industry, formerly running the Sandy Black Knitwear company, selling internationally. Her current inter-disciplinary research is into the role of design and new business models in addressing issues of sustainability in the fashion sector. In 2005 she initiated the *Interrogating Fashion*

network to create a research agenda for future fashion, and led the project *Considerate Design for Personalised Fashion Products.* Recent funded research into the designer fashion sector bridges research, innovation, business models and sustainability under the umbrella F.I.R.E (Fashion, Innovation, Research, Evolution). Sandy has published widely on Sustainable Fashion including *Eco Chic the Fashion Paradox* 2008; *The Sustainable Fashion Handbook* 2012; *The Handbook of Fashion Studies* 2013, and also on knitwear including *Knitting: Fashion, Industry, Craft* with the V&A Museum. She is founder and co-editor of the journal *Fashion Practice: Design, Creative Process and the Fashion Industry*, published since 2009.