CIRCULAR TRANSITIONS

Proceedings

A Mistra Future Fashion Conference on Textile Design and the Circular Economy

23–24 November 2016
Chelsea College of Arts & Tate Britain, London

ual: university of the arts london

CENTRE for CIRCULAR DESIGN

ff

Circular Transitions 2016

University of the Arts London
23–24 Nov 2016

The first Circular Textile Design Conference was held in November 2016 at The Tate Britain and Chelsea College of Arts, Millbank, London with over 150 attendees from 12 countries; Finland, USA, UK, Sweden, New Zealand, Denmark, Israel, Germany, Belgium, Netherlands, Hong Kong and Canada.

There were over 40 keynote and paper presentations over the two days, with high-profile speakers from both academia and industry. The audience split was around 65% academia and 35% industry. This collaborative spirit was an essential part of the event's success, enabling rich and varied discussions throughout the sessions. Alongside the conference was the 'Making Circles' exhibition, with 25 international exhibitors representing the very best in current Circular Design practice.

In this proceedings you will find 31 full papers with perspectives and practice from across a spectrum of circular approaches. The conference was framed by exploring circular textile design through three lenses on **Day 1** – materials, models and mindsets:

In the Materials theme we heard how design might create change through new industrial systems which respond to material, technology, and scientific developments. Papers and exhibits in this theme looked at the challenges and benefits of new modes of production, opportunities for cleaner processes in the textile materials value chain and the potential for digital processes to enable a circular economy.

In Models we explored design to evolve new Systemic Models through manufacturing, services, networks and communities. New business models and tools, cradle-to-cradle thinking were explored through highly collaborative approaches. Papers here discuss the tensions between our traditional modes of competition and collaboration, social equity within the circular supply chain and opportunities for designers to bridge understanding of scientific tools and methods.

In Mindsets we explored design to change behaviour and shape new habits, attitudes, beliefs, frameworks and experiences. We heard ideas for facilitating collaboration across disciplines, pioneering and enabling the changing role of the designer in a circular economy. We considered new roles which can contribute towards well-being and develop circular cultures, and how design can support both designers and end users to be more conscious of their decision-making.

On Day 2 we continued to explore these themes through parallel sessions on topics including; design and user engagement, finishing and 3D technologies, design driven material innovation, interdisciplinary research, repair and models for reuse, production technologies and lifecycle thinking for design. The variety and richness of these sessions contributed to a lively and inspiring debate across the day, with many new collaborations hatched and networks created.

On behalf of the whole University of the Arts London and Mistra Future Fashion Programme teams behind this conference, and the many contributors you will see on the following pages, we welcome you to enjoy these proceedings and celebrate progress towards a circular future.

Proceedings Editors:
Prof Rebecca Earley and Dr Kate Goldsworthy

Design & Production:
Polimekanos

Academic Committee:
Dr Kate Goldsworthy (Chair), Prof Rebecca Earley, Prof Kay Politowicz, Prof Malcolm Quinn, Prof Sandy Black, Prof Dilys Williams, Prof Adam Thorpe, Prof Lorraine Gamman, Prof Mike Press, Dr Rosie Hornbuckle, Dr Faith Kane, Dr Louise Valentine, Dr Chris Holland, Prof Martin Charter, Dr Kirsi Niinimäki, Dr Hjalmar Granberg, Dr Lucy Norris, Clara Vuletich, Bridget Harvey, Miriam Ribul

Organising Committee:
Prof Rebecca Earley (Chair), George Blacklock, Josefin Landalv, Gabrielle Miller, Lynne Finn, Ania Stawarska, Eva Wilkinson, Susan Hamilton

Acknowledgements:
Tate Britain, Polimekanos, Idenk, Sophie Thomas, Cyndi Rhoades, Elin Larsson, Orsola de Castro, Prof David Crow, Sigrid Barnekow, Gwen Cunningham, Nick Morley, Dr Amy Twigger-Holroyd, Prof Marie O’Mahony, Ed van Hinte, Ella Doran, Dr Lucy Norris

Circular Transitions Partners and Sponsors:
University of the Arts London, Mistra Future Fashion Programme, Camira, Hato Press, Wired, Jane Dawson, Camilla Stacey, Dr Robin Hawes

Index

Day 1, Tate Britain

Materials

8 Colours in a Circular Economy
Kirsi Niinimäki, Eugenia Smirnova, Elina Ilén, Herbert Sixta, Michael Hummel (Aalto University, School of Arts and School of Chemical technology)
kirsi.niinimaki@aalto.fi

20 What Else Do We Know? Exploring the application of design knowledge and skills for the circular economy beyond materials selection and design for production.
Rosie Hornbuckle (University of the Arts London, UK)
r.hornbuckle@arts.ac.uk

Models

32 Operating in the Third Space: the space between
Jennifer Whitty (Massey University, NZ)
jenwhitty1@gmail.com

46 Re-Mantle and Make: the role of maker spaces in empowering a new wave of circular thinking for textile designers
Jen Ballie, Paul Smith, Lynn-Sayers McHattie (Glasgow School of Art, UK)
jen.ballie@vandadundee.org

Mindsets

57 Shifting Perceptions: The Reknit Revolution
Amy Twigger-Holroyd (Nottingham Trent University, UK)
amy-twigger.holroyd@ntu.ac.uk

68 Whole Circles: Models for Academic Textile Design Research Leadership in the Circular Economy
Rebecca Earley (University of the Arts London, UK)
r.l.earley@arts.ac.uk

Day 2, Chelsea College of Arts

Design and User Engagement

81 Shared Emotional Values in Sustainable Clothing Design Approaches
Marium Durrani*, Louise Ravnløkke** & Kirsi Niinimäki*
(*Aalto University School of Arts, Design and Architecture &
**Design School Kolding)
marium.durrani@aalto.fi

92 Designing Alternative Economies to Create Cultures of Sustainability
Rachael Taylor (Southampton Solent University, UK)
rachael.taylor@solent.ac.uk

103 Weave Your Own Economy: Speculative Economic Design
Monica Buchan-Ng (UK)
mjb-ng@hotmail.com

122 A Dematerialised Approach to Sustainable Fashion Design
Jade Whitson-Smith (University of Huddersfield, UK)
J.E.Whitson-Smith@hud.ac.uk

131 Mundane Matters: Laundry, Design and Sustainability
Emma Dulcie Rigby (University of the Arts London, UK)
e.rigby@arts.ac.uk

Finishing and 3D Technologies

141 An Exploration of the Sustainable and Aesthetic Possibilities of
3D Printing onto Textiles as an Alternative to Traditional Surface Decoration
Kirstie Burn, Samantha Vettese Forster (Edinburgh Napier University, UK),
John Shackleton (University of Glasgow, UK)
kirstie.burn@napier.ac.uk

155 Laser Moulding for Textiles: Supporting Sustainability
in Design and Manufacture
Laura Morgan (Loughborough University, UK)
L.E.Morgan@lboro.ac.uk

169 A Closed Loop Model for 3D Printing Fashion
Emma Grain (University of Huddersfield, UK)
E.E.Grain@hud.ac.uk

184 A Space of Waste
Karen Dennis (Ketchup Clothes), Claire Evans, Charles Kahabi
(University of Huddersfield, UK), Alfred Lugallo (Independent Tanzanian Designer)
ketchupclothes@yahoo.co.uk

Design Driven Material Innovation Interdisciplinary Research

197 Can Design-Driven Material Innovation Also Drive Circularity?
Marjaana Tanttu, Cindy Kohtala, Kirsi Niinimäki
(Aalto University School of Arts, Finland)
marjaana.tanttu@aalto.fi

208 Towards a quantified design process: bridging design and life cycle assessment
Kate Goldsworthy (University of the Arts London, UK), Sandra Roos,
Gregory Peters (Chalmers, Sweden), Gustav Sandin (RISE, Sweden)
k.goldsworthy@arts.ac.uk

222 Designing Cycles: an interdisciplinary approach to coloured fashion & textiles
Dawn Ellams (University of the Arts London, UK)
d.ellams@arts.ac.uk

236 The Material Affinity of Design and Science for a Circular Economy
Miriam Ribul (University of the Arts London, UK), Hanna de la Motte
(Research Institutes of Sweden, SE)
m.ribul1@arts.ac.uk

Repair and Models for Reuse

249 RepairAbility Through Repair Thinking
Bridget Harvey (University of the Arts London, UK)
bridget@bridgetharvey.co.uk

262 Developing Models for Successful Upscaled Upcycling of Fashion
Emmeline Child (University of the Arts London and University of Northampton, UK)
emmeline.child@northampton.ac.uk

273 The Creation of Made to Measure Recycled Garments
Andre West and Sanjaykumar Patil (North Carolina State University, USA)
ajwest2@ncsu.edu

Production Technologies

285 Design for Circularity: Material Innovation for Wearable Technology
Anne Prahl (UK)
anne.prahl@btinternet.com

303 Where Does Wearable Technology Fit in the Circular Economy?
Marie O’Mahony (OCAD University, Canada), Alison Gwilt (Sheffield University)
marie.consultant@gmail.com

316 Digital Denim by Design
Dawn Ellams (University of the Arts London, UK), Nick Morley (Faering, UK)
d.ellams@arts.ac.uk

327 The Designing of a Speciality Hand Knitting Yarn using Appropriate Technology
Manju Sugathan (Nottingham Trent University, UK)
manju.sugathan@googlemail.com

Lifecycle Thinking for Design

338 A Sustainability Textile Design Course as a Transformative Process
Yuval Etzioni, Ziv Neeman (Shenkar College of Engineering, Tel Aviv, Israel)
yuvaletzioni@gmail.com

349 Whole Systems Thinking for Circular Economy Design Practice
Sara Li-Chou Han, Nick Hall, Phoebe Apeagyei, David Tyler
(Manchester Metropolitan University, UK)
S.Han@mmu.ac.uk

366 Using A 'Five Perspectives of Sustainable Design' Model in Fashion and Textiles
Karen Marie Hasling (Design School Kolding, Denmark)
kmh@dskd.dk

377 Material Futures: Crafting Circular Conversations
Jen Ballie (Glasgow School of Art, UK)
jen.ballie@vandadundee.org

391 Circular Speeds: towards a new understanding of designing
for fashion textile rhythms
Kay Politowicz, Kate Goldsworthy, Rebecca Earley (University of the Arts London, UK)
k.goldsworthy@arts.ac.uk

CENTRE for CIRCULAR DESIGN

CIRCULAR TRANSITIONS

23 – 24 November 2016

Colours in a Circular Economy

Kirsi Niinimäki, Eugenia Smirnova, Elina Ilén, Herbert Sixta, Michael Hummel
(Aalto University, School of Arts and School of Chemical Technology)

Abstract

This paper reports on preliminary results on the recycling of coloured cellulose-based textiles using a novel dry-jet wet spinning denoted as the Ioncell-F process. The practical possibility of colour circulation is useful knowledge for colour designers in the industry. The findings can help define further parameters for circular economy products.

Introduction

The objective of this research is to study the stability and possible modifications of colours during the dissolution and regeneration processes with the intention to avoid dye stripping and further dyeing of recycled fibres. This is essential knowledge for a textile industry that aims to transform its practices towards circularity. A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the "end-of-life" concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models (Ellen McArthur Foundation, 2012).

Recycling should be understood as part of the strategy whole, which aims at building a new kind of society. This society consumes and disposes only the necessary amount of raw materials. A recycling economy has been hindered by, among other factors, lack of systematic strategy wholes (Aarras, 2015). Resources to make primary textile fibres are decreasing and the world population is rising; therefore textile recycling needs to stay on the agenda. It is necessary to develop processes to design textiles that are easy to recycle (Gulich, 2006a). All existing textiles exhibit some colour whether it is achieved by the means of dyeing or being the textile's own natural colour. One of the issues faced by developers will be the presence of finishes and dyes in the textiles. Strategically it is best to have as neutral-coloured fibre in the stock as possible, white or off-white, which could thus be dyed on demand in the desired colour. However, in order to achieve this neutral colour, the dyed textile needs to be bleached and later dyed again, consuming energy, water and chemicals in both processes. Most of the literature is more concerned with purification and decolorisation of the water than with the recycling of the chemicals (Buschile-Diller, 2006). Through colour design, previous dye work applied to the disposable textile could be utilised as such and manifest in the remanufactured fibre as an attractive design element.

Fletcher (2014, 122-124) reports about mechanical fibre extraction technique for fibre reclamation, which involves tearing the fabrics mechanically apart using carding machines. It can be applied to cotton fabrics. For polyester chemical recycling process can be used. In polyester recycling a polymer feedstock is repolymerized to produce a recycled material that is purer and of a more consistent quality than produced by the mechanical method, although more energy intensive to produce (Fletcher 2014, 122). Fibres of both of these reclamation methods can be found on the market but chemical waste recycling of cotton and other cellulosic fabrics seems to be only in development stage.

The paper begins with the test description and results of dyed textile conversion. Based on the achieved results of colours in the remanufacturing process, a concept of colours in a circular economy will be constructed. The colour design concept is intended to contribute to the systemic regenerative nature of a circular economy, and it aims to give guidelines for designers working in a circular economy context. “Colour Library” is a conceptual system for colour design that it based on disposable textiles and their colours and provides expertise and resources to produce yarns for textiles of desired colour and quality.

Methodology

A set of laboratory experiments were performed using dyed cellulosic materials employing the Ioncell-F technology. According to Michud et. al. (2015) it is an alternative to the viscose and Lyocell process for the manufacture of man-made cellulosic fibres, With the solvent used in this process the cellulose solutions could be spun at substantially lower temperatures than in the NMMO-based Lyocell process, which reduces energy consumption and prevents cellulose degradation.

A variety of dyed textiles was collected to test their feasibility in remanufacturing and their colour translation to new fibre. The textiles were a combination of different kinds of textile made from the same polymer (cellulose) forming single-material composite systems, including cotton and man-made cellulosic fibres such as viscose, modal, lyocell or cupro. Some minor presence of elastane per item (1% - 5%) was accepted. When collecting second-hand textile items, the material information given on their wash tags was trusted. Precise background information about post-consumer textiles as well as industrial cut waste, their dyeing methods and earlier treatments was unavailable; thus, some assumptions were made based on general knowledge of textiles. According to Forss (2000) reactive dyes are mostly used to dye cellulosic fibres and they are degraded by chlorine compounds, so the textiles were tested with quick hypochlorite drop test. Because of the popularity of blue jeans, indigo is still one of the most important of all dyes in present use (Broadbent, 2001). Thus, cotton jeans along with were assumed to be indigo-dyed.

The textiles were first sorted according to colour or desired colour mixture and cut into small pieces; seams were excluded to minimise the increase of the percentage of non-cellulosic materials, such as polyester. The cut textiles were ground into a fine pulp by means of a Wiley-mill. At this point a certain average colour could be already seen from an optic mixture of multiple colours' “optic average colour” (later as OAC): for example, 9 different shades of yellow pulped together formed optic average yellow. If the pulp was formed of two different colour sources, for example 50% pink and 50% yellow, the OAC of that was orange. At this point the first glimpse of the direction of the end fibre colour was observed. Homogenous pulp of ground colour components was subjected to treatment in 3% H_2SO_4 solution at various temperatures, for various periods of time in order to reach a particular viscosity level suitable to form spinnable cellulose solutions. Intrinsic viscosity values of all of the final spinning pulp blends were targeted to be 450 ml/g, which was achieved by either one successful treatment or with treating two parts of the same pulp in different conditions and mixing them in a defined calculated ratio. The intrinsic viscosity of the resulting mixture was also tested and adjusted on demand by remixing before preparing the final spinning dope. Ready pulps were pre-mixed by hand with the ionic liquid solvent and then dissolved in a vertical kneader within 90 min at 90°C. Dissolved cellulose was filtered and spun using a customized laboratory piston spinning unit.

The success of colour translation of the end fibre was defined in relation to the OAC of the ground untreated materials. The colour difference evaluation was done visually and employing CIELab spectrophotometry. The optical appearance of the final fibre was compared to the pulp sheets prepared from the mixture of the ground waste textiles. All sheets of pre-remanufacturing average optic textile pulps were prepared in the following manner: ground, untreated textile pulp was measured in amounts of 200g/m2 with added compensation of dry matter content, disintegrated in water and turned into a sheet of even thickness. The sheets were later pressed and dried, folded to form pieces of four layers and, because of their instability, measured through glass with an L&W Electropho spectrophotometer. The fibres were measured by arranging them under the spectrophotometer aperture covering the background completely and placing them under the same glass as the pulp sheets, thus making the presence of glass relative and insignificant. Eleven samples were tested, and they were categorized according to their success in translation to the fibre of second generation.

- Successfully translated colour. This category refers to fibres that preserved their lightness, saturation and hue relatively well and visually could have been connected to their OAC.
- Colours that were altered in translation only slightly. This category refers to fibres that changed their lightness, saturation or/and hue resulting in a visually noticeably different colour, yet that still could have been connected to their OAC.
- Colours that were altered in translation rather noticeably. This category refers to fibres that changed their lightness, saturation or/and hue resulting in a visually noticeably different colour, yet other than white.
- Drastic loss of colour. This category refers to the fibres that lost their saturation, hue and rose on the lightness scale towards white after the dissolution process.

Table 1: Samples of remanufactured fibres, their colours and origins

	Colour and total consistency	Origin	Colour components	Dyeing method (certain or estimated)	Success of translation from average optic colour in regenerated fibre
1	Yellow 55,4% Cotton 43,5% Viscose 1,1% Elastane	Flea market, mostly post-consumer source materials	All various shades of yellow	Most components were dyed with presumably reactive dyes	- Visually rather similar to source material - darker than OAC, reduced chroma in red, increased chroma in yellow Successfully translated colour
2	Blue 49,4% Cotton 19,8% Viscose 4,8% Cupro 10,2% Modal 4,6% Lyocell 1,1% Elastane	Flea market, mostly post-consumer source materials	All various shades of blue	Most components were dyed with presumably reactive dyes	- Visually hue change noticeable from royal blue to purple - darker than OAC, increased chroma in red, reduced chroma in blue OAC was altered in translation
3	Blue Denim 50% Cotton 50% Lyocell	½ of the material from post-consumer item. ½ of the material from pre-consumer item.	Two shades of denim blue	Components were dyed with presumably indigo dyes	- Visually hue change noticeable from light blue to rather dark, dull petrol - darker than OAC, increased chroma in green, reduced chroma in blue OAC was altered in translation
4	Red 50% Viscose 42% Cotton 8% Modal	Fabrics were bought from fabric store and dyed for testing purposes. Pre-consumer materials.	All red	Reactive dyed. All components dyed in the same pot.	- Visually drastically lightened - Lighter than OAC, reduced chroma in red, reduced chroma in yellow. Drastic loss of colour
5	Optic Orange 50% Cotton 30% Viscose 20% Modal	Fabrics were bought from fabric store and dyed for testing purposes. Pre-consumer materials.	50% Red 50% Yellow	Reactive dyed. Red components dyed in the same pot. Yellow components dyed in the same pot.	- Visually hue change noticeable from bright orange to wheat yellow COMMENT: Red colour component from the same pot as in sample 6, thus loss of red parent colour foreseeable. - Lighter than OAC, reduced chroma in red, increased chroma in yellow. OAC was altered drastically in translation
6	Optic Purple 50% Cotton 30% Viscose 20% Modal	Fabrics were bought from fabric store and dyed for testing purposes. Pre-consumer materials.	50% Red 50% Blue	Reactive dyed. Red components dyed in the same pot. Blue components dyed in the same pot.	- Visually hue change noticeable from deep purple to cold violet COMMENT: Red colour component from the same pot as in sample 6, thus loss of red parent colour foreseeable. - Lighter than OAC, reduced chroma in red, increased chroma in blue. OAC was altered in translation

Table 1: *continued*

7	Emerald Green 100% Cotton	Industrial cut waste from local knitting factory. Pre-consumer materials.	All green from single source	Presumably reactive dyed	- Visually slight change in lightness and hue noticeable from emerald green to slightly colder green - Darker than OAC, reduced chroma in green, no chroma change in blue OAC was slightly altered in translation Colour in translation still green, but slightly colder and darker
8	Peony Pink 50% Cotton 30% Viscose 20% Modal	Fabrics were bought from fabric store and dyed for testing purposes. Pre-consumer materials.	All pink	Vat dyed. All components dyed in the same pot.	- Visually colour slightly brighter than source material - Darker than OAC, increased chroma in red, increased chroma in yellow OAC was slightly altered in translation Colour in translation still pink, but slightly more intense in chroma
9	Turquoise 49,18% Cotton 29,51% Viscose 19,67% Modal 1,64% Elastane	Flea market, post-consumer source materials.	All various shades of turquoise	Most components were dyed with presumably reactive dyes	- Visually rather similar to source material - Darker than OAC, increased chroma in green, reduced chroma in blue Successfully translated colour
10	Mint Green 52,26% Cotton 36,48% Viscose 9,86% Modal 1,39% Elastane	Flea market, mostly post-consumer source materials.	50% All various shades of turquoise 50% All various shades of yellow	Most components were dyed with presumably reactive dyes	- Visually rather similar to source material - Darker than OAC, increased chroma in green, reduced chroma in yellow - Successfully translated colour
11	Light Orange 60% Viscose 32% Cotton 8% Modal	Fabrics were bought from fabric store and dyed for testing purposes. Pre-consumer materials.	50% All various shades of yellow 50% All various shades of peony pink	Yellow components were dyed in the same pot with reactive dyes. Pink components were dyed in the same pot with vat dyes.	- Visually colour slightly brighter than source material - Darker than OAC, increased chroma in red, reduced chroma in yellow Average optic colour was slightly altered in translation Colour in translation still orange, but more chromatic in red

Results

This experiment opened a certain phenomenology associated with the chemical remanufacturing of dyed cellulosic textiles.

- The OAC of ground textiles, while manifesting in optical form as one colour, can alter after dissolution and the colour of the fibres will be different. This can apply to pre- and post-consumer fabrics.
- The OAC of textiles, while manifesting in optical form as one colour, can be preserved rather well after dissolution and the colour of the fibres will be corresponding. This can apply to pre- and post-consumer fabrics. Successful translations can be found among presumably reactive dyed textiles as well as vat dyed textiles.
- It was observed that colour theory can be applied to textiles of two differing colours in order to form fibres of a new colour. This works with both pre- and post-consumer fabrics. The feasibility of this exercise depends on how well the parent colours endure the dissolution process.
- The accurate application of colour theory fails if the parent colour cannot withstand the dissolution process.
- Textiles that were vat dyed in documented circumstances preserved their colour through dissolution very well, even adding slightly to the chroma intensity of the new fibre.
- Denim textiles shifted slightly towards a greener hue.
- A case of reactive dyed textiles altering from their OAC manifestation by exhibiting drastic loss of colour was observed.

In Figure 1 the process of material transformation is shown in three stages: source material textiles, pulp sheets formed from the ground textiles and spun fibres.

Figure 1: Textile source materials (rectangle pieces), optic pulp sheets of average colour (round pieces), remanufactured fibres in upper part of the picture. (photo Eeva Suorlahti)

Concept development

Colour library

Some important benchmarking for a colour design could be taken from former or current practices, such as mechanical fibre regeneration. According to Prato Textile Museum didactic tables (2016) reclaimed wool was the principal product of Prato's textile industry (Italy) from the mid-19th to the mid-20th century. It is made from fibres of shredded used textiles and textile industry off-cuts which are subsequently re-spun and rewoven. Selected and sorted rags were delivered to the factory in bales classified according to two criteria: type of fibre and colour or rather the prevalent shade. The rag sorter, a man whose experience and sensitive touch enabled him to classify fibres with amazing accuracy was an important professional figure in that industry. The sorting resulted in creation of piles of rags which are named after their colour: 'aviator' (shades of blue similar to the Air Force uniforms); 'camel' (beige), 'railwayman' (dark grey), 'flag' (bright green) and multicoloured. (ibid.)

As Gulich (2006b) argues raw materials and waste disposal are becoming more and more expensive. When looking for suitable raw materials to make reclaimed fibres, household textile waste as well as industrial waste should receive more attention. Mechanically recycling textiles into fibre that can be spun into a good quality yarn is a more difficult proposition, and rather than using post-consumer waste, the best results come from using clean pre-consumer textile waste of the same colour and fibre type (Payne, 2015). When pre-consumer textile waste is mechanically recycled (e.g. denim offcuts), being of the same fabric allows a yarn to be produced with a consistent staple length and thus of a quality suited to textiles for apparel. However, with clean pre-consumer textile waste, the mechanical recycling process will still result in shorter fibre lengths. For this reason, recycled fibres are frequently blended with virgin fibres for apparel applications (Payne, 2015).

The Finnish clothing company Pure Waste also employs mechanical reclamation technique in its fabrics. The company's production manager explains that in their process the fibres are obtained from cotton cut waste provided by selected sewing factories. A small unevenness in colour is a result when recycled polyester from PET bottles are combined with cotton. The cotton colours of their tricot and sweatshirt fabrics originates directly from the colour of the raw material. Melange grey is mixed from grey cut waste and fibres of differing tones so there is a showcase of forming a new tint by optical mixture of fibres. Pure Waste does have an occasional seasonal colour besides their basics like blue or red, their choice of special colour is mainly dependent on its current popularity and thus on the abundance of raw material (Pesola, personal communication, 23.2.2016).

Both mechanical and chemical methods of fibre reclamation are employed in following concept. Mechanical fibre regeneration provides a good start, since the colours of single fibres could remain as they are with little to no alteration. By combining fibres of two or more colours in one yarn they can optically form totally new colour. In a chemical regeneration process, blended colours could produce fibres of new colour. Managing existing colours as parent colourants for the purpose of creating new colours gives a good space for manoeuvre on the trend-sensitive textile market. The methods and tools considered apt for this concept are presented in Fig. 2.

In a colour design method suitable for mechanical fibre regeneration, a motley, melange surface could be considered as a certain visual hallmark for the method. However, even though an interesting aesthetic, it might be considered somewhat too stylised for universal use, thus limiting the interest of customers to a seasonal basis. Another downside of this method is the fact that the fibres are shortened when subjected to mechanical regeneration and form yarns of lower quality. Thus the fibre and the colour it manifests can be recycled only for a limited number of rounds. In addition, if optical mixing of the material is done, it needs to be considered in further colour design when the colour mixture becomes the parent colour itself.
In a chemical regeneration process of cellulosic materials the length of the fibre can be as long as needed, the colour is uniform and various behaviour of dyes could be used to further employ in colour design purposes or production disciplines.

Discussion

The wide range and uncertainty of dyes and dyeing methods applied to existing textiles worldwide will pose challenges to the colour conversion via the Ioncell-F remanufacturing method. However numerous successful examples of colour translation to the fibre of the second generation demonstrate that colour conversion is possible and with dyes designed for remanufacturing this development could be refined. Development in accuracy of colour translation could create a tool for dyeing professionals to achieve colours demanded by the market. Alternatively, the results of decent but not precisely accurate colour conversion from OAC to the new fibre suggest there could be some increase of tolerance to minor colour shifts in future industry as well as by the future consumer.

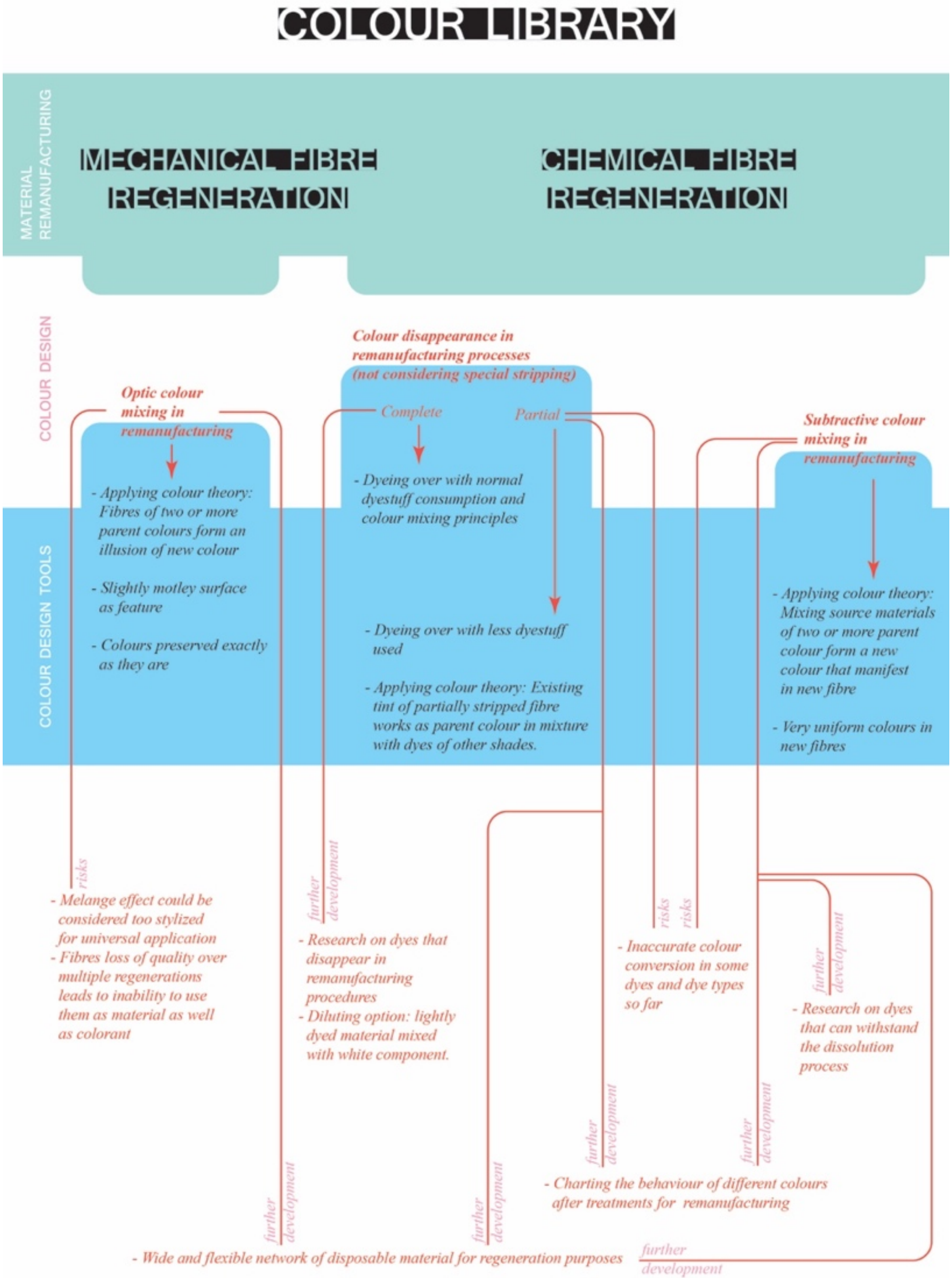


Figure 2: Colour design concept: methods and tools

Two successful samples show that colour theory works under the condition that both parent colours endure the dissolution process. Thus, in the future this could be one of the hands-on tools for colour designers to research new hues by mixing existing disposable textiles. Samples that altered their colour after dissolution represent a wild card tool for designers to use in their search for new colours. Some dyes' inability to withstand the dissolution process could be considered as an alternative for dye stripping. Partial disappearance of colour can contribute to reducing the amount of dyes applied to textiles of remanufactured fibres and thus achieve full coloured fabrics with minimised consumption of dyestuff. Colour design is also relevant in this case since textiles with partially preserved colours could be dyed in the conventional way with other hues.

Earlier described options could be applied to post-consumer textiles as well as pre-consumer textiles such as industrial cut waste or surplus fabrics. This study suggests that disposable cellulosic textiles be brought back into circulation as raw material through colour design, considering them not only as material but also as a colorant thus leading to more careful use of manifesting colour qualities of the existing materials.

References

Aarras, N. (2015) *One company's waste is another's raw material – Recycling and remanufacturing as an economically and environmentally sustainable business opportunity* ("Toisen jäte on toisen raaka-aine – kierrätys ja uudelleenvalmistus taloudellisesti ja ekologisesti kestävänä liiketoimintamahdollisuutena") (Doctoral Dissertation), Turku School of Economics, Suomen yliopistopaino Oy Juvenes Print, Turku

Broadbent, A. D. (2001) *Basic Principles of Textile Coloration.* Society of Dyers and Colourists. Kent: Thanet Press

Buschle-Diller, G. (2006) *Recycling and re-use of textile chemicals.* Auburn University, USA. Cambridge: Woodhead Publishing Limited

Ellen McArthur Foundation (2012) *Towards the Circular Economy Vol. 1: an economic and business rationale for an accelerated transition.* Study report. http://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf <retreived 8.1.2016; 20.20>

Fletcher, K. (2014) *Sustainable Fashion and Textiles: Design Journeys*. Oxon: Routledge

Forss, M. (2000) *Methods of Dyeing* (Värimenetelmät); Taideteollinen Korkeakoulu; Gummerus Kirjapaino Oy, Jyväskylä

Gulich, B. (2006a) *Designing textile products that are easy to recycle.* Saxon Textile Research Institute, Germany. Cambridge: Woodhead Publishing

Gulich, B. (2006b) *Development of products made of reclaimed fibres.* Saxon Textile Research Institute, Germany. Cambridge: Woodhead Publishing

Michud, A; Tanttu, M; Asaadi, S; Ma, Y; Netti, E; Kääriäinen, P; Persson, A; Berntsson, A; Hummel, M; Sixta, H. (2015) *Ioncell-F: ionic liquid-based cellulosic textile fibers as an alternative to viscose and Lyocell.* Textile Research Journal. Thousand Oaks, USA: Sage Publications

Payne, A. (2015) *Handbook of Life Cycle Assessment (LCA) of Textile and Clothing.* Cambridge: Elsevier

Prato Textile Museum (2016) *Didactic Tables.* Prato, Italy: Prato Textile Museum.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646226.

What Else Do We Know? Exploring the application of design knowledge and skills for the circular economy beyond materials selection and design for production

Rosie Hornbuckle (University of the Arts London, UK)

Abstract

There has been an awakening in recent years in the field of design research to the idea that designers can take on a number of roles other than the traditional narrow focus on products. This paper draws on existing research to explore new ways of applying design knowledge in the circular economy, and in particular in relation to the development of materials. Early observations from the current EU H2020 Trash-2-Cash project build on this current understanding within a consortium project. Three new roles are presented: 1) bringing new design-driven insights - hands-on materials knowledge and introducing the social context; 2) translation, interpretation and boundary spanning to bridge disciplinary barriers; and 3) introducing design tools and methods to support interdisciplinary collaboration. This research concludes that there are various ways that designers can use their knowledge and skills to support circular materials systems other than designing products, but they need to be better equipped to identify and practice these roles.

Introduction

It has been suggested that designers could play a significant role in the circular economy; it is estimated that 80 to 90% of a product's lifecycle impacts are decided during the design phase (Graedel *et al* 1995). Yet the implications of this statement – that designers have the power to make sustainable choices - is far from the reality of mainstream design practice (Hornbuckle 2010).

However, there has been an awakening in recent years in the field of design research to the idea that designers can take on a number of roles other than the traditional narrow focus on products (for example Manzini 2015; Tan 2012; Cooper & Press 2003). Some *design scenarios* – the circumstances under which the designer applies their knowledge – may be more conducive to positively influencing circular materials systems (Hornbuckle 2010) and it would benefit designers frustrated with the constraints of their current practice to understand other ways in which to apply their skills and knowledge in the circular economy.

This paper draws on existing research to explore new ways of applying design knowledge in the circular economy, and in particular in relation to the development of materials. Early observations from the current EU H2020 Trash-2-Cash project will then add insights to current understanding on how design knowledge and skills can be applied and developed within a consortium project.

Defining the focus within the circular economy

'The Circular Economy' is a broad concept encompassing many ideas related to a number of disciplinary fields. A concern for health, the environment and social issues has led designers and design researchers to explore various avenues related to these connected ideas, from service design to design for emotional durability. The particular focus of the research presented in this paper is the circularity of materials, as a starting point, taking the commonly misunderstood notion of 'specifying recycled or recyclable materials' from its rather static and solitary position within the conventional design-for-production phase of the product lifecycle and reframing the design challenge as 'the consideration of materials as part of a circular system'. The inevitable consequence of designers thinking about materials in a circular system is that to act, they sometimes need to break out of their conventional role.

This paper asks 'what else do designers know' which could support movement towards circular materials systems; what other roles can they perform other than attempting to use recycled or recyclable materials? The research reported here sets out a specific alternative scenario for the application of design knowledge – a research project where the aim is to develop new circular materials, as a particular case study, although the roles observed are applicable more widely.

About Trash-2-Cash

Trash-2-Cash is an EU Horizon 2020 funded Design-Driven Materials Innovation (DDMI) project (grant agreement no. 646226) focusing on the development of novel fibres made from regenerated cellulose and polyester derived from textile waste. The consortium consists of 18 European partners encompassing science, design and manufacturing expertise within research institutions and industry. Design involvement includes academic design researchers, textile and industrial designers (within agencies and manufacturers) who – according to the project proposal – will:

- Lead the recycling initiative, defining the material properties, and will feed the material scientists to evaluate newly developed eco- efficient cotton fibre regeneration and polyester recycling techniques.
- Develop new material and product opportunities via creative design from waste or process by-products
- Use design for recycling with the vision of closing the material loop.

The task of design can be seen to be that of informing the technical development stream using conventional design for production and design for recycling processes. This paper will reflect upon some ways that designers have so far expanded their role beyond this traditional notion of design.

The author is part of the 'methodology team' and therefore works closely with the coordinators to plan the workshops (where the main collaboration activities take place). During the workshops, the author is mainly responsible for observing how participants respond to the planned activities, and occasionally is involved in facilitating particular sessions. The research on which this paper is based therefore, adopts auto-ethnographic and ethnographic approaches to gather data and analyse the effect of these interventions whilst acknowledging the author's involvement as part of the field of study.

The reflections included in this analysis come at an early stage of the Trash-2-Cash project, but significantly at the end of the first of three iterative phases. The first completed 'Design' phase, would perhaps most accurately be characterised as 'setting up the collaboration' and 'forming design directions for the materials development'. The design involvement reported therefore reflects this focus; it is expected that phase 2 of the project will involve more conventional applications of design knowledge as identified in the project proposal extract above.

At this early stage the data comprises field notes, feedback 'Tips & Tops' and worksheets from Workshops #01-04, selective interview transcripts, as well as worksheets and reflective interviews with some of the facilitation team. These analyses should not therefore be viewed as conclusive but rather as early observations.

Reframing the role for designers in the circular economy

On face value the role of designers in material circularity is fairly straightforward. Designers are involved in the selection of materials for products. How those materials are shaped, combined and the context in which the resulting product may be used will have a significant influence on whether that material can be an effective part of a biological or technical cycle (McDonough & Braungart 2002). Designers also have the ability to draw waste materials back into the material cycle by incorporating them into new high-value products. Therefore, the role of designers in the circular economy has frequently been framed by their traditional function of design for production. However, research suggests that fulfilling this role is far from straightforward; materials selection is constrained by existing modes of production and established supply chains, creating effective materials cycles involves systemic change across a large number of actors and even the apparently straightforward aim of 'specifying recycled materials' presents a myriad of problems for designers (Hornbuckle 2010; Chick & Micklethwaite 2008). Therefore, designers who want to work in a way that support materials circularity must find new ways of applying their knowledge and skills other than though materials selection alone, which is problematic.

Other roles for designers in the circular economy

In recent years design researchers have begun to expand this view of design's role in addressing the challenges of material circularity. In this section, the author will present three ways that designers have been seen to apply their knowledge to positively influence materials use in the circular economy. The discussion will draw on existing research as well as early observations from the Trash-2-Cash project.

Experiential knowledge of materials and the social context

In 2005 Dehn was awarded a UK Arts and Humanities Research Council (AHRC) grant to investigate the role of designers in developing problematic waste materials. A designer herself for many years, Dehn was interested in the value of design intervention which goes beyond the straightforward selection of these materials. For example, playing or "tinkering" (Karana *et al* 2015) with materials enabled designers to bring new experiential materials knowledge to the materials development process, whilst also finding new applications and developing higher-value products. This observation has also been explored by Karana *et al* (2015) through a method they term Material Driven Design to facilitate "designing for material experiences"; fundamentally acknowledging the designer's ability to make materials meaningful by adding value through hands-on material development and making.

However, the value that designers can bring to materials development can be seen to go beyond hands-on materials knowledge and translation into meaningful products. In her research, Dehn found that the impacts were manifold:

- Transform our perception of waste
- Reappraise unconventional materials
- Promote sustainable values through involvement with design education
- Collaboration with manufacturers leading to design innovation and commercial success
- Design desirable products, generate business, create employment and sustain communities (Dehn 2014)

Designers have the desire and ability to collaborate, to communicate, and to create positive social impacts. These applications of design knowledge have also been observed within the first four workshops of T2C and particularly workshops #03 & #04; the designers from agencies and academia both sought to introduce social issues into the conversation of how the new fibre might be used in future scenarios. This was also noted by scientists in the Tips & Tops feedback session which take place at the end of each workshop, commenting "I like the way designers connect to the wider context" [Post-Doctoral Fibre Scientist].

In workshop #03 one of the agency designers suggested running a session on 'Megatrends' which sought to explore how the project work might align with cultural trends. This was an unplanned intervention but was welcomed by the methodology team as it aligned well with the current project phase and challenged the project direction, broadening the participants' vision beyond the immediate and straightforward. The success of this design intervention was the impact it had on the dialogue within the group, not just amongst designers but also senior scientists. Subjects such as humanitarian issues, the refugee crisis and healthcare were bought into the discussion.
In workshop #04, during an assessment exercise, the issue of migration reemerged in one discussion group of designers alongside the pollution and resource concerns of 'water/ocean' and 'cotton', highlighted in the corner of their worksheet. This ability to raise the discussion of material development above the more straightforward questions of western commercial markets and material issues to ones related to social and humanitarian needs is

arguably an unexpected but nevertheless important application of design knowledge within the context of materials innovation.

Materials translation and project interpretation

The term Materials Translators was first introduced by the author in 2013 and refers to the important role of a person working with a materials collection in translating materials benefits for designers (Hornbuckle 2013), 'boundary-spanning' (Rieple et al 2005) the worlds of materials specialists (suppliers) and non-specialists (designers):

> [Materials Translators] are in a unique position between the scientific and creative communities. From the investigation, it became clear that this position and consequential understanding enables these specialists to translate the benefits of materials for design through workshops, exhibits, talks, articles, books and consultancy (Hornbuckle 2013:105)

This is supported by the author's 2008 doctoral research which found that to encounter and understand alternative materials designers need to talk to a materials specialist; dialogue is the central method in obtaining materials information in a way that is understandable to designers (Hornbuckle 2010:185).

All but one of the Materials Translators observed in the study had a design background at least to the level of training but many had also practiced as designers, suggesting that having 'design knowledge' and consequently an understanding of design thinking and methods is an important feature of the Materials Translation. This is, it is argued, an alternative application of design and materials knowledge and could have a significant role in the circular economy as designers are tasked with setting aside conventional material selections and exploring alternatives which may challenge traditional modes of supply and production.

Within the current Trash-2-Cash project a materials library takes a central position in the project methodology, described in the project proposal as an "intermediary/facilitator". In this context, the Materials Translator's role is extended beyond what was observed in the 2008 study, spanning the boundaries of design, science and manufacturing and, as well as disciplinary differences, there are also barriers relating to national language, culture and location. Whereas the materials translators observed in the earlier study would mainly be working with a few different actors at any one time, T2C involves a large number of people across 18 organisations which arguably demands a different set of skills.

Initial observations suggest that the lead Materials Translator[1] in T2C and his colleagues are performing materials translation tasks such as interpreting material properties into senseoaesthetic language (in written reports and through dialogue) and using materials samples in specific ways to assist communication within the workshop. For example, in workshop #03 there were several discussions where designers were asking questions such as “how strong?” or “what does that Dtex look like?” and “what does Ioncell feel like”. In response, the lead Materials Translator went to find a specific sample to assist with the scientist’s explanation. In workshop #04 the Materials Translators made a selection of materials samples to demonstrate some of the properties that designers would hope to achieve through the material development process alongside some experimental presentations of materials properties which aimed to speak to designers and scientists alike. Therefore, it is clear that the Materials Translators within T2C are performing boundary-spanning or bridging roles within the consortium. However, what is perhaps less expected is the extent to which the lead Materials Translator also takes a central role in interpreting the project aims and objectives and indeed translating these for the broad range of disciplines, languages and cultures represented in the consortium. For example, during the Design Scenario presentation in workshop #02 the Lead Material Translator positioned himself at the front of the auditorium and frequently interjected to ensure design methods and ideas make sense to scientists and manufacturers, and within the context of the project. This is perhaps partly due to the experience of this person in a previous interdisciplinary project and his central role in devising the project methodology, incorporating design methods into a scientific process of material innovation. However, the ability to translate between disciplines is also a central skill which enables the project interpretation to be carried out in this way; as neither a designer nor a scientist the Materials Translator is in a position to take an overview of the project and the interests of its different stakeholders.

---

1 For ease of understanding the author will continue to use this term for people working with a material collection, although the job title of this person is *Project Manager, Innovation & Research*

Design tools and methods: visualisations to support the collaboration

The use of design tools was anticipated in the project proposal in relation to ‘lifecycle representations’ which will start in the second phase (year 2) of the project. However, during the first phase the use of design methods and tools had not been anticipated or well defined in the project proposal, yet their introduction and use was widespread in workshops #01 to #04 with varying success, for example in the ‘megatrends’ session described earlier. Given the confines of this paper the author will focus on one type of tool/method which emerged during the first project phase; the production of visual material to support the collaboration which was instigated primarily by the author as part of the research team at the Textile Environment Design (TED) research group at University of the Arts London (UAL).

Visualising information is seen as a powerful method of supporting understanding (Tufte 2001) and has become a dominant feature of design research in recent years (Boehnert 2016). The great number of barriers to understanding within this project quickly led TED researchers to identify ‘project visualisation’ as a method that could enhance the collaboration and aid understanding. One such example is the Capability Map produced by the author for workshop #04. Project partners were asked to complete an online survey of their knowledge and capabilities in line with the project focus on materials, recycling, design, manufacturing, end-users and lifecycles. A tabular ‘map’ was generated from the results identifying each person’s capabilities and knowledge (see figure 1).

The was to allow partners to quickly see who they might talk to when requiring particular expertise and to build a sense of community within the project. The map was provided in workshop #04 accompanied by an interactive task to be completed by partners in between scheduled sessions. A large poster of the material/product lifecycle was pinned within the workshop space and participants were given their own ‘face stickers’ to place within the project (see figure 2).

The aim was to visualise the knowledge that had been captured in the survey in a fun and engaging way that would draw attention to the map and also produce some research outcomes. Every workshop participant took part and some even added other colleagues (who are involved in the project but not attending workshops) using post-it notes. The feedback from the post-workshop survey was positive, with partners asking for it to be made available online and stating that it will become “increasingly useful”. In the post-workshop analysis, the author was able to code people by their discipline (design, science, manufacturing) which also gives an overview of where different types of knowledge reside within the project (faces have been removed for anonymity). Strikingly designers positioned themselves throughout the project space – in every section apart from fibre science, showing the 'general' nature of design knowledge compared to scientific knowledge which is specific. This echoes the point made earlier, that one potential benefit of design to the scientific process is to introduce a contextual awareness.

Figure 1 (left): A capability map was created from an online survey of project partners' expertise. Figure 2 (right): Face Stickers were placed within the 'project space' poster by each workshop participant

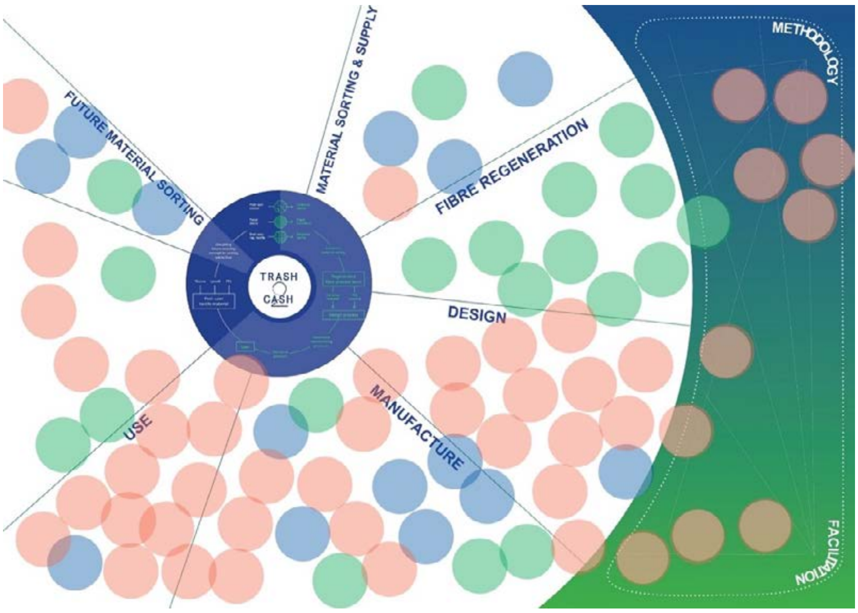


Fig 3: Capability 'face' map: participants were asked to place themselves within the project 'space' (faces have been removed for anonymity) Coded by discipline - red=design; green=science; blue=manufacturing/supply

In summary, design knowledge in the form of tools and methods have been used in T2C to build and support the collaboration and in turn, it is hoped, the development of ‘circular’ materials. However, one central concern with all design tools and methods used in an interdisciplinary context, is that their value to the project is sometimes not clear to non-design participants and therefore every effort should be made to communicate the value of design tools and methods effectively.

Conclusions: new ways of applying design knowledge in the circular economy

Collaborative projects offer a unique opportunity to work towards circular materials systems, where the challenges are too complex and connected to a system of actors for designers to address independently. This paper has sought to present some of the ways that design knowledge can be usefully applied within this context drawing on recent research and observations from the Trash-2-Cash Design-Driven Materials Innovation project: hands-on materials knowledge to provide material and application insights, introducing the social context to address a wider range of sustainability issues; translation, interpretation and boundary spanning to bridge disciplinary barriers; and introducing design tools and methods to support interdisciplinary collaboration.

This however, is just a small selection of the ways in which design knowledge and skills have been applied within Trash-2-Cash, and shows that designers have a great deal more to offer than simply the selection of more appropriate materials. Importantly, more opportunities need to be identified for designers to apply knowledge in this way and scenarios for alternative design practice defined and communicated to designers.

On a final note, the design collaboration within Trash-2-Cash has not been without challenges. While designers have developed tools and methods for interdisciplinary collaboration on a small scale in recent years (for example Ellams 2016; Robertson 2011), there has been little written about the challenges of working in a large consortium and how designers can work together to achieve an effective and valuable creative offer. More work needs to be done to refine and define these methods for designers collaborating *with each other*, including a much clearer understanding of how design knowers from different disciplinary backgrounds and cultures can work together. Whilst being very rewarding, the design and methodology collaboration has also been surprisingly challenging and equipping designers with knowledge about how to integrate and differentiate between different design roles would be extremely beneficial in any future collaborative work.

References

Boehnert, J. (2016) Data Visualisation Does Political Things *DRS2016: Design + Research + Society: Future-Focused Thinking* University of Brighton 27 to end of 30 Jun 2016 Design Research Society

Cooper, R. & Press, M. (2003) The Design Experience: The Role of Design and Designers in the Twenty- First Century. Aldershot: Ashgate

Dehn, J. (2014) Conception and Realization of a Sustainable Materials Library. In Karana, E., Pedgley, O. & Ragnoli, V. (eds.) (2014) *Materials Experience: Fundamentals of materials and design.* Elsevier, Oxford UK.

Dehn, J. (2008) Supporting Communities: Design led collaborations exploring the creative and economic potential of materials made from waste. In Cipolla, C. Peruccio, P. (eds) *Changing the Change proceedings.* Allemandi Conference Press

Ellams, D. (2016) Environmentally conscious fashion through responsible coloration techniques applied to sustainable fabrics: colouring outside the lines. Doctoral Thesis, Heriot-Watt University School of Textiles and Design, Edinburgh

Graedel, T.E., Comrie, P. R., Sekutowski, J. C. (1995) Green product design. *AT&T Technical Journal,* 74:6 pp 17-24.

Hornbuckle, R. (2013) Materials Translators: observations from a study of sustainable materials information provision and design behaviour in London, UK. *Sustainable Innovation 2013* conference, Epsom, UK

Hornbuckle, R. (2010) Design and The Material Cycle: An investigation into the use of secondary materials in design practice. Doctoral Thesis: Kingston University

Karana, E., Barati, B., Rognoli, V., van der Laan, A. Z. (2015) Material Driven Design (MDD) A method to design for material experiences. *International Journal of Design* vol 9 no. 2 pp 35-54

Manzini, E. (2015) Design, When Everybody Designs. An Introduction to Design for Social Innovation. The MIT Press.

McDonough, W. & Braungart, M. (2002) Cradle to Cradle: Remaking the Way We Make Things. New York: North Point Press

Rieple, A., Haberberg, A. & Gander, J. (2005) Hybrid Organisations as a Strategy for Supporting New Product Development. Design Management Review 16(1), 48-55

Robertson, S. (2011) An investigation of the design potential of thermochromic textiles used with electronic heat profiling circuitry. Doctoral Thesis, Heriot-Watt University School of Textiles and Design, Edinburgh

Tan, L. (2012) Understanding the Different Roles of the Designer in Design for Social Good. A Study of Design Methodology in the DOTT 07 (Designs of the Time 2007) Projects. Doctoral thesis, Northumbria University.

Tufte, E. R. (2001) The Visual Display of Qualitative Information. 2nd ed. Cheshire, Connecticut: Graphics Press.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.646226.

Operating in the Third Space: the space between

Jennifer Whitty (Massey University, NZ)

Abstract

Space Between is a social enterprise/research platform at the College of Creative Arts in Massey University, which enables students' recent graduates and fashion researchers to work together with a shared philosophy to bring about 'positive change' in industry. It works according two distinct but complementary strategies to design with the textile waste from the current system and to ultimately eliminate waste from industry by design in closed loop' solutions.

Introduction

Fashion is dominated by a linear operating system at both a macro and a micro level which has set narrow parameters for all fashion activities to occur. This is exemplified by the compartmentalised 'take, make, waste' approach which has influenced consumer culture to consume and discard clothing at their earliest convenience. These linear sequential pathways of action have, for the most part stifled social innovation and our innate human resourcefulness. They have conditioned us, as both users and creators of fashion, to stay within the designated spaces. We are not encouraged to stray outside, to the space between or an alternate 'third space' outside of the conventional view of fashion to enable more dynamic, circular, bottom up practices to emerge to acknowledge the incredible depth and complexity that a flourishing, circular fashion ecosystem can be. These issues seem to be a residue of 20th century thinking which tended to compartmentalise and separate activities for efficiency. In Fletcher's (2016) opinion the separation of design from production has led to a reckless, unhinged fashion system that operates without an authentic sense of its context. In an attempt to address and interrogate these issues the practice based research project Space Between (Whitty, J. McQuillan, H. 2015) was established by the researchers Jennifer Whitty and Holly McQuillan in 2015. Its aim is to explore and disrupt the space between the components of this linear system which is inherent within industry, consumer culture, and education with the aim of creating a more expansive, inclusive circular mode of operation. This paper examines Space Between, a social enterprise/research platform at the College of Creative Arts, Massey University, New Zealand as a case study for implementing sustainable design strategies within the construct of the circular economy. Situated in a tertiary institution working in conjunction with the not for profit and private sector it takes the form of design-led activism as described by Alastair Fuad – Luke (2009) and Von Busch (2012). The 'third role' (Nieminen, 2004, 22) of universities in contemporary society which prioritises knowledge creation based on current problems and projects is key to the development and relevance of initiatives such as Space Between. This paper will ask can cross -sector innovations, such as Space Between, operating from the third space of academia, create a catalyst for a circular system for fashion that encourages more new systems thinking (Niinimaki 2013) across fashion users and makers?

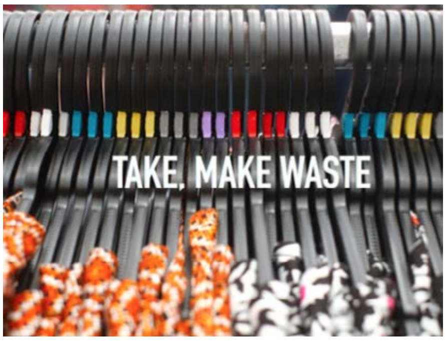
SPA
CE
BETW
EEN

Figure 1 (left): Fashion = Fast + Cheap + Throwaway? Image credit: Space Between, Thomas McQuillan/ Jennifer Whitty. Figure 2 (right): Space Between. This is not fashion as usual. Image credit: Space Between: Jennifer Whitty/ Jane Street Photographer Nikita Brown

Context

Take and Make: linear practices of industry

The conundrum of current linear fashion system is that viewed from a narrow perspective; that only takes account of its financial and manufactured capital; it appears successful, as it produces more clothes than ever before (Chen and Burns, 2006). However if we evaluate the system in its entirety; to include natural, human and social capital (Porritt, J. 2015) we cannot ignore its failings as is one of the most resource intensive and arguably polluting on the planet (Eco Watch, 2015). It does Research indicates that waste is endemic and inherent to the operation of this system which relies on the creation of superfluous clothing and textiles which are a huge cost to planet and people. According to a recent source approximately one third of all clothing produced for retail is never sold and is often incinerated. (Ecotextile 2016) and approx. 15% of fabric intended for clothing ends up on the cutting room floor. (Rissanen, T, 2005). The damage and impact to humans is also significant as a huge proportion of people work in compromised conditions that put their lives and health in danger (Allwood et al. 2006, p.2, p.14). This system largely ignores the wider context in which it operates and its ramifications on a planet composed of natural limits. As the global population reaches an all-time high of 7.4 million and the machines of our age spits out more goods than ever before often for single use it is clear this model is not responding truthfully, with a conscience to its 21st century context. In a world where damaging environmental and social implications are considered 'normal' by our fashion system, it is time to develop alternatives that integrate and acknowledge all forms of capital and work in the previously ignored spaces between these compartmentalised practices.



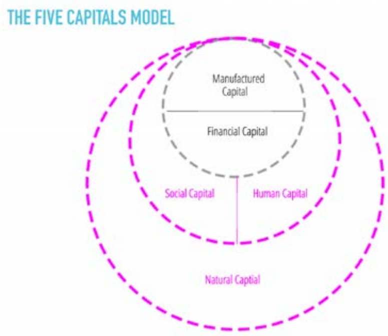


Figure 3 (left): TAKE, MAKE, WASTE linear system: image credit Jennifer Whitty, Thomas McQuillan. Figure 4 (right): The Five Capital Model. Image credit Jennifer Whitty based on Porritt, J. Forum for the Future.

Shop/Use/Waste: linear practices of our everyday consumer culture

The fast fashion system has conditioned consumers into thinking that buying new clothing on a regular basis is a harmless, acceptable activity that has no consequence on people or planet. This behaviour seems to show no sign of slowing down, as for example in the UK the consumption of fashion per capita has increased by 37% between 2001 and 2005 (Allwood et al.2006). The lifespan of garments is decreasing as globally 80 billion pieces are thrown out every single year, which is 400% more than 20 years ago (Morgan, 2015). Discarding these garments also means wasting all the embodied energy and materials that they contain, such as fibres, dyes, chemicals, water, human time and labour, fossil fuels and electricity. This mind-set is damaging our planet while wasting a multitude of resources both material and human, yet fashion users are seemingly unaware that there are alternatives to this linear fashion practice. Recycling options are also held up as solutions but this too has it's limits and causes problems further down stream and may no longer be an option if proposed bans in developing countries are enacted. (Halling, K, 2016). Consumers have been disconnected and shielded from the complexity and impact of their clothing, which has in turn shortened our experience and our understanding of the depth and impact of what 'fashion' is and what it can be.

Design education, part of the problem or part of the solution?
Current fashion design education is based upon preparing designers to operate within the linear machine where the emphasis is placed on giving form to new products based upon the logic of growth in a world of finite limits (Daly 1992; Jackson 2009). The field of design has not traditionally been taught in the context of its ecological impact on our planet that in many cases design is seen as part of the problem (McDonough, W. and Braungart, M. 2013, 7). Transition design (2014) posits that the issues confronting us in the 21st century requires fundamental change at every level of society. If university research is still the principal focus for knowledge creation and dissemination in the world (Marttila and Kohtala, 2014) it is key that higher education plays a more transformative, 'third role' (Nieminen, 2004, 22) in developing new skills in design (Perella, M. 2014). Fashion design education can be a powerful tool for enabling and empowering future designers to critique their role as secondary players within a larger system to be part of the solution (Manzini, E. 2008, p.4). A number of institutions including the Centre for Sustainable Fashion (2015) and Textile Environment Design at The University of the Arts (2015) are both leading the way in using fashion to drive change and build a sustainable future. The College of Creative Arts at Massey University (2015) is an innovative research-led art and design institution and its enterprise portfolio has opened up opportunities for new initiatives that are focussed on developing solution oriented design to deliver environmental, economic, social and cultural benefits to society.

Exploring the space between: The third space

Space Between (2015-2016) is practice based design research project that proposes an alternative system for fashion practice. It is informed by the Ellen MacArthur Foundation (2015) key concepts for the circular economy to create a restorative fashion system which is directed towards designing out waste which aims to re-think and redesign the way we make clothing.

It draws from the emergent design discipline of Transition Design (2015) which acknowledges the key role design plays in contemporary society as it applies an understanding of the interconnectedness of social, economic, political and natural systems to address problems in society. Alastair Fuad-Luke's framework for contextualising design activism (2009) in order to rethink some of key aspects of the industry, to foster innovation and provide a new vision and practice for fashion. The design actions and outputs adopt the strategies of the 'Considerate Design' (2007–9) by Sandy Black, part of the 'Designing for the 21st Century' research initiative (2005–2009). It sits in the rich but challenging nexus, or third space, between research, enterprise and education where it is simultaneously speculative / "scenario of design", (Fry, 2009, p. 152), proposing the shape a fashion practice might take when redirected for circularity whilst also operating under the constraints of a commercial framework, as it attempts to disrupt established ways of doing and thinking fashion. The imperative to take on this project came about as the synthesis of these perspectives as a method of integrating my experiences and role as a fashion academic, consumer and entrepreneur towards a redirected fashion practice that acknowledges its actual context as it has impact on people, both its users and producers and the planet. It enabled me to develop as Bert Mulder (2011) describes a more strategic, systemic use of design, beyond the design of clothing, which can, as Otto Von Busch (2012) says confront the status quo and suggests new possibilities.

A fashion system with an authentic sense of its context

Kate Fletcher (2016, p85) believes that in order to foster a climate for change we must first come fully to terms with the realities of our current fashion context to locate ourselves in our actual condition. One of the overwhelming realities of the system is the staggering waste it is has produced. The impetus to work in this capacity was reinforced by the strategic cross sector partnership with New Zealand Post Group; a state-owned enterprise which operates as a commercial entity which consists of a range of businesses providing communication and business solutions; and their corporate manufacturer Booker Spalding. In 2012 NZ Post identified that a vast number of their used uniforms – approx. 9,000 every year were in a workable condition, but were being down cycled or exported to Papua New Guinea to be disposed. Hollingsworth (2007) claims that about 45% of garments can have a second or third life cycle prior to their disposal and every tonne of discarded textiles reused saves 20 tonnes of CO_2 from entering the atmosphere. The researchers McQuillan and Whitty were contacted to develop a solution to address this issue of post-consumer corporate uniform waste based on their expertise in the area of sustainable solutions with clothing and textiles. The researchers examined their current system and subsequently developed a pilot solution 'Postmodern collection' (2012–2013) to utilise this waste material through a series of up-cycling (remanufacture) processes, design strategies and 3 upcycling techniques (conjoined, spliced and pieced) which could be applied to any given garment, including other corporate uniform manufacturers.

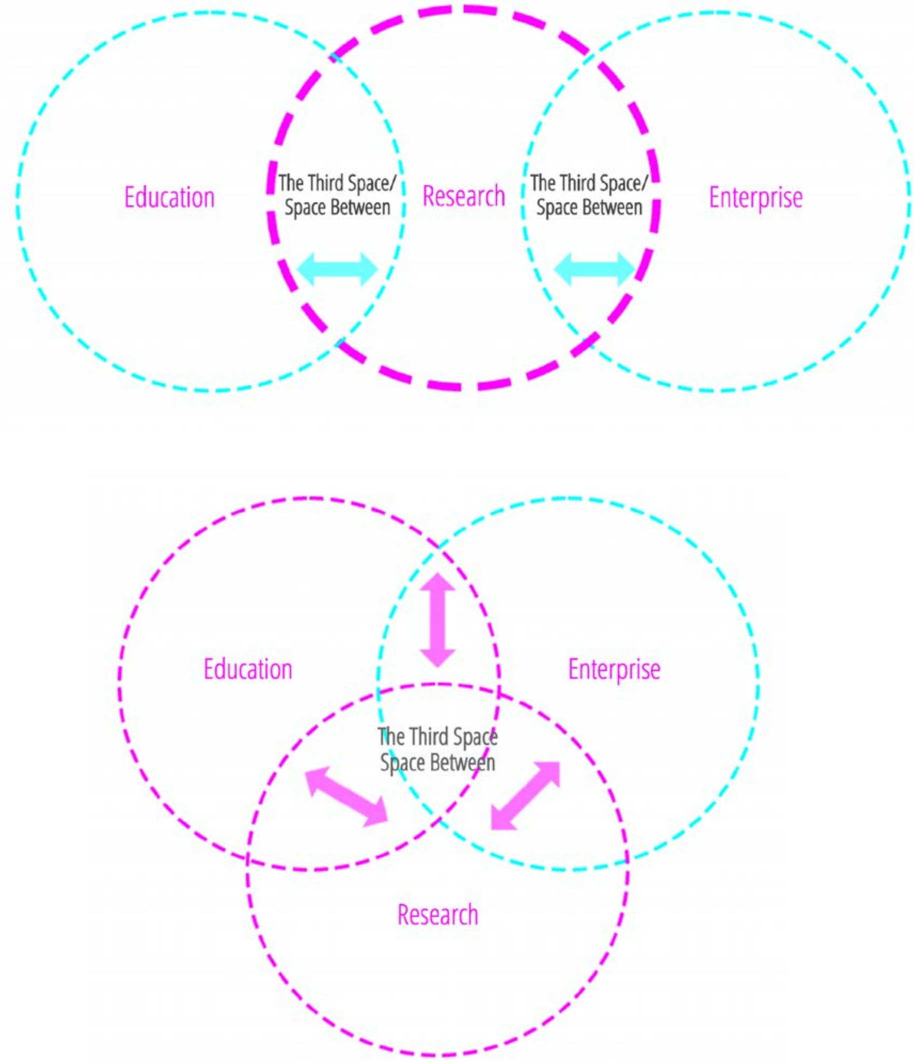


Figure 5 and 6: The Third space between research, enterprise and education (Whitty)

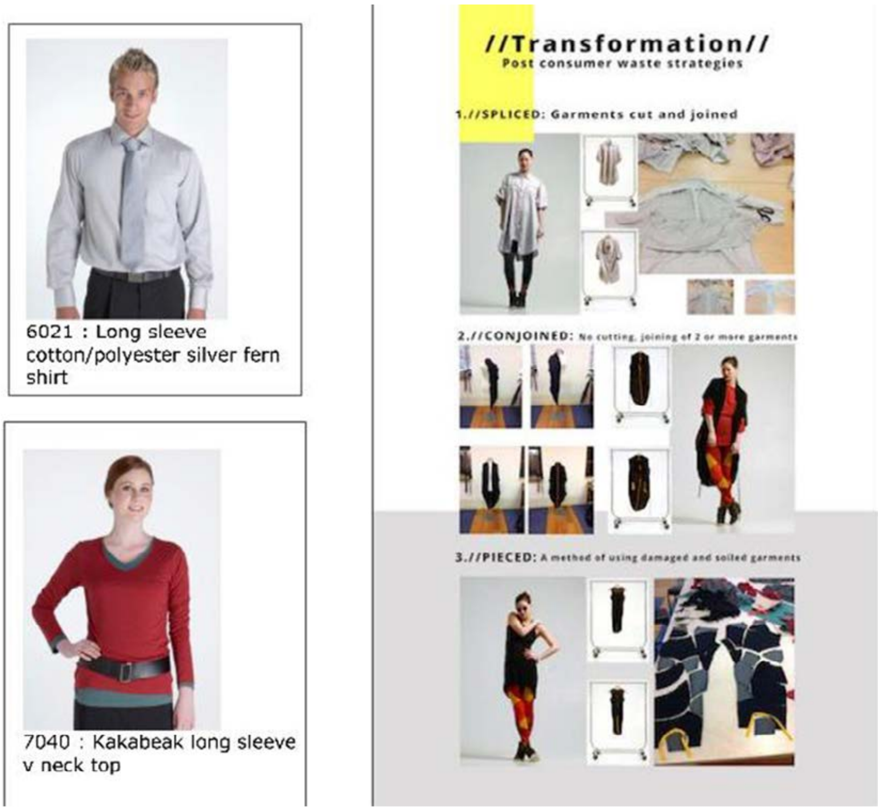


Figure 7: Post Modern Collection 2012-2013) (Whitty, J. & McQuillan, H.)

Changing the mechanism: new partnerships and relationships

It became apparent that the potential of this research was not just in garment design but in how this circular people person service and system for social innovation could operate in an educational institution in an ongoing basis and how this could lead to change in thinking and behaviour across sectors. As Li Edelkoort (2015) asserts we can change the mechanism of the fashion system by bringing together a diverse range of stakeholders to create a collaborative framework, which supports both individual and collective innovation. Thus, ensued a period from 2012-2014 of formalisation and negotiation through a tandem process involving design thinking and the development of legal frameworks in order to find the appropriate solution for all parties. The result was the formation of Space Between, as a strategic enterprise/research innovation situated both physically and virtually at the College of Creative Arts. The procurement of the Vice Chancellor's Strategic Innovation Fund- Entrepreneurial Partnership Platform from Massey University in 2014 was key to the development of the physical and online infrastructure, in addition to overheads, and external costs whilst also being supplemented by in-kind support in the form of the post -consumer uniform from NZ Post.

A remanufacturing/restorative system

After establishing our context, Fletcher (2016) says the second thing to do is to act differently, and think differently. Developing local production as a design strategy which has cultural value and social value (Niinimaki, K 2011) was central initiatives objective. This approach disrupts the linear system as it allows for a reframing of unwanted detritus from the current system as resource, as we work towards increasing the value of the material through design. The human and social capital (Fuad Luke 2009, 7) were central as we engaged in a significant knowledge exchange and mutually supportive relationship with our chosen manufacturers, EarthLink a not for profit who opens the door to employment for many people with health and social barriers (2015). The Space between team of researchers, and students worked in participatory/co-design capacity with Earthlink through the lens of scarcity and circularity to develop good practices across the supply chain which are empowering, participatory. Participants were part of an alternative designer- manufacturer relationship based on shared sustainable goals and the mutually beneficial objective to create a local remanufacturing industry and closed loop-solutions to share with others. Making on demand challenges the inherent waste which is part of the mass manufactured model while also altering the relationship with the manufacturer so that it is ongoing which could also have a positive impact on the workflow as it is staggered through the year.

Figure 8 and 9: Earthlink Apparel Remanufacturing/restorative system (Whitty, J.)

An expansive fashion practice

This project has enabled Massey researchers to engage in multiple cross channel knowledge transferences and secure wider connections both from within and outside of the university. To date it has brought together researchers/students/participants with a shared interest in sustainability from different disciplines which enables a multifaceted approach to the area of sustainable fashion throughout the formation and operation of this design service. Whitty has become a research associate of The New Zealand Social Innovation and Entrepreneurship Research Center at Massey, and is linked to The Zero Waste Academy, and the New Zealand Life Cycle Management Centre. A Life Cycle Analysis of our work has enabled us to determine and communicate the environmental benefits of our range scientific terms. An aligned research led teaching programme 'Fashion Activism' received the Prime Minister's scholarship for Asia as it brought together a multidisciplinary group of 12 undergraduate students from textiles, fashion, industrial, visual communications, Maori Visual Arts, and photography to China with the shared focus of addressing issues in the fashion industry and creating positive change. It is hoped that this education/ research/enterprise knowledge will build critical mass of knowledge and resources in this field of solution oriented design for sustainability.

Figure 10: Fashion Revolution poster Space between (Whitty, J., Street, J.) Create it, Not Waste it Event, Space between (2015) Photo: Courtney Howley

The third space of tempos between fast and slow

Thriving ecosystems are dynamic and Space Between attempts to find a contemporary balance between the philosophies of fast and slow, high and low, new and traditional, to create a relevant fashion system that is circular in its approach (Fletcher 2010, p.265). We have examining the product-service system to transform negative patterns by adopting slow fashion methods, counterbalanced with the speed and agility that a networked society affords for marketing, distribution and ultimately 'made on demand' approaches. The upcycling techniques involved in the Fundamentals range involves a level of craftsmanship and time that is outside of the efficiency logic of the industrial system but which is of value in a circular system that honours waste as a resource and instils a resourcefulness in its makers. The techniques serve to highlight the provenance or history of the garment with functional and aesthetic nods to its previous life as a corporate uniform. The global campaign Fashion Revolution (2016) believes that transparency the first step to transform the negative impact of our current industry. Space Between has put in operation a wholly transparent arguably 'slow fashion' system which is supported by the agility and dissemination that our digital world enables where all of our manufacturing info, price calculations and methods are available to share and use through multi media channels and platforms.

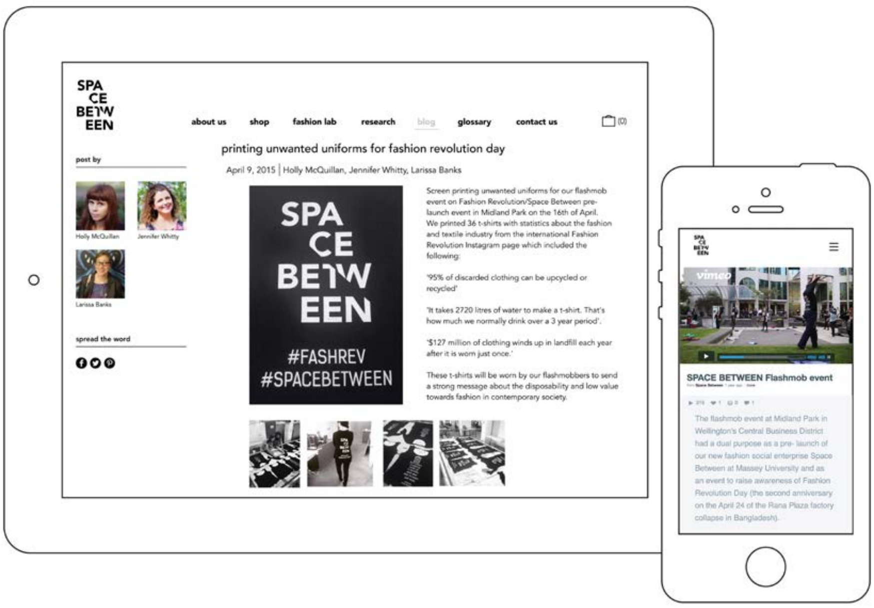


Figure 11: Fashion Revolution Day: Space Between (Whitty. McQuillan, H., Given, T. & Banks, L.)

Future Strategies

Our ultimate goal is to change consumer behaviour to decouple economic growth from resource consumption. Space Between aims to enable participants to work and acknowledge our post-industrialised system to apply their design thinking to the post purchase/use stage of garments and to continue to develop strategies for putting them back into the system (Tonkinwise 2016, Fletcher 2008-16). We are keen to extend of the capability of the online space to explore alternative business strategies, drawing on participatory processes to challenge experiences of consumption, retail and purchase in consultation with consumer psychologists.

Figure 12: Changing consumer behaviour/disrupting take, make and waste (Whitty, J.)

Conclusion

Fashion is an integral, vital, and influential part of the global system and like any other responsible and adaptive global player in the context of 21st century realities it needs a period of self-reflection and radical change. The move away from a linear economy towards a circular, regenerative economy, based around feedback-rich flows is both timely and necessary for fashion in order to remain relevant in the 21st century. The lens of scarcity is important for designers to utilise in order to create work that is of value to the future of our planet to transition towards a restorative, circular model. The future of fashion is ripe for challenging the predominant roles and relationships between and among resources and waste and relationships between designer, producer and consumer. Strategies for a circular sustainable economy are complex and approaches are many.

Operating from a "third space"— real or metaphorical — enables us co-produce restorative models together to effect new thinking and new participants by altering the engagement between universities and their communities. We recognize that while our impact may be small in terms of manufactured and financial capital, what we have achieved as an agent for change in terms of human, social and natural capital has exceeded our resources. Space Between offers a method of aligning education, industry and enterprise to create positive change from the spaces between, inside and outside of the dominant system.

References

Allwood et al. (2006) Well dressed? The present and future sustainability of clothing and textiles in the United Kingdom, University of Cambridge, Institute for Manufacturing, p.2, p.14.

Centre for Sustainable Fashion. Home. [ONLINE] Available at: http://sustainable-fashion.com/ [Accessed 5 July 2016]

Chen, H.S. & L.D Burns. (2006): 'Environmental Analysis of Textile Products', Clothing and Textiles Research Journal 24.3 248-61

College of Creative Arts, Massey University. Enterprise. [ONLINE] Available at: http://creative.massey.ac.nz/enterprise/enterprise/. [Accessed 11 of June 2016]

Daly, H. (1992) Steady-State Economics. London, UK: Earthscan

Earthlink Incorporated. (2016). Home [ONLINE] Available at: https://www.earthlink.org.nz/. [Accessed 17 October 2017]

Ecotextile (2016) 'One third of all clothing never sold'. http://www.ecotextile.com/2016042122078/fashion-retail-news/one-third-of-all-clothing-never-sold.html [Accessed on 10 of June]

EcoWatch (2015) Fast Fashion Is the Second Dirtiest Industry in the World, Next to Big Oil. [ONLINE] Available at:
https://www.ecowatch.com/fast-fashion-is-the-second-dirtiest-industry-in-the-world-next-to-big--1882083445.html. Accessed on 10 of June]

Edelkoort, L. (2015) 'End of fashion as we know it.' Dezeen. http://www.dezeen.com/2015/03/01/li-edelkoort-end-of-fashion-as-we-know-it-design-indaba-2015/ 2015. [Accessed 15 March]

Ellen McArthur Foundation. (2015) Home. [ONLINE] Available at: https://www.ellenmacarthurfoundation.org/ [Accessed 5 July 2016]

Fashion Revolution. (2014). Home. [ONLINE] Available at: http://fashionrevolution.org/about/transparency/ [Accessed 10 feb 2016]

Fletcher, K. (2008) Sustainable Fashion & Textiles. Design Journeys. London, Earthscan

Fletcher, K. (2016) Craft of Use: Post Growth Fashion. New York: Routledge.

Halling, K. (2016) Not So Fast (Fashion)! African Countries to Ban Secondhand Clothing Imports. Sustainable Brands. Accessed 10 August http://www.sustainablebrands.com/news_and_views/waste_not/kelsey_halling/not_so_fast_fashion_african_countries_ban_secondhand_clothin

Hollingsworth, J. (2007) "Waste Couture Environmental Impact of the Clothing Industry", Focus, Vol. 115, No 9, p. 2, September

Jackson, T. (2009) Prosperity without Growth. London: Earthscan

Manzini, E. (2008) 'New Design Knowledge. Introduction to the conference Changing the Change.' In Cipolla, C. Peruccio, P. (eds) Changing the Change proceedings. Allemandi Conference Press

Marttila, T. & Kohtala, C. (2014) 'Transdisciplinary Platforms: Teaching Sustainability to Design Students.' In Vezzoli, C et al. (eds) In Product-Service System Design for Sustainability, Greenleaf Publishing, Sheffield, UK

Morgan, A. (2015) The True Cost, Untold Creative

McDonagh, W. & Braungart, M. (2013) The Upcycle: Beyond Sustainability--Designing for Abundance, North Point Press, New York

Nieminen, E., Linke, M.,Tobler, M., B. Vander Beke. (2007) 'EU COST Action 628: life assessment (LCA) of textile products, eco-efficiency and definition of best available technology (BAT) of textile processing', Journal of Cleaner Production 15: 1259-1270

Niinimaki, K. (2013) Sustainable Fashion: New Approaches, Aalto University publication series. [Accessed 10 June] https://www.taik.fi/kirjakauppa/images/57175badb573d97c59ec6a99ecc1011c.pdf .

Perella, M. (2014) 10 things you need to know about the circular economy, The Guardian Sustainable business. [ONLINE] Available at: https://www.theguardian.com/sustainable-business/10-things-need-to-know-circular-economy

Porritt, J. (2015) The Five Capitals Model – a framework for sustainability, Forum of the Future, Capitalism As If The World Matters. London, Earthscan

Rissanen, T. (2005) "From 15% to 0: Investigating the creation of fashion without the creation of fabric waste," Presenter, Kreativ Institute for Design og Teknologi, September

Webster, K. (2015) The Circular Economy: A Wealth of Flows, Ellen MacArthur Foundation Publishing

Scaturro, S. (2011) Could Polyester be the next Eco-Friendly Fabric. Ecouterre. Accessed on 3 May 2016 http://www.ecouterre.com/could-polyester-be-the-next-eco-friendly-fabric/2/

Space Between. (2015) Home. [ONLINE] Available at: www.spacebetween.ac.nz [Accessed 10 June 2016]

Street, D. (2014) The Impact of Throwaway Threads. The Wireless. http://thewireless.co.nz/themes/impact/the-impact-of-throwaway-threads [Accessed 12 Feb]

Tonkinwise, C. (2016) Failing to avoid Futures: from Design to the Proactionary Test Drive. [ONLINE] Available at: https://www.academia.edu/26994039/Failing_to_avoid_Futures_from_Design_to_the_Proactionary_Test_D rive?auto=view campaign=weekly_digest [Accessed 10 August 2016].

Textile Design Environment. University of the Arts London, Chelsea. About. [ONLINE] Available at: http://www.tedresearch.net/about/[Accessed 10 Feb 2016]

Transition Design. (2014) Home. [ONLINE] Available at: http://transitiondesign.net/ [Accessed 10 August 2016].

Whitty, J. & McQuillan, H. (2015) Space Between. About. [ONLINE] Available at: www.spacebetween.ac.nz [Accessed 10 June 2016]

Whitty, J. (2015) Space Between: A model of social innovation for fashion. Unmaking Waste 2015 Conference Proceedings.22–24 May 2015 Adelaide, South Australia. http://unmakingwaste2015.org/wp-content/uploads/2015/09/UMW_Session_20.pdf

Re-Mantle and Make: the role of maker spaces in empowering a new wave of circular thinking for textile designers

Jen Ballie, Paul Smith, Lynn-Sayers McHattie (Glasgow School of Art, UK)

Abstract

Through a review of 'Re-mantle and Make', an exploratory approach for repurposing textile waste within the Scotland and discuss how we might expand upon the role, skills and capabilities of the textile designer to equip them to operate within a circular economy. This approach utilises Maker Spaces as local hubs to experiment with new processes, provide support and educate designers and citizens alike around sustainable design and build up material awareness with the aim of reducing the rapid replacement of textile artefacts. Alongside making recommendation for further research to consider how industry, higher education (HE) and academia might collaborate with Maker Spaces in the future to enable a more considered circular approach to textile design.

Introduction

We live in a 'throwaway and replace' culture, our growing population and demand for new products has placed huge pressures on our planet's resources. Our economy is locked into a system in which everything from production to economics and the way people behave favours a linear model of production and consumption, where resources pass through from sourcing to disposal in a 'take-make-use-dispose' construct. Climate instability, volatile commodity prices, ocean dead zones, vanishing forests, stalling economic growth, expanding food insecurity and resource conflicts are all part of the resource to waste linear economics (Grayson, 2008). Any of these are surely justifiable reasons to explore a new pattern. The Circular Economy is a new construct being positioned as a solution to addressing complex issues around material waste and linear models of resource use. This paper explores this concept within the context of fashion and textile design in the UK, and does so from the textile designer's perspective to explore how this might be achieved. The circular economy offers a new outlook for design practice and designers will need to learn how to adopt a more pro-active, systems-based approach that truly ‘closes the loop’ (Goldsworthy, 2014).

This paper provides a preview of a six-month feasibility study titled ‘Re-Mantle and Make’ led by the Glasgow School of Art. This research is funded by a larger project titled ‘Future Makespaces in Redistributed Manufacturing’, a two-year research project funded by the Engineering and Physical Sciences Research Council (EPSRC). The larger project is led by Baurley, Tooze, Stewart and Hunter (2014-16) from the Royal College of Art, London, and explores the role of maker spaces in redistributed manufacturing (RdM). Our study will be undertaken in partnership with Kalopsia Collective, a micro-manufacturing unit based in Edinburgh, Scotland. Together we will conduct practice-led research to produce a small collection of fashion accessories within a circular economy model. In addition to the collection we will prototype a potential future maker space for circular textile design to scope what tools, techniques, equipment and materials might be required. Currently there are limited practical examples and it is unknown if it is truly possible to implement close loop innovation within the textile sector and on what scale. Our study aims to explore the barriers and opportunities to this closed loop scenario.

Through the research we aim to investigate how we can use maker spaces to cultivate circular thinking for textile designers and provide them with resources to develop circular design knowledge and practice. Re-Mantle and Make was defined as a term by the authors as a provocation to challenge our perceived perception of a finished artifact. This is also a model aiming to demonstrate how future maker spaces could be developed to experiment with strategies for material recovery, repair and reuse on a local scale, providing educational hubs for designers to experiment and learn. This will be achieved through consultation and partnership with textile manufacturers, engagement with higher-education institutions, small to medium enterprises and policy makers to investigate the potential for sustainable, circular design futures in the textile industry.

The following sections begin by outlining some of the challenges concerning textiles, fashion and sustainability before contemplating the ways in which the textile designers’ role might change in the future. It goes on to describe the scope and design of our study. Finally, recommendations will be made for future enquiry beyond the research.

Textiles, Fashion and Sustainability

Throughout the wider fashion system changes are emerging in response to a call for a more circular economy and responsible resource use. Within the UK alone we dispose of approximately 10,000 garments every ten minutes (Kerr & Foster, 2011), a level of waste that is unsustainable. Conventional methods of dealing with these issues have been cited as being symptoms based and they have not addressed continuous and rising consumption levels.

Value needs to be placed on consumer use, attachment and stronger 'user-product' and 'user-manufacturer' relationships (Chapman, 2006; Niinimäki & Hassi, 2011). Due to the low cost of high street fashion combined with a lack of service offers post consumption, it has become more cost effective to dispose and replace a garment once it has served its purpose. The whole economic system in the industrialised world is based on a products fast replacement and planned obsolesce (Jackson, 2011), and the field of fashion and textiles is no exception. The concept of planned obsolesce prompts the shortened life cycle of products to ensure a market need for future products (Walker, 2011). Change in fashion is stimulated leading to product designs that reflect short life cycles and disposal, which in turn stimulates change. There is further disparity through disconnection between the designer, the process of manufacturing, and the consumer who is often left unsatisfied long term, which encourages the rapid replacement of products.

There is limited literature relating to the role of the specifics of ethics within the fashion or textile industry from a designer's perspective, for example acknowledging their responsibility within the supply chain and the lifecycle of a garment. Traditionally fashion designers do not write, or theories; they cut and make (Thomas, 2001:4). Whilst interrogating the modus operandi of the fashion industry there could also be an interrogation of sustainability and the circular economy, and what it could mean if universally adopted by design practitioners and by the fashion or textile industry in general. While the work of Black (2012), Fletcher (2008), Tham & Jones (2008) and Lee (2006) have expanded upon this territory within a fashion context. Fletcher (2010) a founding scholar of the slow fashion movement calls for a re-examination of the entire design, production and distribution process. Prior to these publications, fashion design practitioners and the industry have had to adapt and co-opt sustainability arguments and theories from product design and architecture design writers, such as Chapman (2006) and Manzini (2005). While McDonough & Braungart (2009) expand upon sustainable design if "we understand that design leads to the manifestation of human intention and if what we make with our hands is to be sacred and honor the earth that gives us life, then the things we make must not only rise from the ground but return it, soil, to soil, water to water, so everything is received from the earth can be freely given back without causing harm to any living system. This is ecology. This is good design. It is of this we must now speak" (Braungart & McDonough, 2009).

Circular Thinking for Textile Designers

Within the UK textile sector there is increasing awareness of the requirement for new textile initiatives to be linked with the concept of the circular economy (Goldsworthy and Earley, 2016), but there is a lack of innovation tools and practical knowledge and accessible evidence available to provide support. Within the UK, the RSA's Great Recovery programme has focused on the role of the design community in delivering a more circular economy. They highlight the importance of acknowledging that it is not the designer's responsibility alone to change whole supply chains. Businesses must begin to develop design briefs around new business models that take account of provenance, longevity, impacts and end of life (RSA, 2013) therefore partnerships will be crucial. Moving forward, knowledge exchange will be essential to support joined-up thinking to connect all stakeholders involved in the lifecycle of textile material journeys and new supply chain models. Most recently, the Ellen MacArthur Foundation has partnered with world leading design agency IDEO (Jan, 2016) to explore how design might play a strategic role in supporting circular innovation to support systemic change.

This research aims to learn from this ongoing work and expand upon it further to identify what strategies and innovation tools are required to cultivate 'Circular Textile Thinking'. Here, for the purpose of this paper, the term 'designer' is applied to define fashion and or textile designers. However, it is worth acknowledging that traditional design disciplines are no longer a clear-cut categorisation of design professionals, and that new hybrid roles are emerging, particularly within the area of maker spaces (Thomas, 2015). Within these physical hubs, technology, skills, ideology and education can come together to explore and experiment with new ideas and possible futures. The propagation of open workshops that are supporting small producers to access skills and equipment to design and make, termed the 'maker space movement', has been coined 'the next industrial revolution' by Anderson (2011). Where Designers are learning that co-creation, rather than individual authorship, is becoming a more effective way to understand and meet social needs and new tools and platforms are becoming more effective than finished artifacts (Thackara, 2013). This is part of a shift towards transmaterialisation, where service design concepts are evolving in parallel to product design development to construct new scenarios of use, reuse, design and redesign. In a genuinely circular fashion and textile system, design and use would comprise a single whole. What actually happens in the lives of people who use garments would provide inputs for fashion and textile design and production (Fletcher, 2015). Therefore, an important part of cultivating circular textile thinking must involve fostering skills and practices that are conducive to promoting a satisfying use of garments. The designer's role will move beyond just consideration of functionality and aesthetic sensibility. Designers are finding new socially aligned roles, envisioning new ways to produce goods, services, and even policy (Smith & Mortati, 2016). To work this way, designers need to acquire new skills, knowledge and experience to enable them to act as social innovators and become agents of change.

Positioning Re-Mantle and Make

Re-Mantle and Make is an exploratory model designed to pilot a new approach for trialing a circular fashion system on a local scale contextualised within Scotland's textile sector. It is important to acknowledge that this feasibility study is currently within the early stages and in order to flourish partnerships, prototypes and pilots will be integral. The following sections outline the timeline and include a detailed overview of the four key stages of; sourcing; prototyping; piloting and evaluation.

Our approach is to pilot a range of different approaches for repurposing textile waste within a future maker space. However, to align to the principals of the circular economy we will endeavor to preserve and enhance natural capital, optimise the use of resources and foster system effectiveness by designing out wastefulness. This will require collaboration and a range of manufacturers have generously agreed to provide access to their textile waste. Three designers have been commissioned to produce circular archetypes in response to a design challenge and the archetypes will be presented and the textile techniques will be demonstrate within design jam events to orchestrate further ideas for circular innovation. A panel of specialists across the supply chain will review the concepts and be invited to make recommendations on feasibility and the most viable concepts will be produced within the Kalopsia micro-manufacturing unit. A short film will be produced to document each stage and this will be showcased alongside a Pop Up exhibition.

Stage 1: Sourcing – textile waste on a local scale

The first stage of the study has been undertaken through a consultation with key stakeholders situated within the Scottish textile sector and identified a growing awareness and responsiveness to circular innovation. This could be credited to the work undertaken by Zero Waste Scotland who provided a range of training programs and master classes (Zero Waste Scotland, 2014-16) tailored to demonstrate a wealth of different strategies such as design for modularity, collaborative consumption, zero waste design and pattern cutting and material efficiency. The Scottish Textile and Leather Association (STLA) that provides support for approximately ninety-five businesses of varying scale were also consulted. They made recommendations of manufacturers who might be responsive in donating textile waste and participating within the study.

The Scottish Leather Group are providing leather waste generating during manufacturing processes, MYB Textiles are providing offcuts of traditional Scottish lace and Begg and Company are providing remnants of traditional Scottish cashmere.

Stage 2: Prototyping – circular archetypes

Prior to introducing the design brief for prototyping it is important to acknowledge that context is everything. Earley and Goldsworthy (2015) highlight that we need to be very clear about which segment of the fashion industry we are designing for and also which specific garment archetype. They continue by stating that while strategies may be more relevant for the mass market and high street fashion (short-life), others will be focused on more niche, SME brands and even reach beyond industry to the user (long-life) (Earley and Goldsworthy, ibid). The Re-Mantle and Make model aims to prototype a long-life, circular archetype that has the potential to be transformed within a maker space to enable the archetype to evolve through different design loops. The market place may be positioned somewhere in between the high street and luxury retail.

A design brief was written (see below) which provides an overview of a circular fashion archetype. Three textile designers have been commissioned to conduct research and development to produce a concept, demonstrated through a prototype and presented as an open source package for others to replicate or modify. The maker space facilities will be available to support sampling and production and at least one of the materials need to be included.

The Design Brief: Circular Collar

'Fashion clothes capture a moment in time and are as quickly forgotten. But what if that moment was not one but many moments... a process of transformation?' (Earley & Fletcher, 2003).

- Design Challenge: To prototype a circular design concept for a collar that can be worn with existing garments. This project aims to shift our perception of fashion archetypes and the collar needs to be open source, the original conception of a collar can be hacked or modified to produce a hybrid concept. This must apply a modular design approach and consider how to sustain a long-life. The collar will be initially produced within a maker space and this can be used to provide a range of different services to support transformation through workshops or a menu of tailored options.
- Facilities: 3-D Printer, Digital Textile Printer, Digital Embroidery Machine, hand stitching and embroidery, screen printing
- Materials: leather, lace and cashmere
- Inspiration: The following open source fashion archetypes are available to reference; the Uniform Project (ref), Smock Shop (ref), SHOW studios Design Download project (2009 - ongoing) provides downloadable fashion garment patterns from previous catwalk collectives from several high-profile fashion designers (McQueen, Galliano, Pugh, Yamamoto, Watanabe, Price and Margiela, 2009). Each of these projects utilise social media to adopt an open source approach for distributing patterns and downloadable templates.
- Designers: Three textile designers have been commissioned - Shirley McLauchlan, Heather Martin and Aimee Kent. They have been invited to design a circular collar with reference to the design brief, documenting the process for others to replicate or reference. They have also been encouraged to challenge themselves as designers to re-think new ways of designing, with value associated to consumer use, attachment and stronger 'user-product' and 'user-manufacturer' relationships. The emphasis on product care and maintenance will become more important, and the cultivation of a more considerate approach to consumption in which the user is provided with an opportunity to learn new skills, knowledge, and are motivated to extend the life or use of their clothing. This research endeavors to learn more about the drivers for cultivating resourcefulness and cherishability within fashion and

textiles, but experimentation will be required to identify creative methods through which they may be implemented.

Stage 3: Piloting – assembling a circular maker space for textiles

This research will pilot Re-Mantle and Make within a design jam, an interactive event orchestrated to invite a selected group of stakeholders to work collectively to address a design challenge or problem over an intensive period of time. Within this instance they will take place over one day and the study will host an event in both a rural and urban context. While we focus on the role of the textile designer within this paper, it is worth acknowledging that the design jams will support collaboration and input from additional stakeholders across the supply chain from the manufacturers providing the textile waste, to other local businesses, design students, policy makers and citizens.

The commissioned designers will be invited to share their prototypes and to demonstrate their making processes and reflect on their personal journeys. Within these events, we will explore additional design ideas for circular collars through ideation and prototyping activities. An experience prototype of a future maker space will also be curated to enable participants to experience the model in situ and to provide them with an opportunity to offer feedback and make recommendations. The project partner Kalopsia will play a pivotal role in servicing the production of emerging design concepts.

Stage 4: Evaluation - lifecycle analysis

The final stages of the research will evaluate the prototypes and introduce lifecycle thinking as a visual framework for design ideation that allows for a deeper understanding of the key issues and barriers to closing the loop on textiles. By mapping the varied routes around and through the lifecycle, we can design new briefs for the designer working towards a more connected material economy.

Although in general terms consumer products have come to be considered disposable, it is argued that through 'good' design there is an opportunity to establish an emotional bond or attachment between the user and the product but this will require associated practices of care in order to help sustain and extend product lifetimes (Chapman, 2005; Walker, 2006; Schifferstein & Zwartkruis-Pelgrim, 2008).

The manufacturers will be invited to an internal seminar towards the final stages of the study that will share the learning outcomes and include a presentation of future scenarios.

Closing Reflections

So far, the findings have identified that there is a large cohort of highly innovative independent textile designers based in Scotland who are growing frustrated with the lack of support available to enable them to design and manufacture on a local scale. Some of the challenges include: being unable to access innovative new materials due to a minimum order requirement; onshore manufacture is too expensive and unequipped to support small orders; and finally, business support programs within public sector agencies are tailored to high growth businesses within the textile sector.

This study provides an opportunity for textile designers and students to experience the concept of the circular economy through participating within a practical intervention. Discussion will be facilitated to challenge existing perceptions and prompt conversation around circular innovation to re-think design, production and use. The circular economy can provide a new lens to preview how we as designers would like to experience fashion. Research and development is beginning to help design and the textile industry to understand the value, viability, scalability and role of circular approaches in the future (De Castro, 2014). By engaging education institutions in the research, we will develop resources for circular design thinking and explore the role maker spaces can play in future learning experiences for students around sustainability in design and circular economy.

References

Bianchini, M., Arquilla, V., Maffei, S., Carelli, A. (2012) 'FabLand: 'Making' digital/analog distributed urban production ecosystems' (2014b) Ginger, J., McGrath, R., Barrett, B., and McCreary, V., 'Mini Labs: Building capacity for innovation through a local community fab lab network', http://cba.mit.edu/events/12.08.FAB8/workshops/CUCFL-F8-2012Submission08-14-2012.pdf (last accessed July 2016).

Canessa, E. & Fonda, C. (2015) 'Making Ideas at Scientific Fabrication Laboratories', https://arxiv.org/pdf/1512.01093.pdf (last accessed July 2016).

Black, S. And H. Alexander (2012) 'The Sustainable Fashion Handbook'. London: Thames and Hudson.

Braungart, M., W. McDonough, A. Bollinger (2007) 'Cradle-to-cradle design: creating healthy emissions–a strategy for eco-effective product and system design'. Journal of cleaner production, 15:13: 1337–1348.

Chapman, J. (2005) 'Emotionally Durable Design: objects, experiences and empathy'. London: Earthscan.

De Castro, O. (2014) 'Upcycling'. Keynote at Scottish Textile Symposium. Glasgow, Scotland, November.

Earley, R, and K. Goldsworthy. (2015) 'Designing for fast and slow circular fashion systems: exploring strategies for multiple and extended product cycles'. PLATE conference, Nottingham Trent University

Earley, R. and K. Goldsworthy (2014) TED's Ten. Keynote at Circular by Design Chiasma, Design in Action. Edinburgh, Scotland, March.

Earley, R. (2007) The new designers: working towards our eco fashion future. In Dressing Rooms: Current Perspectives on Fashion and Textiles Conference, Oslo, Norway.

Fletcher, K., L. Grose, P. Hawken (2010) 'Fashion & sustainability: Design for change'. London: Laurence King.

Fletcher, K. (2011) 'Sustainable fashion and textiles: design journeys'. London: Routledge.

Goldsworthy, K. (2012) 'Laser-finishing: a new process for designing recyclability in synthetic textiles'. PhD diss. London: University of the Arts London.

Goldsworthy, K. (2014) 'Design for Cyclability: pro-active approaches for maximising material recovery', Making Futures, 3.

Grayson, J. (2008) 'Systemic Economic Instruments for Energy, Climate, and Global Security'. NATO Science for Peace and Security Programme. Springer, Netherlands.

Lloyd, A.E. And Luk, S.T. (2010) 'The Devil Wears Prada or Zara: A Revelation into Customer Perceived Value of Luxury and Mass Fashion Brands'. Journal of Global Fashion Marketing, 1(3), pp.129-141.

Manzini, E (2005) Network, Localismo cosmopolitan. Prospective per uno sviluppo locale sostenibile ed ipotesi sul ruolo del design, Milano: Agenzia SDI. D.E.S.I.S. and London, UAL.

Niinimaki, K. And Hassi, L. (2011) 'Emerging design strategies in sustainable production and consumption of textiles and clothing'. Journal of Cleaner Production, 19(16), pp.1876-1883.

Vezzoli, C.A. And Manzini, E (2011) 'Design for environmental sustainability'. Springer Science & Business Media.

Shea, P., (2016) 'Civic Practices, Design, and Makerspaces', Chapter 13 in Negotiating Digital Citizenship: Control, Contest and Culture edited by Anthony McCosker, Sonja Vivienne and Amelia Johns (Rowman and Littlefield 2016) USA: Rowman and Littlefield International.

Smith, P., M. Mortati, (2016) 'Commons People: Additive Manufacturing Enabled Collaborative Commons Production (by design)', International Journal of Rapid Manufacturing.

Jackson, T. (2011) 'Prosperity without growth: Economics for a finite planet'. Routledge.

Thomas, S. (2014) 'Hacking the Circular Economy'. The RSA Great Recovery Blog, April 2nd, 2015. Accessed May 12. https://www.thersa.org/discover/publications-and-articles/rsa-blogs/2015/04/hacking-the-circular-economy/
THAKARA, J. "A Whole New Cloth: Politics and the Fashion system." Routledge Handbook of Sustainability and Fashion. London: Routledge, 43–46.
Walker, S. (2011) 'The spirit of design: objects, environment and meaning'. London: Earthscan.

Acknowledgements

The authors would like to thank the research team at the Royal College of Art (RCA) within the Future Makespaces in Redistributed Manufacturing project for their support and The Engineering and Physical Sciences Research Council (EPSRC) (EP/MO17591/1) for the funding to undertake the feasibility study. Additionally, we would like to thank MYB Textiles, the Scottish Leather Group and Begg and Company for providing material resources to undertake this research.

Special thanks to Dr Michael Pierre Johnson and Zoe Prosser for their research assistance and design support.

Shifting Perceptions: The Reknit Revolution

Amy Twigger Holroyd (Nottingham Trent University, UK)

Abstract

An ongoing initiative seeks to encourage hand knitters to use their skills to rework existing knitted garments, extending product life and contributing to the 'domestic circular economy'. A pilot project demonstrated that inspiration, information and confirmation can help knitters to overcome barriers and embrace the challenge of reknitting.

Introduction

In this paper, I will discuss an ongoing initiative that seeks to encourage hand knitters to expand their craft practices to encompass reknitting: reworking existing knitted items using knit-based skills, techniques and knowledge. This activity offers potential benefits in terms of promoting repair and re-use by individual users within the domestic sphere, and thereby contributing to the constellation of initiatives that, together, will build a circular economy.

These techniques were developed and creatively explored during a previous research project (described in this paper as the 'pilot project'), working in collaboration with a group of six amateur knitters (Twigger Holroyd 2013). Although the primary aim of the pilot project was the generation of new knowledge about the lived experience of making and remaking, the outputs of the design activity – the reknitting techniques themselves – also have value. The pilot project demonstrated that it is possible to engage skilled knitters with reknitting, but that support is needed to help makers shift their perceptions of what is both possible and desirable. An exhibition at a public art gallery in summer 2017 and an associated series of participatory workshops will provide an opportunity to explore the sharing of the reknitting techniques beyond the pilot project.

I am using this paper to consider how to promote reknitting, drawing on the experience of the previous research and the insights that it generated. I will discuss the relationship between reknitting and the 'domestic circular economy'; outline barriers to participation in reknitting; and consider the development of support to overcome these barriers, using the focus points of *inspiration, information* and *confirmation*.

Reknitting and the Domestic Circular Economy

Reknitting

Reknitting was a common element of domestic knitting practice in the past, when necessity impelled people to exploit the inherent 'tinkerability' of the weft knitted structure. When items became worn at the cuffs, elbows or collars those elements would be unravelled and replaced (Pearson 1980; Sundbø 2000). During World War II rationing prompted an intensification of reknitting activity, with instructions guiding women in how to reclaim yarn from worn garments and combine these precious materials into fresh items (Koster and Murray 1943). Since this period, as knitting has shifted from a domestic necessity to an optional leisure activity, reknitting activity has dwindled. The knowledge of how to open, alter, unravel and reknit has largely been lost.

The pilot project sought to address this issue by developing reknitting techniques appropriate to the knitted items in our wardrobes today. Although many of these items are made from fine gauge knitted fabrics, with stitches much smaller than would normally be hand-knitted, the structure retains the same capacity for alteration. Drawing on a range of documented instructions and using my experience as a designer and maker of knitwear to generate new ideas, I developed a 'spectrum' of reknitting techniques (Figure 1). The spectrum captures the full range of technical processes, or 'treatments', which could be used to alter and rework an item of knitwear. Each treatment is endlessly variable, according to the specifics of the original garment and factors such as the colour, scale and gauge of the alteration.

In a series of four day-long workshops I worked with a group of six amateur knitters to test these reknitting treatments, finding that the knitters drew on their tacit making knowledge to develop the practical and creative skills required. The project culminated in each participant reworking an item from their own wardrobe. The techniques were used to address problematic items: garments which were significant enough to be kept, but with problems which excluded them from wear. The participants were pleased with their reworked garments and the knowledge that they had gained. They responded positively to the challenge of reknitting, finding that the experience offered the many benefits that they associated with their usual knitting practices.

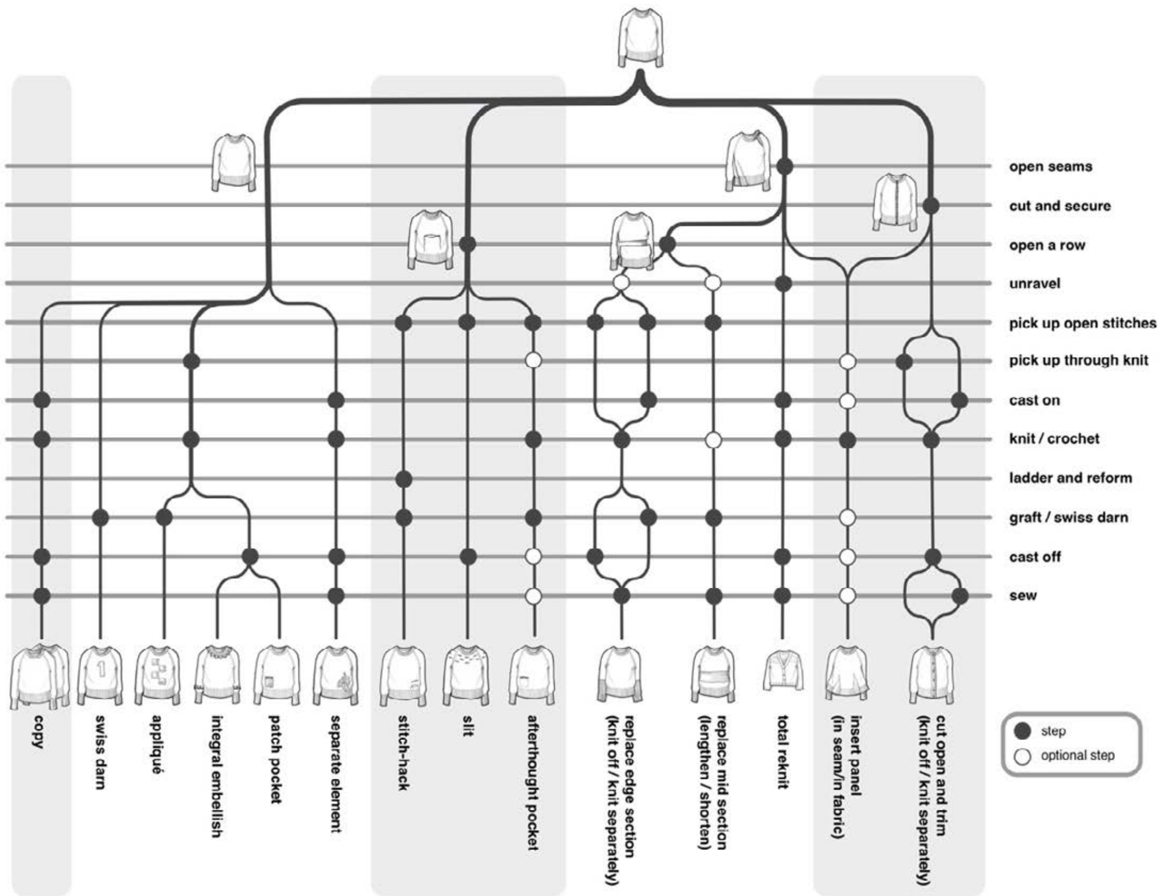


Figure 1: The spectrum of reknitting treatments

The circular economy

The circular economy is perhaps best introduced using the 'cradle to cradle' concept famously proposed by McDonough and Braungart (2002). As an alternative to the linear industrial system of 'take, make and dispose', cradle to cradle thinking views materials as nutrients that can flow through the system time after time. Unlike the vast majority of current recycling initiatives, in which materials decline in quality as they are reclaimed and transformed, true circularity demands that quality is maintained indefinitely.

The holy grail of sustainable design is to develop products whose materials can be eternally re-used. When they reach end of life, they could be taken back to their base materials and transformed into a completely different form or function. In short, a product lifecycle that behaves just like a natural one, repeatedly transforming materials for new cycles of growth. (Goldsworthy 2014: 250)

The circular economy is built on this idea, creating ‘a continuous positive development cycle that preserves and enhances natural capital, optimises resource yields, and minimises system risks by managing finite stocks and renewable flows’ (Ellen MacArthur Foundation 2015). The cyclical approach is not confined to the re-use of base materials; recycling should arguably be seen as a ‘last resort’ once less energy-intensive opportunities for re-use have been exhausted. The circular economy system diagram created by The Ellen MacArthur Foundation (2015) illustrates four nested levels of re-use, descending in terms of scale and involving different stakeholders:

- **recycle** to reclaim base materials (parts manufacturers)
- **refurbish** and **remanufacture** (product manufacturers)
- facilitate **re-use** and **redistribution** (service providers)
- **maintain** and **prolong** useful life (individual users)

Goldsworthy (2014) distinguishes between re-active approaches to re-use and recycling, which respond to waste generated by the present linear system, and pro-active approaches, in which the reclamation of high quality base materials is considered from the earliest stages of design. She argues that both approaches are necessary in order to deal with the materials in circulation today while starting to develop a more robust circular system. Thus, overall, the circular economy requires us to ‘keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life’ (WRAP 2016).

The domestic circular economy

The circular economy concept has gained traction amongst businesses and policy-makers in recent years, and work is progressing across a range of industrial sectors to investigate the development of this alternative system. As Perella (2014) explains, ‘Ground-level innovation in this field is being driven by large corporations who are piloting business models based on leasing, product performance, remanufacture, and extended lifecycle thinking.’ These corporations are motivated by long-term business benefits such as protection from fluctuating commodity prices (Hower 2016).

While this work has obvious value, it is crucial that we do not fall into the trap of associating the circular economy exclusively with commercial activities and thereby sideline the domestic arena. Action by individuals has great potential in terms of clothing, because textiles are accessible materials with an inherent capacity for repair. As Fletcher (2016) points out, such actions require little in the way of energy or material inputs. Although individual instances of repair and remaking may seem insignificant, when aggregated they have the potential to deliver genuine change. And while repair and remaking activities at this scale are, by their nature, re-active, they still have an important part to play in extending product life and contributing to a circular economy.

In order to focus attention on the domestic sphere, I propose that we should consider the notion of the 'domestic circular economy'. Inspired by the diverse economies framework put forward by Gibson-Graham et al. (2013) and the social economy discussed by Murray (2012), this encompasses all activities contributing to the circular economy at the domestic level, including all of the unpaid, non-market, reciprocal and gift-based processes involved in day-to-day household life. While activity in this sphere is of little interest to large corporations, there is a potent opportunity for design activists, such as myself, to make a contribution.

Research indicates that very little activity is currently taking place in the domestic circular economy. For most people mending, if practised at all, is limited to small tasks such as replacing buttons and sewing up hems (Fisher et al. 2008). The public-facing Love Your Clothes campaign, associated with the UK's Sustainable Clothing Action Plan, is seeking to address this lack of knowledge by providing information on repair and refashioning. However, as Goldsworthy (2014: 252) observes, 'changes in consumer habits are very difficult to achieve'. Furthermore, any attempt to encourage people to make and repair their garments must contend with the mixed meanings of homemade clothes in contemporary culture (Twigger Holroyd 2013). In short: even if garments are repaired, it is far from certain that they will return to regular wear.

It may be more productive to target the growing numbers of people who enjoy making clothes as a leisure activity, inviting them to consider using their skills to rework, rather than always to make new. This is already taking place in terms of sewn garments: refashioning is seeing a notable resurgence, with support available via books, workshops and online resources. The reknitting initiative under discussion seeks to encourage experienced knitters to extend their practices in a similar way. In order to pursue this approach, I must consider the barriers which are currently limiting action, and explore ways to overcome them.

Barriers and Support

Barriers

Why is there not already a whirlwind of reknitting activity taking place in the domestic sphere? First, and most fundamentally, the idea of reworking a knitted item using knitting skills and knowledge is simply not in circulation. There is a widespread perception of knitting as a process of construction, rather than reconstruction. This perception is shaped by the established understanding of what it is to 'do' knitting: use a pattern, yarn and needles to construct a finished item. In order for a culture of reknitting to develop, this understanding needs to be challenged. Furthermore, repair must be reframed as a positive, creative act rather than a practice associated with poverty.

Even when knitters become aware of the idea of reknitting – as in the pilot project – a range of issues arise. These issues shape both the experiences of those who might want to reknit, and the efforts of those who aspire to support them. Concerns include:

- **deconstruction:** the idea that if you 'open' a knitted fabric, it will disintegrate uncontrollably
- **lack of skill:** knitters frequently fail to recognise their transferable tacit knowledge
- **differences in gauge:** many pre-existing garments are constructed from smaller stitches than hand-knitted fabrics
- **no prescriptive pattern:** because garments to be reknitted are endlessly variable, any instructions must be open-ended
- **the need to design:** open-ended instructions require the knitter to make creative decisions, a task that can feel daunting to amateur makers
- **aesthetic appeal:** anxiety about whether the reworked item will look intentional and 'whole'
- **contingency:** a recognition that unexpected problems often emerge during repair

The pilot project demonstrated that it is quite possible to shift knitters' thinking around all of these potential barriers. With support, the participants embraced the concept of reknitting and began to see it as part of their normal knitting practice. By playing around with scrap garments, they gained a deeper understanding of the knitted structure and its capacity for deconstruction. They came to recognise their own tacit making knowledge and draw on their experience to use open-ended instructions. They gained confidence in their ability to design for themselves and developed strategies for ensuring that their items looked coherent and finished. They even came to see reworking as a rewarding journey into the unknown.

An alternative way of thinking about barriers is to consider the steps that would be involved if a novice reknitter were to successfully execute an alteration. These steps are summarised in Figure 2, below.

Support

Any initiative aiming to support knitters to engage in reknitting must address the barriers discussed and also provide assistance at each step of the reknitting journey. Reflecting on the pilot project, it is evident that multifaceted support is required. This support must not only offer practical advice on how to reknit; it must also achieve the more nebulous goal of shifting perceptions of what is possible and desirable in terms of domestic knitting and repair practices. Three interconnected elements can be identified within this support, all of which proved to be crucial: *inspiration, information* and *confirmation.*

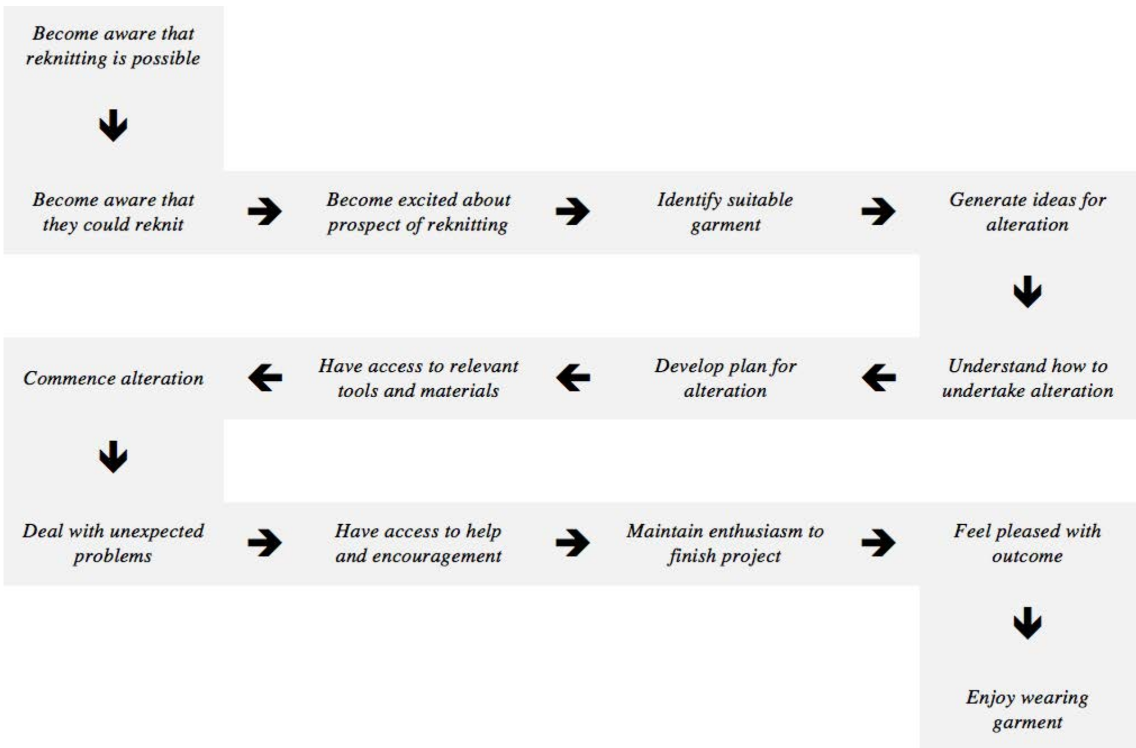


Figure 2: Steps involved in a hypothetical first reknitting project

Inspiration

The first element, inspiration, primarily aims to challenge knitters' established perceptions of both knitting and repair by providing positive examples of reknitting. In the pilot project I found that sharing precedents – whether stories of reknitting from the past or sample garments I had produced – helped the participants to develop a mental space for reknitting. Conversations from the workshops revealed that several of the knitters were inspired by the notion of connecting with a practice from the past. The examples helped them to imagine what reknitted garments could look like, and begin to generate ideas.

The public exhibition provides an opportunity to create further inspirational examples, ranging from relatively simple sample garments to 'showpiece' items. The pieces I make will inevitably demonstrate my own preferred aesthetic, and this could potentially put off people with different stylistic preferences. To emphasise the aesthetic diversity of reknitting, the exhibition will include projects completed by participants in the preceding workshops. A similar gallery could be collaboratively developed online, either in a dedicated space or by using a hashtag to connect relevant posts on social media platforms.

Figure 3: Reknitting sampler, created to provide inspiration

Information

The second element encompasses all of the information and advice needed to assist knitters in undertaking reknitting projects. As described above, the design of this information presents a challenge: because every item to be reknitted will be different, the instructions must be open enough for the knitter to adapt, but detailed enough to be of use during a complex process. For the pilot project I developed a range of materials, including:

- **General advice** on how to approach a reknitting project
- The reknitting **spectrum**
- Information on each treatment including **step-by-step visual instructions, stitch patterns** and **specialised advice**
- **Tools** to help knitters cope with changes in gauge
- Instructions on how to carry out **operations** common to many of the treatments
- **Tips and exercises** to develop design skills

Although I gathered these materials together in an online resource, the primary aim underpinning all of this instruction was to provide support while we were working on the pilot project. Further development of the instructions and advice will be necessary in order to maximise their usefulness for people working independently. In particular, entry-level instructions are required to support knitters through their first reknitting projects. Video footage would help to more clearly communicate tricky techniques. A key challenge is how to encourage independent knitters to develop confidence in their design abilities.

Confirmation

The final element of support needed to foster a culture of reknitting relates to confidence: makers generally need positive feedback from their peers in order to feel happy with their projects and gain confirmation that reknitting is a worthwhile activity. The pilot project demonstrated the importance of this type of support, with one of the knitters commenting: ‘I need to feed off other people, I think, to get ideas, and then to gain confidence in my ideas.’ Homemade clothes are marginal in contemporary culture; it is rather risky to make clothes without the sanctioning influence of professional manufacture or even a professionally-designed knitting pattern for support. By making alongside other people, the knitters benefited from an alternative source of sanctioning.

It was not difficult to establish this feeling of mutual support when working with a small group of like-minded makers over a period of time. The challenge for the future will be to nurture a similar environment for independent knitters. The obvious solution is to use online platforms, whether through organised groups and 'knitalongs' or informal connections and conversations. As Bratich and Brush (2011) suggest, 'the knitting circle now meshes with the World Wide Web'. But at present reknitting activity is extremely sporadic and disconnected; there is not yet a community of reknitting practitioners to provide constructive feedback and praise for completed projects. Therefore I need to consider how I might provide *inspiration* and *information* to kickstart activity and, in turn, build crucial capacity for *confirmation.*

Conclusion

In this paper I have discussed an initiative to promote the use of knitting skills to rework items within the wardrobe and thereby contribute to what I have termed the 'domestic circular economy'. While non-market domestic activity is inevitably of little interest to commercial corporations, it provides an important opportunity to extend product life and delay the need for more energy-intensive processes of re-use, remanufacture and recycling.

With a recent resurgence of interest in making clothes at home, a significant community of knitters have the skills required to rework existing garments. A range of barriers currently discourage this community from contemplating reknitting projects, including a lack of awareness that it is possible to knit without 'knitting new'. Analysis of the support provided in the pilot project identified three interconnected elements: *inspiration, information* and *confirmation.* All three are needed to help knitters to embark upon and accomplish reknitting projects in the home, and will need to be constructed at a larger scale if reknitting is to gain in popularity.

Stepping back from the case of reknitting, I would argue that these three elements are crucial to any initiative seeking to promote activity within the domestic circular economy. It is my hope that this initial discussion of the three elements will be of use to others attempting to develop or evaluate such initiatives.

References

Bratich, J. Z., and Brush, H. M. (2011) Fabricating Activism: Craft-Work, Popular Culture, Gender. Utopian Studies, 22:2 pp 233–60.

Ellen Macarthur Foundation (2015) “Circular Economy Overview.” Ellen MacArthur Foundation. Available at https://www.ellenmacarthurfoundation.org/circular-economy/overview/concept. Accessed 15 August 2016.

Fisher, T., Cooper, T., Woodward, S., Hiller, A. and Goworek, H. (2008) Public Understanding of Sustainable Clothing. London: Defra.

Fletcher, K. (2016) Craft of Use: Post-Growth Fashion. Abingdon: Routledge.

Gibson-Graham, J.K. (2013) Take Back the Economy: An Ethical Guide for Transforming Our Communities. Minneapolis: University of Minnesota Press.

Goldsworthy, K. (2014) Design for Cyclability: Pro-Active Approaches for Maximising Material Recovery. Making Futures, 3 pp 250–61.

Hower, M. (2016) 8 Companies to Watch in the Circular Economy. GreenBiz, 10 August. Available at https://www.greenbiz.com/article/8-companies-watch-circular-economy. Accessed 15 August 2016.

Koster, J. and Murray, M. (1943) Knitted Garments for All. London: Odhams Press.

Mcdonough, W. and Braungart, M. (2002) Cradle-to-Cradle: Remaking the Way We Make Things. New York: North Point Press.

Murray, R. (2012) Global Civil Society and the Rise of the Civil Economy. In M. Kaldor, H.L. Moore and S. Selchow (eds.) Global Civil Society 2012: Ten Years of Critical Reflection. Basingstoke: Palgrave Macmillan pp 144–65.

Pearson, M.R.R. (1980) Traditional Knitting of the British Isles: The Fisher Gansey Patterns of North East England. Newcastle: Esteem Press.

Perella, M. (2014) Ten Things You Need to Know About the Circular Economy. The Guardian. Available at https://www.theguardian.com/sustainable-business/10-things-need-to-know-circular-economy. Accessed 15 August 2016.

Sundbø, A. (2000) Everyday Knitting: Treasures from a Ragpile. Norway: Torridal Tweed.

Twigger Holroyd, A. (2013) Folk Fashion: Amateur Re-Knitting as a Strategy for Sustainability. PhD thesis, Birmingham City University.

WRAP (2016) WRAP and the Circular Economy. Available at http://www.wrap.org.uk/about-us/about/wrap-and-circular-economy. Accessed 15 August 2016.

CIRCULAR
TRANSITIONS

23–24 November 2016

Whole Circles: Models for Academic Textile Design Research Leadership in the Circular Economy

Rebecca Earley (University of the Arts London, UK)

Abstract

New leadership approaches are needed in design research to support the creation of more resource-efficient models for material resource loops and cyclability. Designers will need to take on enhanced roles in order to drive changes to products, systems and behaviours. The conceptual model, Characteristics of High-Performing Research Units (Higher Education Funding Council for England (HEFCE) 2015), cites people, collaboration, partnerships and networks, and departmental practices as all key factors in successful research hubs. In this paper, the author discusses insights drawn from an original auto-ethnographic study and proposes a revised model which provides researchers, practitioners and managers with questions they need to consider in order to lead in ways that academia, industry and the planet urgently needs.

Introduction

The work at Textile Environment Design (TED) and Textile Futures Research Centre (TFRC) and University of the Arts London (UAL) is in grounded in practice-based textile design research for the circular economy which includes considering new roles for future designers. To understand and prepare for these roles textile designers need to consider leadership in an industry where traditionally they have been taciturn (Igoe, 2015); and needing support to 'step out' (Press & Heeley, 1997). The opportunity here is for progressive leadership approaches from industry to be applied to academic design research units, so that they can create the systemic change the textile industry requires (LeJeune, 2016).

This paper primarily draws upon the experience and reflections of the author, a textile designer and the Director of a University research Centre, and triangulates this with a conceptual model and a corporate leadership model, in order to identify insights to support design leadership for the circular economy.

Inspired by the 2015 HEFCE conceptual model, Characteristics of High-Performing Research Units, the author has reflected upon building the unit and delivering circular fashion textile projects across a five-year timeframe. In seeking to describe and systematically analyze personal experience in order to understand cultural experience (Bochner & Ellis, 1992:165-172), the author used questions derived from a workshop and Skype session with Ayelet Baron whose seven signposts (Baron, 2016) frame this study. The questions explored were:

1. *How can I lead this research Centre, meeting all the objectives I have been set?*
2. *How can I make sure all members get involved in the Centre and projects?*
3. *How can I become a whole self when I am so many different things to so many different people here?*
4. *How can I develop a shared purpose for the Centre and its members?*
5. *How can I work at living, rather than live to work; and how can this become a healthy way for my research team to work too?*
6. *Who do we want to work with and why?*
7. *How can I work differently to support the diverse interests of group?*

Context

Traditional industry leadership approaches place importance on position and productivity above people (like Maxwell's *Five Steps*, 2011); however, in the same way that the field of sustainability has evolved away from a focus on the product and towards systems and social equity, recent leadership approaches have become more people-centric (like Mackey & Sisodia's *Conscious Capitalism*, 2014).

The HEFCE model (figure 1) puts people in the middle of the circle surrounded by strong leadership, culture and values - and proposes that these are pre-requisite factors for success. Strategy and funding positioned as enabling, along with collaborations, networks and institutional practices. The publication of the model coincided with end of the five-year leadership period covered in this paper. The author's Centre was not one of those that took part in the research that formed this study, but was rated as a high-performing and impactful Centre within the UAL (University of the Arts London, 2016).

Figure 1: The conceptual HEFCE model, 'Characteristics of High-Performing Research Units' (HEFCE, 2015)

Baron's seven signposts

Baron's book, *Our Journey to Corporate Sanity: Transformational Stories from the Frontiers of 21st Century Leadership* (2016) is based on many years as an international manager at Cisco, followed by a period of consulting for companies around the world testing her guidelines for more people-centric approaches. Baron's signposts were developed to support leadership endeavors that address new problems that are emerging as we enter an era where 'we are the leaders at the forefront of a human-to-human, purpose driven experience.' (2016:8), as the increased interest in sustainability and social equity issues also evidences.

Figure 2: 7 Signposts to Thriving in the 21st Century (Baron, 2016)

Methods

The author conducted a review of the process of establishing the Centre itself and key projects within this timeframe, seeking to describe and systematically analyze personal experience in order to understand cultural experience. Writing about an experience to share with an audience can in itself be seen as a form of leadership and as a research output. 'A researcher uses tenets of autobiography and ethnography to do and write auto ethnography. Thus, as a method, auto ethnography is both process and product.' (Bochner & Ellis, 1992)

Auto ethnography is a method that is growing in use amongst textile researchers, as they seek to describe, analyse and share personal experience in order to understand more about their work – and often the things that they do and make which seem to happen instinctively. The call for textile designers and researchers to become more vocal and engaged (Press & Heeley, 1997) has been one which the author responded throughout their career; but more through action, than written reflection. In writing about design and research decisions and textiles made previously and the shifting of boundaries that happened as a result, it brought the author '…closer to the truth of lived experience and more scientifically valid than more detached and seemingly more objective methods.' (Goett, in Jefferies, Wood Conroy, Clark, 2016:125)

A workshop at the Centre with Baron in July 2016 introduced the 7 Signposts to the researchers which later led to the development through Skype calls of seven questions which were used by the author to reflect on the experiences of both building the Centre and leading circular design research projects. A 10,000-word text by the author in response to the questions was used to draw out a series of insights and observations. These were then placed into a table that was created to form a triangulation with aspects of the HEFCE model. The insights table is included below and was edited further to write up the results section of this paper.

The text and the HEFCE characteristics have been used to form four areas for discussion in this paper: people, culture & values; community and network; and strategy, funding and institutional/departmental practices. Baron's seven signposts formed four themes for this study which correlate with the four areas from the HEFCE model: Creating and Leading an Inclusive Centre and Being Whole Within it; Developing a Shared Purpose, which includes Working at Living; Co-creating Communities and Finding New Ways of Working.

Results – People

Baron's signposts that were applied here were Conscious Leadership, Integrating the Team & Becoming Whole. When considering questions for the HEFCE circle of 'People' – the idea of the leader as a person, and leadership as an agreement and relationship between people, came to the fore. Unlike the HEFCE model, where leadership was separate to people, and less central, Baron's signposts encourage leaders to be the most 'whole' person possible – supporting others and the self to achieve the best results. The questions developed from this part of the study were:

1. *How can I lead this research Centre, meeting all the objectives I have been set?*
2. *How can I make sure all members get involved in the Centre and projects?*
3. *How can I become a whole self when I am so many different things to so many different people here?*

Creating and Leading an Inclusive Centre and Being Whole Within it

The answers to these questions reveal certain things that are of paramount importance for the leader to establish at the outset of the role. These include setting one's own objectives and building one's own team. The business plan must be authored by the leader in order to enable commitment to a vision. The team and membership should avoid being too big, with too many conflicting interests, and too many managers. Integration is an ongoing process – making sure that all people feel included in the Centre's vision, and able to participate as fully as possible.

The leader should aim to surround themselves with people they want to work with and ensure they are properly resourced. Aim to create opportunities for others, above oneself, as a leader – looking for projects that will be bring out the strengths of the team. But – key to success – is that the leader also IS the researcher they want to support. "As Director, you need to lead by example. Make the time to be a researcher – don't just manage others. Create a work and time plan, based on realistic objectives – that ring-fences time to write. And make sure your team know how important it is for you to be absent to do this."

In order to achieve the above, in particular the last point - it's important to know when to bring in the managers. "If new ventures mean more time and commitment, and new knowledge levels or greater degrees of administration, identify the limits of the team and work towards getting in extra support." Learn to delegate well, as spreading the load and knowing when it's time to ask a team member to take on more responsibility is part of delivering a vision for all the people in the Centre.

The vision of the Centre should include developing projects with open briefs to support broad participation by members – researchers of all levels should be able to contribute – and the participants should develop practices where group reflection and knowledge exchange is a regular occurrence. This way of working improves many aspects of a Centre by making the people in it feel supported, heard and understood, but also serves the group well when difficult situations arise. The leader needs to set an example through how they communicate, to encourage the members to see communication between people as essential to good research practice.

In order to support the members of a Centre in becoming better researchers the leader needs to ensure that coaching, mentoring and training are regularly delivered and reviewed as part of the appraisal process. Personal growth and development are key to original research – for the members as well as the leader. "Learn new things together. As a leader, as you learn, so you can share." Becoming whole is about being your best self – inside and outside of work – and not separating too much the way that you present yourself in these contexts. Progressive leadership in industry is about being 'authentic'. From the experience of the author, this particular approach proved to be the most successful in enabling the Centre to recruit good people and retain them, which HEFCE recognize as key to high performing units (2015:20).

Finally, ironically, the last insight is about developing a sense of limits or boundaries to other people who make demands of the leader. It became clear through the reflection process that 'growing a thicker skin' was important to being able to counter certain pressures arising from people both within and without the Centre. Finding a balanced view on what can be done for oneself and for others will enable a leader to sustain a role, whilst also developing vision and ambition within the membership.

Results – Culture and Values

Baron's signposts that apply here are Creating a Shared Purpose & LIFEworking. When considering questions about culture and values, the following questions were developed:

4. *How can I develop a shared purpose for the Centre and its members?*
5. *How can I work at living, rather than live to work; and how can this become a healthy way for my research team to work too?*

Developing a Shared Purpose, which includes Working at Living

What emerged through these questions was that a desirable internal culture – especially when exploring circular economy ideas – was a highly collaborative one, and that every collaboration should be seen as an outcome in its own right. “Collaboration means making time to bring people together to co-create a shared purpose.” It was felt to be important to work out the details of collaboration upfront. “Don’t work it out as you go along – sit down and talk through the potential outcomes and ownership issues, as well as the methods and processes. Find the foggy bits, and note them.”

When it was not possible to work this way – members had different approaches and could not collaborate easily on ideas – a much more disjointed and less comprehensive set of results were presented at the end of projects. In some cases, members left the Centre to set up their own hubs or groups; and whilst this is not necessary a negative outcome, building and growing a Centre that is ‘high-performing’ would not be possible if members did not ascribe to the culture and values that exist at the heart of the organization.

Democratic decision making and systemic development in an academic context is important to trust and collaboration efforts. “Academic research loves to hold up its high-achievers, its philosophers, its award-winners. But these individuals are becoming rarer as the environment changes. Embrace diversity and enable progression across the board. And if the academic system seems outdated, challenge it to change.” Research leaders need to make fairness, equality, accessibility and generosity central to the group’s collaboration ethos.

The reflective texts revealed that spending time together as a team was important to how the culture and values developed at the Centre. Eating meals together – at work, on trips, and for social events helped researchers to debrief and ‘digest’ the activities and ideas. The informality of these events built an understanding for all that was hard to capture through other feedback routes. “Formal feedback mechanisms rarely capture the human interactions.” Likewise, working together outside of the physical office space was beneficial, as “we connect differently in different spaces – and by being connected we are more resilient.”

In terms of resilience, the culture and values need to seek to sustain researchers as well as project outcomes, aiming to “Look after each other. Know what each individual needs – what makes them happiest and what will make them flourish. Support their efforts.” The notion of liking and enjoying your work sounds obvious, but if practice-based researchers only produce written outcomes like journal articles, their unique offer to the field is at risk when it needn't be, "…our field of practice-based textiles research we have the flexibility of defining it for ourselves." The culture needs to support a range of practices and approaches, and the leader can find ways to ensure time and work load planning takes into account creative, hands-on action.

Finally, stress can negatively affect a culture and it was found to be something that needs to be openly discussed and addressed, and even monitored. Whilst insights like these fall into the category of Human Resources at an organization, and many measures are provided to support researchers centrally, a research Centre culture can also enable a healthy balance for its members, which in turn enables strong levels collaboration, trust, knowledge exchange, generosity, understanding and creativity to be maintained.

Results – Collaboration and Networks

Baron's signpost that was most relevant for the author here was Co-Creating Communities. The internal collaborations seen above will naturally foster external collaborations which lead to more developed networks. For the author, the Centre had a large membership served by people that were all well connected, so this question was less about building these communities from scratch, and more about being selective with time, energy and resources:

6. Who do we want to work with and why?

Co-Creating Communities

Through the reflective process the author realised that the first step in this process was to enable the people in the Centre "be conscious of the need for community". For academic researchers, a Centre can often feel like enough of a community in its own right – isolated study being the basis of traditional academic pursuits – but external networks and communities are the lifeblood of research connected to the circular economy, as the ideas are most often applied and needing context. Also, all major funding calls require a great degree of cross-sectoral collaboration and these most often come from trusted communities and networks that have taken time to develop. The reflective texts also highlighted the need to "understand the community through the local and global lens."

It was vital that the Centre and its members were properly represented online and fully visible. Clear and evidenced statements supported by links to strong research outcomes would mean that the community and network could then self-select. “Be abundantly online. Don’t worry about over-sharing online. Ideas are just ideas; actions actually make things real. By building your audience you will receive feedback, support and new approaches.” This can also mean changing the language – shifting it away from an academic style to a more generalist audience. This is hard for a group of people to do and needs strong leadership, creative direction, and lots of consultation. “Communicate your success. Traditionally research under-sells itself. It doesn’t seek a broad audience, for fear of devaluation. It’s important to show yourselves and the world what you are doing and bring them with you on your journey.” Ask researchers to be accountable for communicating the work of the Centre as well as their own ideas, in both formal and informal contexts. “The team need to understand milestones and work openly towards them – presenting them brings new insight and feedback during the project process, rather than just at the end.”

What became most interesting about this part of the study was that when some of the community became real – not online but in the room – what had been previously regarded as different communities quite easily became one. The sense of potential for sharing ideas and approaches was greatly increased in situation where co-creation took place. “Find ways to connect up the different community groups. Explore the potential of bringing groups together to create new synergies, ideas and maybe projects.” This highlighted the need for developing both online and offline communities in quite different ways, for the way in which they benefit the research – as well as the research benefitting them – is changing through real time interaction with the ideas.

Results – Strategy, Funding, Institutional and Departmental Practices

These attributes are presented in the HEFCE model as desired, but not a pre-requisite, for high performing research Centres. In many ways reflections on these aspects could form their own study, as practice-based design research is lacking in useful guidance in this area. For this paper, the author focused here on one question, framed by Baron’s signpost Finding New Ways of Being:

7. How can I work differently to support the diverse interests of group?

Finding New Ways of Working

Up to this point in the study the subject of funding and finances had not been expanded upon, yet as most researchers working today will recognise, the opportunity to lead may only come through a project with funding attached. Financial resources underpin performance levels in a Centre, as it buys time to explore and develop new ideas that can evolve into bigger projects. Whilst staff on teaching contracts may produce research outcomes, the time dedicated to teaching duties often puts such enormous pressure on them that unless funding is available to buy-out teaching hours, the time commitment to a research unit is very limited. Finding funding to support staff is a critical part of the leadership role, and can be approached through a strategy that builds a range of projects directed at different levels of research outcomes and activities.

Traditional sources of funding will support communities and networks – at local and international levels – as well as larger community projects. Non-traditional sources – like industry partners and independent organisations – can support research that is designed to take new forms, such as ‘design researchers in residence’ in scientific organisations (for example, Ribul & de la Motte, 2016). Enterprise work - contract research – can also create ‘seed funding’ opportunities. Centre leaders need to evolve multi-level strategies to attract funding to grow the productivity of its membership.

Finding ways to develop and implement a strategy will often involve meetings – and finding a way to make the most of the many meetings leaders have is key. The advice from the study was clear – meetings are time consuming but they enable progress: “if used well, they can provide ‘boosters’ or foot-holds; they can give you the next step up.” The study also recommended that a leadership strategy should include making aspects of the role recognizable and consistent. “Establish a series of recognizable leadership tasks for yourself. This creates physical signals to your team about how you are leading.”

New ways of working in a young field like academic design research may mean that assumptions need examining before proceeding with projects and activities, to ameliorate against cross-sectoral misunderstandings. “Art Schools are not like science institutions. Design research projects – especially when practice-based – are very different to most science research projects.” After this, if questions remain unanswered, it is important to know when external support is needed. “Bring in the experts… Don’t be afraid of reaching out for help – you will gain the respect of your peers, not lose it.” Art, design, science research is dynamic and innovative – that is the appeal – “but we can’t be expected to know how to do everything in a culture that is constantly changing.”

Consider a strategy where your team can offer more than just the research outputs – impacts can be a broad variety of things. Despite the economic and performance pressures that a Centre may bring about, part of a strategy should be about creating a team with optimum membership. Too big, and the role of leading becomes difficult as the people in Centres all need to make identifiable contributions to the shared vision. “Collaboration has optimum scales – people play a specific range of roles – learn about this and use it internally, and externally.”

When the team dynamics work well, then the learning curve can be great and can provide ample ‘data’ that can be more rigorously reviewed and shared. These endeavours all provide other design research units with new knowledge. “Make everything you do data. Your team is an experiment, as the field is so new. You have much to offer other ‘start ups’ in the sector.” When a team is not working – the leaders’ role is to spot this. “Not all the pieces fit, all the time. Know when to let go… recognise this and make a new strategy.”

The Revised Model

The revised model (figure 3) which resulted from the study and discussion fuses ‘People’ and ‘Leadership’ as one entity – the text that formed the auto-ethnographic study highlighted the fact that leaders are people, and that progressive leadership is so much about co-creation and collaboration that individuals working in the Centre must form one whole entity – the centrifugal force of the Centre. In this revised model people and leaders are together, and they weight the model – they ground it. In this way, the diverse interests of the group are embraced and the model can evolve outwards in new directions from a stable core.

This study has revealed that at the heart of a high-performing research unit – (this Centre was the most financially profitable of nine research Centre’s at the University during the period examined) – people and leadership are one entity. Cultures and values are essential in terms of success, with collaboration and network coming afterwards; as culture and values need to be consistent and reliable, whilst collaboration and networks can be flexible and ever-changing. Strategy, funding and institutional and departmental practices provide leaders with new ways of working to support the core focus - people, culture, values - through collaborations and networks.

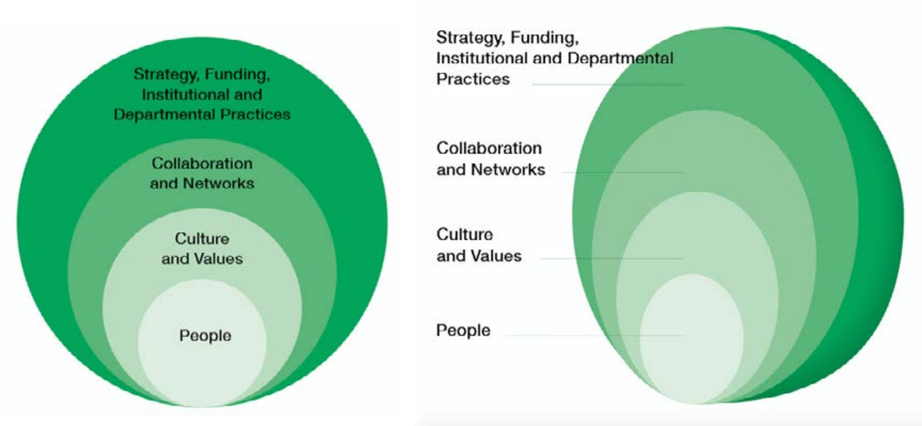


Figure 3 (left): The revised HEFCE model. Figure 4 (right): A model for Whole Circles Leadership

The model can be expanded further to enable the people at the Centre to evolve their own leadership opportunities – their own cohort of researchers with their own particular take on culture and values that still relate to the Centre. These emerging researchers may then need to develop their own collaborations and networks, and evolve their own circles. Thus, the final model (figure 4) shows how leadership in the circular economy might take the form of *Whole Circles*. The two-dimensional model has evolved into a three-dimensional model as researchers in the Centre progress into the leaders of their own areas of specific expertise – interests and activities remain connected but diversification and growth is enabled – making the Centre not larger, but more rounded, more global, more aligned with the earth.

Conclusion

This paper highlights the importance of using the academic space for telling the stories of our research experiences; so that design research leadership can make a vital contribution to addressing the complex challenges of the emerging circular economies and cultures. The study could be expanded to include other reflective accounts from the same period. The circular economies of the future face people-centric challenges and need people-centric styles of leadership from all design fields.

References

Baron, A. (2016) Our Journey to Corporate Sanity: Stories from the Frontiers of 21st Century Leadership, Vancouver: Param Media.

Bochner, A. P., Ellis, C. (1992). Personal narrative as a social approach to interpersonal communication. Communication Theory, 2(2), 165-172. New Jersey: Wiley-Blackwell. Available at http://onlinelibrary.wiley.com/doi/10.1111/j.1468-2885.1992.tb00036.x/abstract <accessed 23.8.16>

Bochner, A. P., Ellis, C. (2000) Autoethnography, Personal Narrative, Reflexivity: Researcher as Subject, in The Handbook of Qualitative Research. New York: Sage. Available at: http://works.bepress.com/carolyn_ellis/49/ <accessed 23.8.16>

Ellen Macarthur Foundation (2015) Circular Economy Overview. https://www.ellenmacarthurfoundation.org/circular-economy/overview/concept. <accessed 15.07.16>

Goett, S. (2016) Materials, Memories and Metaphors: The Textile Self Re/collected, in The Handbook of Textile Culture (Jefferies, J., Wood Conroy, D., Clark, H. (eds) 2016) by Ebook Library [supplier]. London: Bloomsbury Academic.

HEFCE (2015), Characteristics of high-performing research units, http://www.hefce.ac.uk/pubs/rereports/Year/2015/highperform/Title,107168,en.html <accessed 24.3.16>

Igoe, E. (2013) In Textasis: Matrixial Narratives of Textile Design, Royal College of Art (RCA) thesis, London. http://researchonline.rca.ac.uk/1646/1/IGOE%20Digital%20Thesis.pdf <accessed 18.8.16>

Lejeune, T. (2016) The New Leaders: An Inspired Approach to Business Leadership. Ethical Fashion Forum: London. Available at: http://source.ethicalfashionforum.com/article/the-new-leaders-an-inspired-approach-to-business-leadership <accessed 26.9.16>

Mackey, J., Sisodia, R. (2014) Conscious Capitalism: Liberating the Heroic Spirit of Business. USA: Harvard Business Review Press

Maxwell, J.C. (2011) Five Levels of Leadership: Proven Steps to maximize Your Potential. Nashville USA: Center Street (Hachette Book Group)

Press, M. & Heeley, J. (1997) Stepping out: textile design goes outside, conference paper for Textiles, Design and Environment on-line conference, The Centre for Sustainable Design: Farnham, UK.

Ribul, M., de la Motte, H (2016) The Material Affinity of Design and Science for a Circular Economy. Circular Transitions Conference presentation, 24.11.16

University of the Arts London (2016) Textile Recycling, research impact case study. http://www.arts.ac.uk/research/impact-of-ual-research/textile-recycling/ <accessed 11.10.17>

CENTRE for CIRCULAR DESIGN

CIRCULAR TRANSITIONS

23–24 November 2016

Shared Emotional Values in Sustainable Clothing Design Approaches

Marium Durrani*, Louise Ravnløkke** & Kirsi Niinimäki*
(*Aalto University School of Arts, Design and Architecture &
**Design School Kolding)

Abstract

Recent sustainable initiatives in fashion companies are framing design practices that challenge the traditional role of clothing designers. This preliminary study aims to open discussion on challenging traditional clothing design, through an exploration of the shared emotional values between user and designers, when designing for longevity.

Introduction

Extending the useful life of products has been classified as one of the key principles when designing for circularity within fashion (The Great Recovery Report 2016; 14, Brismar 2016). Recent sustainable initiatives to this direction are framing design practices that stand in contrast to and challenge the traditional role of designers (Fletcher 2013; Niinimäki 2011; Riisberg et al. 2015). In doing so, this article is a reflection on the changing role of clothing designers in their attempt at being drivers of values geared towards extending garment lifespans. I Made This (Finland) and Unmade (United Kingdom) are two such companies engaged in minimizing waste, prolonging garment lifespans and increasing user-garment attachments through innovative garment design and user involvement. Looking through the lens of these companies design practices of zero-waste design and production on demand, this preliminary study will begin by illustrating the meeting point of design driven and user centred values. How each of these values are being defined, at what point do they crossover and what implications of this shared value framework has on garment longevity, are the underlying themes of the discussion that is to follow.

Theoretical Framework

In trying to set future paths for a more sustainable garment industry, the user may be considered as an important partner in making change. Short-term use is one of the characteristics resulting in overconsumption of clothing (Armstrong et. al 2014). It is, therefore, highly relevant to focus on the users' garment attachment as an approach to address future consumption. "The user's positive emotions towards a product offer possibilities to create commitment and bonding to this product, which will be cherished and taken care of. Accordingly, emotions play an important role, not only in consumption but also in the commitment process." (Niinimäki 2011; 58). Identity construction, aesthetic needs, ideological inclinations and personal memories are some of the forms that user emotions translate into (Niinimäki 2011). Niinimäki and Koskinen (2011) propose a framework to embed an empathic approach to the design process by taking into consideration these various levels of user emotions. They argue that a satisfying use experience can be achieved when meeting the user expectations for quality, functionality as well as aesthetical dimensions (ibid.; 182). This can then create, what the authors refer to as, 'emotional value' and add to user garment attachment. Furthermore, it is suggested that value leading to sustainable consumption can be created in the design and production phase when oriented towards the future (Niinimäki 2011; 61).

Recent years has seen an increased production in research investigating innovative sustainable business thinking and looking towards opportunities to design for more sustainable consumption in the garment industry (for an overview, see for example Fletcher and Grose, 2012; Fletcher and Tham, 2015; Gardetti and Torres, 2013). Within this, the new role of the designer has also been discussed. According to Walker (2007) sustainability in itself "challenges and calls for new and alternative models to become accepted, validated, and desirable codes or practices." (Marchand and Walker 2007; 3). This creatively challenging design approach is backed up by ecologically driven values in sustainable systems; e.g. design approaches for minimizing waste. The practice allows for re-defining the meaning of new and durable through novel designs. Additionally, it is also proposed that through user involvement, the product is allowed to have the opportunity of gaining more value in the eyes of the user thus, leading to greater user-product attachment (Ibid: 6). In trying to understand the many levels where value is influenced, Niinimäki also emphasizes on catering to the users ideological values. (Niinimäki 2015; 4). For consumers with an interest in the social and environmental impacts of products, addressing these aspects can possibly add value to the consumer and the relation shared with their garments (Armstrong et. al 2014).

However, at what point do these two sets of values (emotional and ecological) interlock with one another, and what subsequent challenges may arise in that space, are questions remaining to be addressed. The following sections will, then, be introducing the two companies chosen for this task and will take the discussion on elongating garment life spans through a further understanding of shared emotional values forward.

Research Approach

For the purpose of this study two small scale clothing companies, I Made This and Unmade, were selected to explore the intersection of ecological values driven by design and emotional values centred at the user and its intentional impact on users' garment attachment. Both companies reflect design practices that aim to minimize waste by different production approaches, and offer their users to be involved in the design and styling choices of the clothing.

In studying the companies, desktop research was supplemented with in-depth interviews conducted at the design studios in the surroundings of the companies work and production. The interviews were conducted in a semi-structured form with the intention to let the companies (designers) narrate their stories while leaving space for related subjects that might come up. The collected data was then analysed from three aspects: sustainable garment awareness, user involvement and garment attachment for longevity. Details of which are given in the upcoming sections.

Company Description and Analysis

Unmade a London based start-up company specializes in on-demand production of knitted scarves, t-shirts and sweaters for both genders. The company provides customers with the options to creatively interact in the making of their garments when placing orders online. By which, the information about the customised garment is sent to the knitting machine in the manufacturing studio. All garments are fully fashioned made of high quality fibres (e.g. extra fine merino and pima cotton). The style options vary in colours and jacquards designed by the Unmade team and other collaborative designers.

I Made This (IMT) is an independent Helsinki based zero-waste design practitioners' company. Troubled by the alarming culture of the current fashion industry, IMT began its ready to wear line in 2012. Since inception, the collection has consisted of clothing items made from scrap and left over fabric purchased from an out of business local fabric store. Using the limited materials, digital and silk screen prints have been used to create an unconventional line of one-size, multi-purpose and comfortable t-shirts, dresses, jackets, and trousers. Each item in the two collections is unique in both its' print, style and design.

Sustainable Garment Awareness

Production methods used by both companies are based on principles of sufficiency and elimination of waste (Walker 2007). On average one piece of clothing contributes to approximately 15-20% of wasted cloth at the fabric cutting stage (Rissanen 2013). Zero-waste design practice aims at eliminating this waste through creative pattern cutting techniques. Patterns are determined before the fabric is cut and the width of the fabric is integrated fully within the pattern or used throughout a collection (Mills 2013; 104). Whereas, conventional garment patterns are produced only after garments have been designed and cut. Through zero-waste design all the pieces of the cloth are adjusted to be used in the garment by merging pattern making and cutting with fashion design. Thus, by using up all of the fabric needed for the garment, waste is eliminated by injecting it back into the design of the garment (Rissanen 2013).

The principles of circular fashion (Brimar, 2016) can be seen being employed in I Made This limited clothing line. Designed and cut solely by IMT the garments are made either by using the fabric in its entirety to form geometric necklines or by reusing the left over cut outs in decorations for the shirts or accessories. This technique not only eliminates waste but allows designers to innovatively use limited materials. "I like to challenge myself and narrow it down, that's why I like using left over materials because you can't do whatever you want but you have to make something out of what you have and I like that. It spurs my creativity more." (IMT, interview). Referring to a two-sided jacket (figure 1), black on one and grey on the other side, IMT explains: "the material I used is used for making bed sheets and I made a jacket out of it."

Figure 1: Two-sided jacket (I Made This 2016).

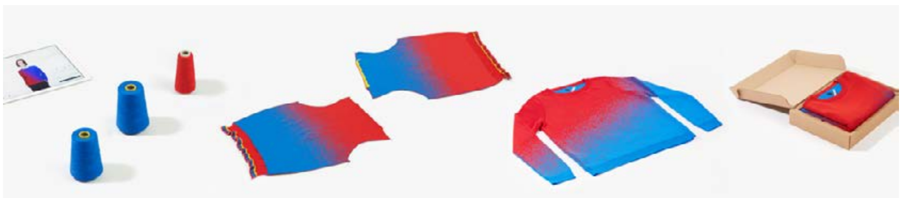


Figure 2: Steps of manufacturing (Unmade 2016a).

Figure 3: The Unmade studio show on social media (Unmade 2016b).

Similarly, Unmade's practice of knitting fully fashioned garments on demand allows for reduction in waste. "Things aren't made until they are wanted which means there is no wastage. Because it is so expensive at the moment with other processes to actually make these designs; to iterate and manufacture, people (designer/producers) have to make hundreds of them (garments){…}a lot of them aren't wanted in the first place, and they just become landfill. So we just make things only when they are wanted" (Unmade, interview).

Production is driven by demand and based entirely on the orders received (figure 2). By which, Unmade challenges the idea of storing clothing in stock, and no unwanted garment is disposed. For the purpose of manufacturing, the company has developed a software system to ease every part of the garment making and to address customer experience of play with personal aesthetics while also fulfilling ideological visions (Niinimäki 2013).

All production (knitting, linking and stitching) takes place in London where knitwear experts work in house with the designers. Social media is used to provide for transparency whilst building customer relations. The company meets consumer expectations of providers of information on production process and implicated partners (figure 3). "The more we talk to people, the more engaged they become. So it only improves things for us. If they feel like they have got everything then they feel more involved in the company as well" (Unmade, interview).

User Involvement: The Style of the Garment

The two companies allow users to participate in the clothing style at different levels for customisation; IMT engages them in the use phase whereas, Unmade does so at the point of purchase. Both companies have the opportunity to achieve deep customer satisfaction through personal aesthetic preferences (Niinimäki 2013). Clothing from IMT is created in ways that let the users' body give form to the garment. Among IMTs' collection is a unique dress that can be used as a blouse if pulled up. It comes with a hoody which when pulled forward can be converted into a lower layered neckline (figure 4). In this way, the user is offered various options of wearing the same garment in different ways. "I like that everybody wears things differently and the same piece of clothing will not look the same on different people" (IMT, interview).

Figure 4: Multifunctional garment on different body types; used as both a top and a dress (I Made This 2016).

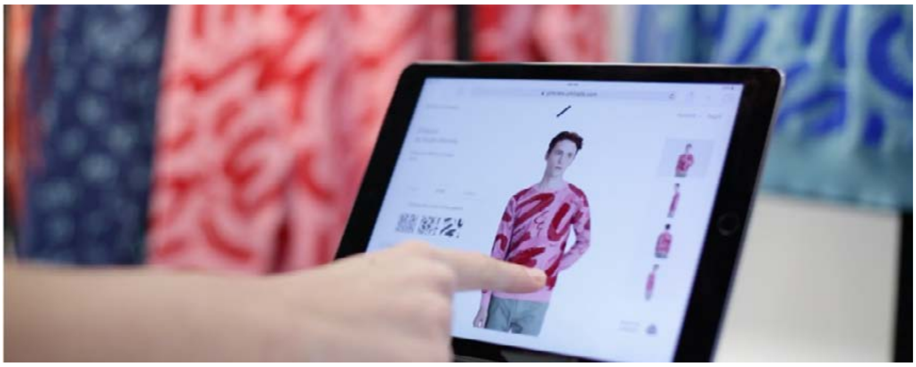


Figure 5: Digital platform of choice making features (Unmade 2016a).

Additionally, the flexibility offered by IMT's one size garments not only allows the user to individualize the products but also use the garment even when body shape changes to get more out of their usage. "I wanted to make a dress for someone who is a bit bigger, and that also look nice on someone who is skinny and could wear it too." (IMT interview). Kirsi Laitala (2014), argues that such designs are emotionally durable as they; "improve the physical and technical robustness of the clothing while also addressing the emotional and expressive quality they can provide to the consumers" (Ibid.; 11).

When placing an order for an Unmade knitted item, it is for the user to decide how it is made with the possibility to make a one of a kind garment. Every piece in the knitwear collection can be customised from options on shapes, jacquards and colours designed by Unmade. The online shop allows users to creatively interact with the virtual version of the clothing and play with the jacquard, patterns and colour hues by e.g. dragging the cursor around (figure 5, Unmade 2016a). "We have looked into new way for people to make sure that it (the design) is individual to them, as for example the striped one, where they can use their name for an individual pattern, and move up and down and things like that, which is really important to us" (Unmade, interview).

Users in both cases are seen as integral to clothing design which is also reflected in the names of the companies. IMT explains: "I really like the idea that everybody who is wearing my design will wear it their own way. I don't want to own it, I want the person who buys my design to own it and say; 'I made this'". The name Unmade is based on the company's concept that the knitted garments are not made until the user has been involved. On social media Unmade is even using the hashtag; #unmadebyyou (Unmade 2016b), in their way of communicating the user involvement approach.

Garment Attachment for Longevity

In the perspective of clothing use time and longevity, IMT offers users multiple options for wearing garments, which gives the possibility to foster more use. The longer the clothing is used the closer the user gets to the product and a nurturing relationship is formed (Niinimäki 2015). Correspondingly, Unmade offer the users the ability to personalize their preferences in co-creatively made knitwear. This involvement, at the design stage, elevates garment appeal and allows users to bond with garments that are one of its kind (Armstrong et. al 2014).

Satisfying use and creating customer relations by promoting clothing attachment are core values to both companies. "I like the idea of having one jacket or dress and getting more out of it{…}The more you get out of something the longer you keep." (IMT interview). Similarly, inside every Unmade knitwear the company sends a personal message for the customer to cherish the shared making of the garment.

Discussion: Challenging the Design Practice

As seen, designers in both companies are adapting to new methods that challenge the traditional comprehension of design practices. Looking towards Unmade's design approach, they are not only involving the users but also inviting other artists and designers to collaborate on the design choices provided. Unmade expresses; "The external (designer) get their own label. We like the fact that we are in-between the product and the designers, and the customer and the designer. Which is where we like to sit.

The idea that you can't make the whole logo without everyone having their part in it." The online interface requires software qualification and at the same time knowledge of knitwear technology. Likewise, producing on demand challenges design thinking and logistics that can handle customised orders and new ways of doing business. In this way, a new role for the designer is being scripted as a facilitator that mediates between stakeholders with different expertise (Fletcher and Grose 2012).

Operating on several levels of aesthetic and ethical values may result in a rather complex design approach. Unmade explains; "As we do this everyday, it is very easy to be at our point, and forget all the steps. All of our customers haven't been there. So we have to take them along in a way that they can understand, that is really open and intuitive{…}meanwhile we are also trying to make sure that they (the knitwear) won't look ugly on anyone, because you know, it might be the coolest concept in the world, but everyone still wants to wear a nice jumper. And also if we want designers to work with us, we don't want no one to take their design, and make it ugly or unaesthetic, so having those barriers and parameters of what people can do is really important, and also if you give like people complete choice over everything it is just so overwhelming." Understanding the design concept of the product is important for the user to participate and interact, and in the end obtain user satisfaction (Walker 2007). Thus, the communication of values around these new design approaches will be a second task to consider in building strong and longer lasting garment-user relations.

Additionally, to make clothes that apply to zero-waste design, necessitate a certain level of skill polishing when finding a balance between aesthetics and ecological ethos. IMT's distinct designs not only challenge conventional design practices but are a testament to the principles of minimalism and circularity both in production and use. IMT explains; "It is very difficult to have zero-waste if you keep having different sizes because the width doesn't change. If you are going to have 5 different sizes it is going to be very difficult to not waste the material{…} Even if you are using geometric shapes you still have to measure and see how you are going to use the whole width of the fabric{...} Zero-waste in general is difficult you can't just make anything you want." Therefore, when trying to create garments driven by ecological values of waste minimization and extended garment life, while also meeting the aesthetic, functional and physiological needs of users, a high level of dexterity is demanded on the part of the designer (Niinimäki 2013; 84).

Concluding Remarks

The contribution of this paper is aimed at drawing attention towards novel approaches to designing for garment longevity. Borrowing from both ends of the design and user-centred design spectrum, are companies working towards the establishment of alternative design approaches. It is within this space that garments have become a common embodiment and carrier of designers' ecologically driven values while also reflecting users' aesthetically emotional values. User involvement initiated through creative and open-ended design practices empower users into opening doors of attachment with their garments. In this new platform, the designer has become the provider of values (emotional and ecological) that the user is in search of. However, not all users may have the desire to be engaged in such an open-ended design approach. For future work, insights on the user perspective may benefit to further strengthen the knowledge on not only shared emotional values but also the negotiations that may arise between these actors (the user and the designer in relation to the garments) that are creating emotional value dependence on each other.

References

Armstrong, C.M., Niinimäki, K., Kujala, S., Karell, E., Lang, C. (2015) *Sustainable product-service systems for clothing: exploring consumer perceptions of consumption alternatives in Finland*. Journal of Cleaner Production 97, 2014 30–39.

Brismar, A. (2016*) No 2: Design for Longevity*. Circular Fashion. Green Strategy. Web. Retrieved from http://circularfashion.com/ Oct. 31 2016

Fletcher, K. and Grose, L. (2012) *Fashion & sustainability: design for change.* London: Laurence King.

Fletcher, K., Tham, M. (2015) *Routledge handbook of sustainability and fashion,* Routledge international handbooks. Abingdon, Oxon: Routledge.

Fletcher, K. (2013) *Design for Sustainability in Fashion and Textiles.* In Black, Sandy, ed. The Handbook of Fashion Studies. London: Bloomsbury, 2013, 557-574.

Gardetti, M.Á. And Torres A.L. (2013) *Sustainability in fashion and textiles: values, design, production and consumption.* Sheffield: Greenleaf Publishing.

I Made This (2016). Retrieved from http://cargocollective.com/imtstreetwear July 4 2016

Townsend, K. and Mills, F., (2013). *Mastering zero: how the pursuit of less waste leads to more creative pattern cutting.* International Journal of

Fashion Design, Technology and Education, 6(2), pp.104-111. DOI: 10.1080/17543266.2013.793746.Taylor & Francis Group.

Laitala, K. (2014) *Clothing consumption. An interdisciplinary approach to design for environmental improvement.* PhD, Norwegian University of Science and Technology, Trondheim, Norway.

Marchand, A., Walker, S. (2007) *Connecting through Time*, Connecting '07 IDSA Education Symposium, ICSID/IDSA World Design Congress, San Francisco

Niinimäki, K. (2011) *From disposable to sustainable: the complex interplay between design and consumption of textiles and clothing*, PhD thesis, Aalto University, Helsinki.

Niinimäki, K. (2013) *Sustainable Consumer Satisfaction in the Context of Clothing.* In Vezzoli, Carlo, Cindy Kohtala, and Amrit Srinivasan. Product-Service System Design for Sustainability. Sheffield: Greenleaf Publishing.

Niinimäki, K. (2013) *A Renaissance in Material Appreciation: Case Study in Zero Waste Fashion,* Journal of Textile Design Research and Practice,1:1, 77-92. Taylor & Francis Group.

Niinimäki, K. (2015) *Ethical foundations in sustainable fashion*. Textile and Clothing Sustainability 1, 1–11. Springer.

Niinimäki, K. and Koskinen, I.K. (2011) *I Love this Dress, It Makes Me Feel Beautiful! Empathic Knowledge in Sustainable Design.* The Design Journal, 165–186. Routledge.

Rissanen, T. (2013) *Zero-waste Fashion Design: A Study at the Intersection of Cloth, Fashion Design and Pattern Cutting.* Doctoral dissertation. Sydney: University of Technology.

Riisberg, V., Bang, A.L., Locher, L., Moat, A.B. (2015) *AWARENESS: Tactility and Experience as Transformational Strategy.* In: Shapeshifting: A Conference on Transformative Paradigms of Fashion and Textile Design., Auckland University of Technology, 21.

The Great Recovery (2016) *Designing for a circular economy. Lessons from The Great Recovery 2012-2016.* Action and Research Centre (RSA). Retrieved from http://www.greatrecovery.org.uk/ July 1st.

Unmade (2016a). Retrieved from https://www.unmade.com July 1st. 2016.

Unmade (2016b). Retrieved from https://www.instagram.com/unmadestudio July 1st 2016.

Designing Alternative Economies to Create Cultures of Sustainability

Rachael Taylor (Southampton Solent University, UK)

Abstract

Radical or sustainable ideas sitting within the same system weakens impact and dilutes the original intention for change. This paper emphasises the need for embedding alternative economies and post-consumption mind-sets into the design process. To encourage sustainable interventions that re-invent concepts of fashion to ripple out into cultures of sustainability.

Introduction

At present, designers create new innovations and sustainability to fit within unchanging systems based upon profit and growth. Design decisions ripple out to circulate within society, affecting the whole framework. Even if ideas are radical or sustainable, sitting within the same system weakens their impact. The aim of this paper is to re-define what design could become when not based solely within the current economic system of profit and growth. This paper argues that when sustainable ideas are solely in the existing system they lose their original intention for change. The concepts for this paper investigate the potential of current alternatives that exist for exchange and re-invention of concepts for buying and selling. Participation and engagement with alternative economies and consumption of fashion can act as interventions, enabling ways for designers and users to create cultures of sustainability. The potential impact for alternatives when combined and used in the design process and as evolving sustainable outcomes. To explore challenges and barriers of the current system in relation to its concentration on growth, profit and scale. It will highlight how design and culture are affected by current methods of economics, investigating the impact of commodification and monetisation of creativity, culture and sustainability. Further insights discuss practical opportunities that exist for new ways of buying and selling, how communities are connecting to participate and engage with consuming differently.
These highlight emerging alternative forms of economy and consumption, drawing attention to tipping points and how solutions can be turned into

commodities. The will demonstrate visually the circularity of the ripple effect when alternative economies and post consumption mind-sets are combined in practice. The overall aim is encouraging designers and users to carve new meanings for fashion, acting as interventions within consumer landscapes by embedding sustainable opportunities in everyday life.

Part 1 – Creatives, Culture and Economy

This section explores the connection between creativity, culture and economy, how each interlink affecting one another, presenting opportunities and challenges for sustainability. Money and design are interwoven into consumption habits of everyday, from systems and ownership to networks and access. A large percentage of creative design innovations and sustainability are created within existing systems based on profit, growth and scale. The discussion argues how use of emerging alternative economies could open sustainable interventions for fashion exchange to present new mind-sets for buying and selling in practice. As designers, we contribute outputs which have consequences within our cultural environment and social condition. Motivation behind how we choose to use our creativity, results in the landscape we see around us and actions can shape the future. (McRobbie 2002) argued that creative and cultural industries have become major drivers for neo-liberal models; governed by value of entrepreneurism, individualisation and reliance of commercial sponsorship. How relationships between art and economies removed negative connotations of commerce with creativity, resulting in independents being squeezed out of the process becoming dependents, critical creativity instead replaced with cultural production driven by market led consumer culture. The global apparel market, valued at $3 trillion dollars and domestic UK market at £66 billion pounds. (www.fashionunited.com). The disjointedness of culture and culture industries is also present within fashion culture and fashion industries, sustainable development continues to justify a focus on profit and growth. The COST Action Initiative for Cultural Sustainable Development Report (2011-2015) investigated culture as a key element of sustainability. Highlighting, artistic creation in cultural industries are not connected to culture as social fabric. The report outlined the focus of sustainability does not always address the present challenges faced towards systematic causes of unsustainability, within areas builds further monetisation of creative culture and sustainability. They argue for more choices rooted in values that drive our individual and collective actions, process and communication of transformation and cultural change. (Broochi 2008) argues the cultural dimension of sustainability and sustainable development means a change of dominate monoculture of globalisation into diversity of sustainability. How 'in standardisation and monoculture, subcultures and alternative lifestyles have a difficulty to develop themselves in this context or simply exist'. (p.3) These findings inspired ideas to connect process and culture together and re-direct narratives of economy towards alternatives that could influence cultures of sustainability.

(Broochi 2008) expressed how people desire sustainable development without radical change, illustrating new definitions of growth are needed that create a radical change of economic structures. This led to consider how the role of economics is central to choices, creating markets, systems driven by supply and demand. These patterns emerge into millions of goods and services to be consumed, processes combined into a social whole creating capitalist fashion mind-sets. Money and consumption are rooted in everyday life and embedded into social relations with people and things. The future of money and creation of alternatives have been subject to debate; resulting within initiatives, intervening to create discourse, rethinking the role of money and economy in daily life. Development of democratic money systems and models include older historical forms, transformed by technology into new DIY systems. A selection includes co-operative organisations, alternative currencies and banks. In 2014 PwC research revealed peer to peer lending and crowd sourcing are the largest sectors and by 2025 will grow 63%. (pwc.co.uk). The Crowd funding model also generates meaningful and valuable experiences for customers and the community; Kickstarter the world largest funding platform for creative projects. 'Threadless' are the earliest example of using crowdsourcing in fashion, providing a platform for artists to have designs voted into production by a community of followers. These examples create inclusive and constructive ways of support through social systems, audiences participate in backing projects as part of a community. In April 2015 at London College of Fashion a debate called Designing Alternative Values was used as a method to test theories in how alternative economies could be integrated into the design process and challenge perspectives towards pre-conceptions of values. The speakers selected for perspectives on alternative economies in theory and practice; Positive Money, Brixton Pound and designer Patrick Stevenson-Keating who used design in 2014 to Disrupt Finance installed at the Design Museum. Each represented alternatives modes of exchange that used social connections to benefit the wider community. The debate revealed that more un-conventional approaches could be used by creatives, offering new methods for creative translation and interpretation of economics whilst challenging norms.

The ideas within this paper provide many democratic ways of selling and buying that create sustainable relationships between transactions and don't rely solely on profit and growth. Alternative economies can influence what type of consumerism that we build as designers and in the next part will discuss if this can influence shifts in lifestyles to inspire and enable change.

Part 2 – Lifestyle Shifts and Post Consumerism

The consumption model in 21st century is embedded in two worlds; a physical and digital one, whether ownership or access, these constant forces create consumer mind-sets. It could be argued that consumption is used for self-discovery, learning through consuming things and making sense of our surroundings. (Gauntlett 2011) states this could also be due to how social production can create value and meaning in a way using ownership as connection. (Douglas 1979) describes the pattern of consumption in a pattern of society, that goods are natural and social. These patterns connect to choices, the decisions we make within the design of everyday lives, which have a ripple effect, spreading outwards becoming habits and lifestyle. DEFRA (2011) stated habits matter, especially within advancing sustainability, as a large majority of unsustainability behaviours are formed through habits. To interrupt consumer habits, radical change is needed towards everyday habits that have embedded a buying mind-set in physical and digital worlds. This section will draw attention to shifts that exist within societies current lifestyle changes and possibilities of post-consumption, to question if alternative buying, selling and lifestyles can carve new ways of being sustainable.

A report in 2010 by Mintel produced a survey, showing 44% of participants intended to decrease the amount of stuff they buy. In October 2015 Mintel reported that '57% of UK consumers say they always or sometimes borrow things instead of buying them and 34% attend swishing or swapping events'. A move towards engaging with needs and consuming less have resulted in the popularity of events such as the 'Library of Things' and 'Repair Cafes'. The first permanent Library of Things shop in the UK was 'Share' in Somerset who state the library is a place to 'borrow objects, share skills and connect with other people'. These experiences move away from traditional transactions, showing small groups coming together creating alternative spaces for all ages, to share and learn. Other alternatives to consumption are Repair Cafés which offer a free meeting place to repair things. Interviewing one of the founders of Brighton's Repair Café revealed how repair brings communities together to communicate, problem solve and share knowledge to build new life into objects. Victoria Jackson-White stated that “repair makes people feel empowered, which can have a knock-on effect to other things, restoration of objects and self.” (2014). The move towards reducing waste and consumption has connected with individuals to live zero waste lifestyles and use platforms to inspire a wider audience. Lauren Singer in New York created the documentary ‘Trash for Tossers’, which demonstrated in practice how she engages with a sustainable lifestyle in her everyday life. (www.trashisfortossers.com). Larger scale organisations such as Zero Waste Europe have also created a platform to empower communities to rethink their relationship with resources, through sharing knowledge and connecting through events. (www.zerowasteeurope.eu) Both examples show how individuals and communities can impact a wider society, influencing a change of habits and behaviour by engaging with people not just as consumers, changing mind-sets from consumption into collaboration.

In 2010 (Botsman and Rogers) stated the Collaborative Consumption movement utilised peer to peer networks, establishing alternatives of the hyper consumption model; producing a system based on shared usage; these economic and social changes made us assess attitudes towards consumption. The internet and social media have made it possible to globally redistribute goods, independently or within organised networks. This has resulted in new types of companies and attitudes for distribution and circulation of fashion. The Swap shop model is not new but reinvention has spread in physical and digital form, from grassroots approaches; homes to clubs, such as ‘Swap Don’t Shop’ initiative to wide spread swapping parties like ‘Swap-a Rama’ which work across Festivals. Back in 2007 larger organisations of Visa Europe and TRAID collaborated on the Visa Swap pop up shop in Brompton Road, an experiment to encourage debt-free and sustainable shopping. In advance shoppers were asked for unwanted items and awarded points on a visa swap chip card to redeem for products when the shop opened. These examples show how alternative views of exchange can cross wider audiences and organisations to be recognised as forms of value. Other exchange methods include ‘Rent the Runway’ which since 2009 has offered opportunities for renting special occasion pieces. ‘Rentzevous’ are an evolved version of renting and established the first peer to peer design fashion rental, members rent, list everyday items and test new designer pieces. These examples create social interactions through clothing without the negative effects of consumption which empowers both parties in meaningful sustainable experiences.

The Collaborative Consumption movement and Sharing Economy have been subject to mainstream, embedding itself in the same system may have assisted in decline of original motivation. The tipping point emerges when movements are scaled up and located within existing systems that focus solely on profit. The models such as Airbnb, part of the Sharing Economy is criticised for losing their original autonomy as a grassroots movement that helped ordinary people, instead now corporate products of Venture Capitalists (Gorando 2013). These points show the difference between motivations of share into sell, communicated by attaching economy to words like sharing. Although**,** current popularity of mainstream engagement could offer opportunities for designers to intervene by flipping concepts back towards authentic value and meaning, which is at the heart of why people seek new narratives and ways to engage with alternatives. (Shi 2014) discusses the relationship between counter culture and mainstream culture, exploring how dominances of corporations co-opts counter cultures but argues how the mainstream could be used as a tool for counter co-option. He states ideologies can be used as redirection and reinterpretation tools against the mainstream to selectively counter co-op some of the mainstream culture by replacing mainstream ideologies and practices for subversive ones. Future evolvement of sharing concepts for sustainability need to consider avoiding owned and static versions of sharing. Instead returning to original grass roots concepts initially recognised within collaborative consumption, reconnecting ideas towards lifestyles that promote sustainable post-consumer societies.

Part 3 – Alternative Mindsets: The Ripple Effect

The first two sections of this discussion demonstrate how design decisions and actions can ripple out to circulate within society. The influence and hold of traditional economics can change or fix creative aims, through definitions of a need for profit, scale and growth. This also demonstrates how good intentions can be turned into commodities depending on motivation. There is a need for ideas to not become static loops that dominate the way but a collage of sustainable solutions. The ripples in effect are a series of circles, inter-connecting and overlapping creating many small shifts, transitions that spread out gradually to affect the whole. The context of a ripple is within small actions that ripple outwards to eventually make waves and change the tide. Ripples are like mindsets, each effect those around you and those around them. The analogy of ripples is used to illustrate the power of combining a collage of alternative economies and new definitions of consumption which when applied in context to ripples, evolve in process to become waves that can impact designers and communities. Each acting as a ripple they overlap in areas to work together individually and collectively to encourage, enable and inspire cultures of sustainability. To create a shift in the designer's roles will involve new mind sets, acting as ripples in the whole to gradually change the system. As a discipline fashion offers the ability to include the concepts of circulation and currency in digital and physical forms. The opportunity for creating new mind-sets and encouraging alternatives need to be embedded into education and industry to release designers, freeing them from the constrains of commerciality and set definitions of fashion.

The circularity of Circular Economy could make a transition into many circles, to overlap with other sustainable solutions so to become part of a bigger whole. The Ripple Effect is made up of many circles not reliant on one element but open ended so that it can evolve in transition through use. 'Nothing Special? (Activist) Design Skills for the 21st Century' (Julier 2012) argues designers should develop open ended structures and unfinished projects reacting to change. He focuses on key areas of the relationship of exchange that cut out corporate profit motives creating new territories of design production and consumption that take control of practice. This shows how there is a need for re-defining value to create new narratives, to interrupt ideas being turned into commodities. Designers considering ways to engage with concepts of buying and selling in different forms of exchange, could alter traditional definitions and widen the diversity of engaging with fashion. Patagonia is a company that demonstrate values in their actions, which include them using advertisements encouraging customers to reduce consumption with slogans of 'don't buy this jacket'. Other campaigns include a mobile service as part of the 'Worn Wear Tour' and in 2014 a decentralized approach to their sustainability Management Department. This links with concepts discussed by (Markussen 2014) who believes intervening in everyday experiences, using all creative acts to take part in distribution. Designers and companies can become active participants; combining alternative economies and re-defined concepts of consumption to assist in presenting new ways that challenge the status quo and override disadvantages. When considering these points and examples there is a flux between solutions, wicked problems and consequences of design. (Thackara 2010) refers to this as 'space of flows' and describes 'the difference between how designers behave from designing on the world to designing in the world.' (p.214). The context and small specific changes can serve as tipping points rippling out into the bigger picture. This demonstrates how design can at times impose itself on society rather than working with society.

The Ripple Effect illustration (see Fig. 1) is designed to encourage designers to practice alternative combinations within their design process and encourage evolving outcomes, defining new territories that interrupt the current static systems within industry and society. These would then inspire more opportunities for sustainable actions which could spread out as ripples across culture to become part of the everyday.

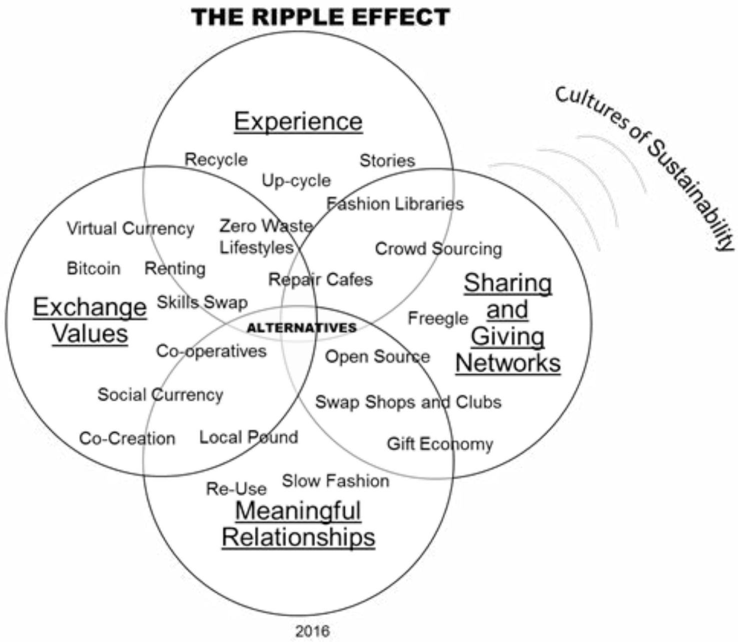


Figure 1 R.Taylor – The Ripple Effect Model is designed to combine alternative economies and sustainable cultures into a design process for fashion.

The diagram has been designed to show how The Ripple Effect works in a way that joins the concepts together creating a variety of alternatives that could be considered when designing within process and outcomes. Each acting as a ripple that evolves the whole. This illustrates how designers could benefit from individual and collaborative actions. Ideas can be combined in many ways to create a framework for social action and build collective meaning. The diagram includes examples of current alternative economies and consumption, in areas overlapping, not fixed but evolving through use and moving contexts. The ripple effect can work parallel to existing systems but are not fixed like traditional economics. Instead designed to evolve in practice and make transitions towards sustainable approaches in circulation. A suggestion is that these could explore design using the following elements: **Exchange Values**: Build alternative micro economies and systems using methods of exchange using digital or physical methods. **Experience**: Design moments of participation for (social) and (active) use. **Meaningful Relationships**: Consider the design relationship to the user, lifetime of the product and its continued journey of being passed on. **Sharing and Giving Networks**: Develop peer to peer or collective action.

As a designer and lecturer, the argument for using The Ripple Effect is how it could connect designers, education and industry towards mind-sets that are not based solely on profit, growth and scale. This enables fashion to evolve its role outside of commercial constraints, into connectors and enablers that circulate new roles for the concept of fashion. This resulting in not only more sustainable ways of working that can evolve use and relationships with fashion but ripple out into society to encourage many alternatives to inspire and enable cultures of sustainability. The opportunity within the ripple effect is to involve individuals and collectives, demonstrating how each and all can make a difference by active engagement to positively change attitudes and behaviour within consumption.

Conclusion

This paper has drawn attention to how economics, consumption and design interconnect and depending on how we each use these will contribute to our environment and social condition. The future will rely on the collaborations of people, designers and industry to think and act differently to create cultures of sustainability.

Part one the paper presented the challenges faced by creatives and independents when emerged in a system based on profit and growth, resulting in creatives and culture becoming financially led. This commodifies designer's original intentions, which weakens the intended message and limits what fashion could become. Alternative economies could enable designers to not solely rely on traditional business methods and by using a variety of alternatives could give freedom to develop their own narratives and opportunities to sustain themselves. In part two this was demonstrated by an emerging shift of alternative forms of consumption, which opens new relationships for designers and communities to connect using the circulation of fashion. This questioned how creatives can carve out new territory to build different landscapes using alternative economics. To show opportunities exist for designers to change their mind-sets by choosing alternative ways to engage with consumption that; connect, empower and encourage participation for sustainable change. The final part illustrated

The Ripple Effect and how alternative approaches to economics and consumption can be combined in practice to affect the whole, using interventions and interruptions that ripple out to encourage a culture of sustainability. This also demonstrated the importance of not relying on one model to fit all, how the future relies on many solutions and collages of sustainable cultures. Avoiding ownership of one static way as this could easily become commodified, instead exploring ideas that constantly evolve. The paper highlighted the challenges of changing a fixed system and tipping points that can turn solutions into commodities.

The contribution as a designer, lecturer and researcher will use the concepts of the Ripple Effect in practice. To show how everyday habits and behaviours can act as interventions and transitions to use alternatives and how every small action affects the whole.

References

Botsman, R., & R. Rogers. (2011) What's mine is yours. How collaborative consumption is changing the way we live. London: Collins.

Broochi., D. (2008) New Frontiers: The Cultural Dimension of Sustainability 1-33 Sustainability a new frontier for the arts and cultures.

Dessein, J. Soini., K Fairclough, G., & Horlings LG. (2015) Culture in, for and As Sustainable Development; Conclusions from COST Action IS 1007 Investigating Cultural Sustainability. University of Jyvskla, Finland.

DEFRA, (2011) Habits, Routines and Sustainable Lifestyles. Summary Report. London. (Viewed on 1/5/2016) Available from: www.sd.defra.gov.uk

Dilly, M. (2014) Patagonia's New Decentralized Approach Sustainability Management. Triple Pundit People Planet Profit http://www.triplepundit.com (viewed on 10/11/2016)

Douglas, M. (2002) The world of goods: Towards an anthropology of consumption. Vol. 6. Psychology Press.

Gauntlett, D. (2013) Making is connecting. John Wiley & Sons.

Gorenflo, N. (2013) Collaborative Consumption is Dead, Long Live the real sharing and Economy. 99 Design. www.pando.com (viewed on 27/5/2016)

Highman, (2011) Buy Bye. Viewpoint (28), (Viewed 5/11/2013)

Ingold, T. (2010) Bringing things back to life: Creative entanglements in a world of materials.

Julier, G. (2012) Nothing Special? (Activist) Design Skills for the 21st Century. Kepes 9.8

McRobbie, A. (2012) Clubs to companies: Notes on the decline of political culture in speeded up creative worlds. Cultural studies 16.4 : 516-531

MINTEL. (2011) Immaterial World Report Behaviour Finance US.

MINTEL. (2015) European Consumer Trends for 2016.

Murombedzi., J. (2013) The Sustainable Development Goals – Are we asking the right questions? Independent Research Forum (online) (viewed 22.3.15)

http://www.studiopsk.com/

Markussen, T. (2013) The disruptive aesthetics of design activism: enacting design between art and politics. Design Issues 29.1 : 38-50.

Shi, T. (2014) Mainstreaming, Counter-Co-Optation, and Depoliticization by a Counterculture. Journal of Marketing Development and Competitiveness 8.3 : 107.

www.trashisfortossers.com

Thackara, J. (2006) In the bubble: Designing in a complex world. MIT press.

CENTRE for CIRCULAR DESIGN

CIRCULAR TRANSITIONS

23 – 24 November 2016

Weave Your Own Economy: Speculative Economic Design

Monica Buchan-Ng

Abstract

This paper explores the term 'economy' within the context of future textile design, calling on designers to consider how they would change economic structures to create (or create for) an economy of their own. It outlines three methods: designing a preferable future, designing a speculative future, and designing within an alternative worldview. These are developed by the author to create a framework for economic design, in order to gain agency over seemingly insurmountable economic structures.

Introduction

What does your economy look like?

It does not have to follow a traditional definition: that of the production, consumption, distribution, and trade of goods and services (Boulding, 1981). It can be abstract or formulaic, made of fibre or thought or diagram. It can investigate a single node or outline a network. It can be ecological, critical, provocative. It can be, most importantly, your own design.

This paper works from Louis Putterman's (2001) extended definition: the systems by which humanity produces, distributes, and satisfies the requirements of human life and society. It goes beyond goods and services to include the flows of wealth and resources, methods of trade, and the fulfilment of physical, spiritual, and aesthetic human needs.

In order to instigate a paradigm shift towards a circular future, we must first democratise the study of economy to include interdisciplinary perspectives. Economics is no longer the sole domain of economist's subject to the myopias of a single discipline (Corning, 2011, and Schumacher, 1993). The textiles industry's skills in synthesis, communication, and dissemination, and the scope and proximity of design to production provide a much-needed fresh perspective.

It is when disciplines are temporarily fused in one space, when the borders disintegrate that entirely new thinking can emerge and action is catalysed (Papanek, 1984: 323). Fashion and textiles in particular are adept at collaborating; what happens when they work with political economics?

The paper outlines three methods for economic design: designing a future you'd prefer[1], designing a speculative future[2], and design within an alternative worldview[3]. From these methods, an economic design framework for the textiles industry is developed, outlining commonalities in the above approaches and possible influences, sources, and points for consideration. This framework is tested to create the author's own system: the modal economy.

Let's design our own economies.

Sustainable Textiles and Capitalism

Can sustainability[4] in textiles and fashion become the norm under our existing economic system?

It is hard to define capitalism, not in ideology but practice – not even economists have a firm grasp of its workings (Corning, 2011). Its basic tenets are formed from Adam Smith's The Wealth of Nations (1981) in which unregulated markets optimise a natural balance between the forces of supply and demand, and financial, human, and material capital is produced to supply the demand of rational, logical consumers.

A major critique of unregulated capitalism is its externalisation of natural capital (Pearce & Turner, 1990). The system does not see biological materials as something to be 'valued' in economic terms but instead a limitless resource to be plundered – after the point of 'consumption' the economic good disappears from the system with no heed for its use, disposal, or waste (McDonough & Braungart, 2002, and Boulding, 1981).

1 As exemplified through Pearce & Turner's Circular Economy (1990), ecological economics, and Fletcher's Craft of Use (2016), among others.
2 As exemplified through Dunne & Raby's Speculative Design (2011), Collett's Biolace (2012), and Gorjanc's Pure Human (2016).
3 As shown in Japanese and New Zealand Māori textile economies.
4 Sustainability itself is also subject to shifting definitions according to different perspectives (Tamagawa, 2006) however in this paper it refers to the wellbeing and longevity of both humanity and the nonhuman alike.

In this linear model textiles has, like other industries, developed little mainstream regard for the environmental and ethical cost of its actions (Fletcher, 2014).

Figure 1. Taslima Akhter. “Rana Plaza Collapse: Death of a Thousand Dreams.” Photograph, Savar, April 2013

The system itself is built to engender greed, envy, and unfairness (Schumacher, 1993). Baumol and Blinder, hardly capitalism’s harshest critics, admit that “the market tends to breed inequality, for the basic sources of its great efficiency is its system of rewards and penalties” (1994: 426). Humans and their work are redefined as dehumanised labour capital in units of time (Berardi, 2011). This manifests itself in the horrific labour abuses of the textiles and apparel industries, from the Triangle Shirtwaist Factory fire to the Rana Plaza factory collapse, as well as inhuman hours and conditions, below-subsistence wages, and removal of rights to trade unions (Fletcher, 2014). The most disturbing point is that all of these are desirable under capitalism in its pursuit for ever-increasing profits – and often justified as a choice made by such workers in exchange for the opportunity to labour (Yglesias, 2013).

Adam Smith’s capitalism is also reliant on limitless growth in order to sustain itself – as Daly (2007: 10) points out, “a world without growth becomes politically unthinkable”. This aligns strongly with fashion, whose growth is spurred by a desire for the new through near-constant cycles of purchase and discard (Fletcher, 2014). Philosopher Georg Simmel (2004) notes that our wealth becomes part of our sense of self, and as a conspicuous form of consumption; fashion allows us to reflect that identity. It is almost easier to ignore the finite limits of the environment than it is to ignore the consumerist demands of capitalism. Sustainable capitalism – that is, growth – is the opposite of ecological sustainability. Are we pitting economics against the environment and behaving as if the economy will win?

Textiles and Economics

Any field of study is subject to certain blindnesses about itself (Schumacher, 2011). Economics as a discipline has failed to address many of the problems caused by capitalist structures and though it is a varied and diverse field, from neoliberal to heterodox, many of the assumptions it is based on do not always reflect reality.

Firstly, many of its models reflect a view of human nature that is logical, predictable, and perhaps optimistic (Corning, 2011). Adam Smith believed that the rich “consume little more than the poor…in spite of their natural selfishness” (1976: 184) and although the hyper-rational *homo œconomicus* outlined by John Stuart Mill has been discredited by mainstream economics, the economic theories that are based on it remain unchecked (Corning, 2011).

Philosopher Bruno Latour (2014) also notes that economics has rebranded itself as a hard science, more mathematical than political. As science is viewed as objective, merely the discovery and translation of pre-existing nature (Latour, 1993), when economics takes on those characteristic it becomes a set of rules more powerful than any political system, to the point where many believe in capitalism more than climate change.

Thus, when there are no inbuilt moral checks on a system, the assumptions on which it is based are found to be flawed, and when the discipline itself is built to avoid outside interference, it is imperative that outside perspectives develop it through interdisciplinary collaboration. This is in part why it is so important that textiles defines for itself an economy that works in its particular interests – that is, a system that engenders ecological and social sustainability. Mainstream economics may not listen to us, but neither do we have to be ruled by its assertions.

Towards Circularity: Why Designers?

Both Schumacher (1993) and Fletcher (2014) state that it is only with diverse perspectives from all citizens that we can action the paradigm shift necessary to change our economic drives, and it is skills developed in refining and experimenting our design practice that lend themselves to the design of economies.

Scope

Design affects everything that humanity makes. It is thus responsible for the way these objects are created, for materials, use and deconstruction – responsible for the current systems of waste (Papanek, 1984), Ezio Manzini's 'worthless goods' (1992: 7), the Great Recovery's designed-in waste (RSA, 2016), and in-built obsolescence (McDonough & Braungart, 2002). This means the scope of what we can positively affect is immense. It represents a dauntingly radical opportunity, the possibility of complete restructure through design.

Dissemination, Communication

Textiles and fashion are well-versed in varied communication channels to reach their consumers, from advertising to digital media to experiential events (Dunne and Raby, 2011). They can imbue a particular brand with prestige, creating want for a concept as well as a physical garment. What happens when this is redirected to alternative economies?

This skill is directly transferable to the popularisation of alternative economies, circularity to be infused with desirability. It also gives designers the ability to determine the best (most subversive, most far-reaching, most effective) methods of communication based on the relevance to their economic alternatives.

Proximity to Markets

Critical designer Anthony Dunne (1999) notes design's unique position between 'consumer' and 'producer' – the intermediaries and translators who can talk to the needs of both parties. The designer's role as interface allows them candid communication that other disciplines lack (Papanek, 1984). This proximity to a wider public is a position to be subversive and critical without alienating audiences.

Interdisciplinarity

Designers also have close proximity to other disciplines through the supply chain, and are used to working across broad fields. They become the “team synthesist” (Papanek, 1984: 29) due to their ability to speak multiple technical languages, or part of subject-specific transdisciplinary projects (Fletcher, 2014).

A circular future cannot be found in fashion, textiles, or economics alone. It needs a synthesis of perspectives into surrounding fields like environmentalism, art, and politics. The form of interdisciplinarity proposed here is holistic: the lines break down into nodes that meld at all points.

Imagination and Synthesis

Arguably the most important of these skills is the capacity to imagine what was not there before, to create out of thin air (Dunne & Raby, 2011). Textiles and fashion can crystallise politics, culture, desire, utopia into cloth, weaving social dreams with dexterity and provocation. As Manzini states, designers are “a cultural figure in the process of creatively linking the possible with the hoped-for in visible form” (1992: 18).

Design Methods for Economies

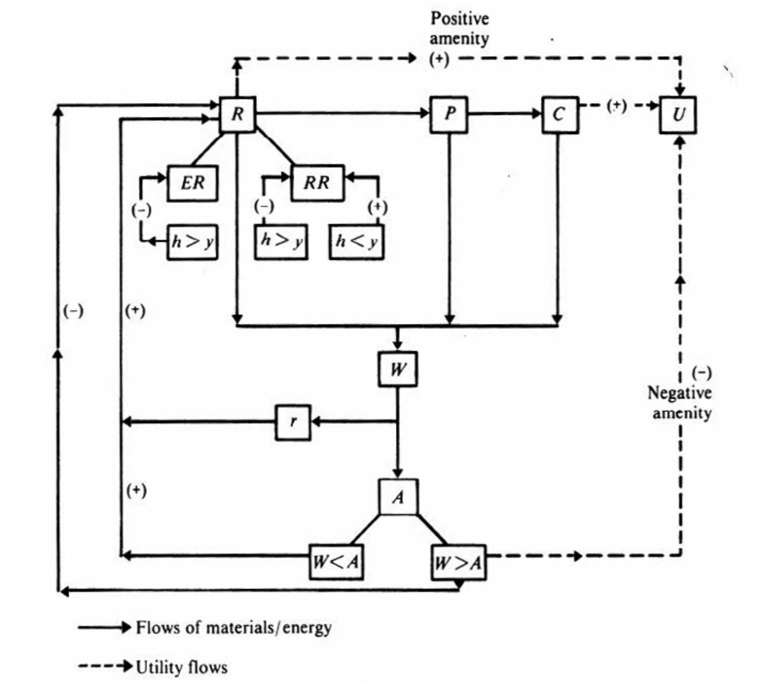
Method 1: Design a Future You’d Prefer

This describes a method to design a future economy that improves on capitalism’s faults, identifying its problematic areas and presenting a new concept or outlook. Within economics there are multiple heterodox voices that present alternatives to mainstream capitalism that designers can draw from, or designer-led systems from a more removed perspective.

Pearce & Turner’s Circular Economy

Critical of capitalism’s externalisation of ecological resources, a linear system with no acknowledgement of waste, and no in-built “existence theorem” (1990: 28) that would ensure ecological sustainability, Pearce & Turner expanded capitalism’s scope. The circular economy includes the environment as a resource with positive functions and a finite yield, giving natural resources an economic value in the hope that they will be conserved accordingly. Figure 2 outlines this embedded, closed-circuit system.[5]

5 R (natural resources) are produced (P) to become consumer goods (C) to create (U) utility and at each stage creating waste (W) . Some of this is assimilated through environmental capacity (A), and some actively recycled (r). Harvest (h), yield (y), and assimilation all monitor the sustainability of (R) use.



The circular economy.

Figure 2. Pearce & Turner. “The Circular Economy.” (1990: 40)

Ecological Economics

Economists E. F. Schumacher, Herman Daly, and Kenneth Boulding share a dissatisfaction in the mechanical, uniform approach to wealth creation with no connection or care for the ecosystem it is born from; Daly notes that economists often forget humans are also part of the environment (2007). Each brings a slightly different perspective.

Boulding re-frames existing theory with an evolutionary approach, applying evolutionary science to economic models to create a system of “ongoing ecological interaction…under constantly changing parameters” (1981: 23) that values the natural over the mechanical. He uses biomimicry also found in Papanek’s design work to create realistic economics embedded in our ecosystem.

Schumacher outlines “economics of permanence” (1993: 20) that is humanistic, organic, and beautiful. Work satisfies the workers and production is by, not for the masses. Technology is accessible, ecologically gentle, and human-centric. Land and nature is inherently sacred, used to strengthen the relationship between man and nature as well as bring forth resources. Ownership is local and decentralised.

Kate Fletcher's Craft of Use

Fletcher defined a lack of fashion creativity and expression without growth and consumption imperatives. Fashion needed an outlet for qualitative development outside of economics (2016: 271), non-market fashion activity that exists within pre-existing alternatives such as post-growth economies (2016: 62).

The Craft of Use approach outlines a deeper satisfaction drawn from existing garments, through histories, sharing economies, and attachments not possible in new purchases (2016: 225). It also enables individualisation of fashion in a homogenous global market (2016:61), and encourages sustainable models of ownership and use beyond obsolescence (2016: 183). It is an open way for people to interact with fashion as they want it to be whilst rejecting the market's myopic focus on growth and waste, creating a new narrative that's in direct contrast to the version that capitalism has engendered.

Design-led Economies

Textiles designer and socialist William Morris outlines utopian socialism in News from Nowhere (2000), in which his design background is threaded through his focus on craftsmanship and work that centres around "the reward of creation" (2000: 117). He takes the reader through all aspects of the utopia's function, from lack of government, ownership, and crime to the freedom of choice in occupation, clothing, and living. It reads not as a map for the future but a vision to work towards.

In contrast, McDonough & Braungart's Cradle-to-Cradle system (2002) describes a more practical approach for designers to utilise. Their vision is eco-effectiveness: not an environmentally aware version of business-as-usual that they describe as eco-efficient. This is based on rethinking the entire purpose of the project in question with two tenets in mind: waste as food (a circular material economy) and a respect for diversity through culture, place, need, and interdependence. Their economic growth is that of a cherry tree: followed by decay and dispersal into other organisms.

Method 2: Design a Speculative Future

Dunne & Raby's speculative design is an incredibly useful tool for economic design. Rather than trying to fix capitalism or create a working future, it fosters the creation of alternative future scenarios to "highlight the weaknesses within existing normality" (2011: 35), with speculations about the way things could be if a different path was taken. The framework provokes discussion and incites thinking through presenting possibilities – twisted, darkly humorous, painful, dystopian, optimistic – for the future.

Their critique is not always a negative response, but instead a wish for something other (2011: 34), and the space between the ‘other’ and the ‘present’ presents infinite possibilities for other realities. Rather than offer ameliorations, speculative design instigates debate through ambiguity, opening up economic or textile design to as many perspectives as possible (2011: 160).

The context for these speculations is a way to ground abstracted possibilities to our current experiences in a capitalist economy (2011: 51). Uneasy closeness to the everyday can blur the boundaries between real and fiction, distant ideal and action plan. To crystallise these alternatives, a specific system or product such as transport can give the audience or user a glimpse of the wider worldview that might have produced it (2011: 92). These synecdoches and visualisations navigate ambiguous territory between unnatural and believable (2011: 95), requiring the viewer to actively engage with an alternate scenario.

Figure 3 (left): Carole Collet, “Strawberry Noir”, 2012. Figure 4 (right): Tina Gorjanc, “Pure Human”, 2016

Carole Collet's 'Biolace'
Designer Carole Collet questions the future of textiles production for a possible year 2050 in which all manufacturing is required to be sustainable. Strawberry plants (figure 3) are reprogrammed to grow lace alongside food. Her speculative project suggests a surprisingly foreseeable production system but leaves it up to the viewer to form an opinion on its relation to the ethics of biological machination and the human–nonhuman relationship.

Tina Gorjanc's 'Pure Human'
Gorjanc's speculative project (figure 4) utilises existing legal policies by patenting human material extracted from Alexander McQueen's DNA and developing a conceptual range of leather goods made from this material (Gorjanc, 2016). The work is as much about the lack of legislation surrounding the commercial use of biological information as it is about offering new and abject forms of luxury and consumption (Paton, 2016).

Method 3: Design within an Alternative Worldview
There are pre-existing alternatives to a linear capitalist system, in which textiles economies take on different characteristics to standard global production. These alternatives and their worldviews are a refuge from Western economic hegemony, providing creative escape from the bounds of consumer demand and viability that much of current textiles design must meet (Papanek, 1984).

Māori
New Zealand's indigenous population are *tangata whenua*: people of the land, physically formed out of Papatuanuku Earth Mother. Humans, being made of the earth, cannot own it any more than they can own their mother (Shirres, 1997). They are guardians of the land for the short time they live on it, not masters (Walker, 1970).

Every life in the nonhierarchical system is imbued with mauri. For this reason, institutions such as rahui exist - a prohibition on harvesting from a particular natural resource like the ocean or forest for a season to let the natural wildlife to replenish its population. Modes of Māori[6] textile production are born of this worldview. As the Māori Queen Dame Te Atairangikaahu notes, harvesting for textiles is taught to "maintain nature's bounty through conservation and sustainable use" (Evans & Ngarimu, 2005: 11). Non-animal materials and dyes are often nurtured from seed, grown

[6] *Mauri:* life force

and processed by the weaver and synthetic materials are very rarely used, even in contemporary practice (Evans & Ngarimu).

Figure 5. Kohai Grace, "Tui Cloak". Muka, dye, copper wire, feathers, 2004.

Māori weaving, particularly cloaks (Figure 3), is an action of weaving *mauri*, *mana*[7], and *tapu*[8] into a textile that links the maker to their ancestry, to future generations, and to the land (Mac Auley & Te Waru-Rewiri, 1996: 195). Textiles production is the physical embodiment of their culture, gaining value from the material creation and its lifetime of use before returning to the earth, the antithesis to disposable consumption.

日本 Japan

A Japanese worldview manifests itself in an aesthetic and cyclical approach to sustainability. Three core concepts the Japanese aesthetic (Teiji, Ikko, & Tsune, 1993) and have immense influence on contemporary Japanese textiles design and the garment industry: wabi , sabi ,and suki , beauty found in nature and time.

Jun'ichirō Tanizaki describes the quiet, subtle, introspective joy that these forms of aesthetic beauty brings. He posits that the difference in aesthetic

7 *Mana:* power, or sovereignty

8 *Tapu:* the sacred

tastes between Japan and the West is the Japanese peace found in existing surrounds, taking satisfaction from natural life. The dark rooms of Tanizaki's ancestors have defined "beauty in shadows, ultimately to guide shadows to beauty's ends" (1977: 18) in contrast to Western needs for betterment and desires for the new.

This worldview has manifested itself in modern Japanese economics. Japan's 2000 Cyclical Society Law enacts some of these principles through the reduction of consumption and complex recycling and disposal laws. Its Extended Producer Responsibility (EPR) ennsures manufacturers and sellers retain management after purchase as they have the most materials knowledge and can make less ecologically disruptive decisions (Yoshida, 2005). One example is Teijin's four-strong ecological materials range, including ECOCIRCLE™, a "closed-loop recycling system" (Teijin Frontier, n.d.) that chemically recycles used polyester fibres without downgrading their use.

Figure 6. Akio Hamatani, "W-Orbit". Rayon, Indigo, 2010.

The Japanese worldview is clearly captured in textiles and apparel. Textile artist Akio Hamatani (figure 6) expresses the *wabi,* intrinsic beauty of materials and natural indigo, "the unadorned splendour of its colour and the cosmic brilliance within it" (as cited in Earle & Hiroko, 2011: 30). Kiyomi Iwata finds use and beauty for *kibiso,* the first ten metres produced in a silkworm's life that's usually discarded for its rough qualities in her work *Chrysalis* (2011: 37).

In the sphere of fashion commerce, multiple designers are gaining popularity for their slow, considered approach to manufacture and materials. Tezomeya offers a lifetime natural dye service for customers and treasures the muted depths and imperfections of *wabi* natural dye colour. FilMelange uses only organic materials and controls the entire production line from yarn to retail in order to utilise local knowledge and craftsmanship. Evam Eva and Niuhans' gentle approaches both use predominantly organic materials and processes to limit their impact.

A Framework for Economic Design

Across the three methods there are deep commonalities: they all start with an alternate viewpoint to capitalism, whether it is dissatisfaction or a different worldview. It is through these commonalities that a framework for economic design can be built – a tool to assist with encapsulating what it is about our existing system you may want to change and how best to express what you'd like to see instead.

The stages outlined are only a brief and simplified suggestion for the possibilities of influence, scope, and action, drawn from the examples across all three frameworks.

Framework Test: The Modal Economy.

1. Author's dissatisfactions with capitalism:

- Profit at the expense of the environment, social equality, and cultural diversity
- Money and currency as a uniform value system
- Human ability to 'own' the nonhuman
- Disparity of wealth and centralised, monolithic corporations

2. Author's influences:

- Ecological economics (Schumacher, 1993)
- Māori worldview of shared stewardship, not ownership (Walker, 1970)
- Peter Singer's ethical framework (2009: 1976)
- Sou Fujimoto's modular architecture

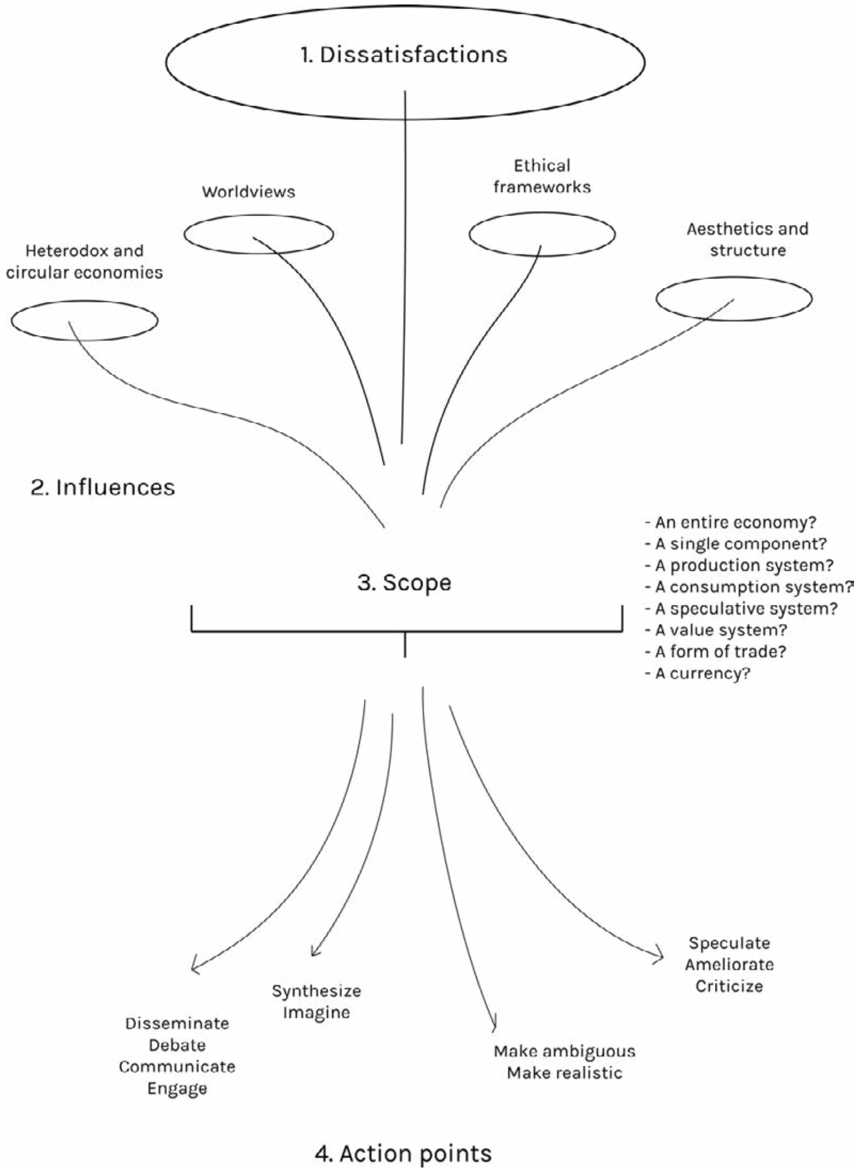


Figure 7. “A Framework for Economic Design”.

3. Scope: An entire economy, including forms of capital, exchange, value systems, and market structure. It is too difficult to isolate any one part without thinking of its implications and interdependencies on the rest of the system.

4. Action: A fictional economic system, to be disseminated through diagrams and video.[9]

The result of this test is the modal economy (figure 8): a modular system made of 5 components. The components are as follows:

- The modal economy runs on four forms of capital: nonhuman, social, cultural, and exchange.[10]
- The four capitals translate into a supporting value system: a dynamic and heterogeneous set of qualities determines economic value.[11]
- A set of five 'exchange tools' – barter, gifting, open-source, digital, and time – is officiated alongside money.[12]
- There are varying degrees of usage: ownership, borrow, temporary usage, and experiential usage. These lie on a spectrum from least to most contact.
- A network structure consists of decentralised, independent economic entities.[13]

Conclusions

This paper argues for the necessity of textiles industries to consider their economic systems: the ones we work within, and the ones we can imagine for the future. It is intended as a form of empowerment for designers: you are as important as any economist, politician, or academic and your perspectives are equally valid. It is our differences and specialities that make up the whole; we need democratic, heterogeneous input to catalyse systemic change. Economics need your synthesis, your imagination, and your ability to create desire.

---

9 For further reference see www.modaleconomy.org

10 This updates the current definition of capital to a more accurate reflection of the diverse world that the economy affects and is affected by.

11 This does not increase the value of goods and services by four, but instead takes into account the myriad of ways they impact their economic environment. Cumulative value is defined through four-way matrix that plots against dimensions from each of the four capital forms.

12 Each of these has an important role to play in forming varied economic structures and more democratic ways of funding. The methods require more time and thought than quick monetary transactions, which will have a positive impact on overconsumption.

13 This includes individuals, communities (geographical or interest-based, formal and informal), organisations, and nation states

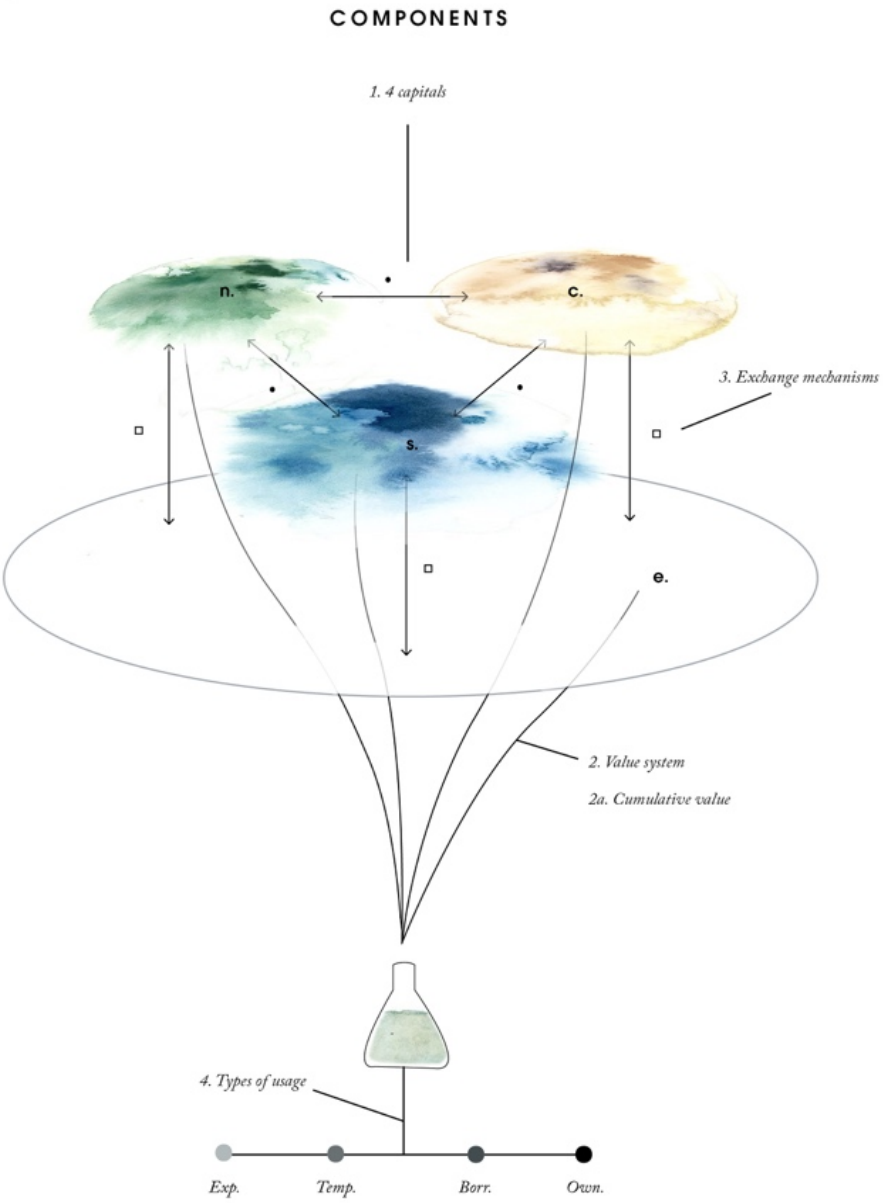


Figure 8. “The Modal Economy”.

This call to action is formed by two parts.

Firstly, the economy is too important to be left to the economists. Even heterodox economics is dominated by a homogeny of actors: all but two of the references here are white, male, and from a developed economy. There are more Williams (Baumol, McDonough, and Morris) than there are people of colour (Tamagawa and Yglesias) – and this is not even mainstream economics. Is it surprising, therefore, that the discipline finds it difficult to understand that the field is not level, that factors of power affect economic decisions (Corning, 2011), that we desperately need a diversity of perspectives?

Secondly, an economy is a structure that is more malleable than capitalism would have you believe. It is made up of us, and thus we can affect it. Whether the form of your effect is critical, ameliorating, speculative, dystopic, or a pre-existing alternative brought to prominence – those are your decisions, and diversity of response is equally important here. You can touch our economic system, to feel the flow of it across your palm – and push it just slightly *that* way around as you desire, as much as you are able. This is radical. This is incremental. This is plausible.

Find your economic Arcadias and design as if you already lived in them. Make a system you could believe in, and then believe in it.

Create an economy in which sustainable textiles flourish.

Design your own economy.

References

Baumol, W. J., & Blinder, A. S. (1994) Economics: Principles and Policy. Fort Worth, TX: Dryden Press.

Berardi, F. (2011) After the Future. Oakland: AK Press.

Boulding, K. E. Evolutionary Economics. (1981) Beverly Hills, CA: Sage.

Colette, C. (n.d.). Alive | Biolace. [online] Thisisalive.com. Available at: http://thisisalive.com/biolace/ [Accessed 18 Jul. 2016].

Corning, P. (2011) The Fair Society: The Science of Human Nature and the Pursuit Of Social Justice. Chicago: University Of Chicago Press.

Daly, H. E. (2007) Ecological Economics and Sustainable Development: Selected Essays of Herman Daly. Cheltenham: Edward Elgar.

Dunne, A. (1999) Hertzian Tales: Electronic Products, Aesthetic, and Critical Design. Cambridge, MA: The MIT Press.

Dunne, A, & Raby, F. (2011) Speculative Everything: Design, Fiction, and Social Dreaming. Cambridge, MA: The MIT Press

Earle, J. & Hiroko, W. (2011) Fiber Futures: Japan's Textile Pioneers. New York: Japan Society.

Evam Eva (n.d.). about us (concept). [online] Kondo Knit Co. Ltd. Available at: https://www.evameva.com/en/about/concept.php [Accessed 20 Sep. 2016].

Evans, M, & Ngarimu, R. (2005) The Art of Māori Weaving: The Eternal Thread. Wellington: Huia.

Filmelange. (n.d) “About Us”. [online] Filmelange.com. http://filmelange.com/about/ [Accessed Oct. 30, 2016].

Fletcher, K. (2016) Craft of Use: Post-Growth Fashion. New York: Routledge.

Fletcher, K. (2014) Sustainable Fashion And Textiles: Design Journeys. 2nd ed. New York: Routledge.

Gorjanc, T. (n.d.) “Pure Human”. [online] Tina Gorjanc. Dropr. Available at: http://Dropr.com/Tina_gorjanc/102660/Pure_human [Accessed Jul. 20, 2016].

Latour, B. “The Affects Of Capitalism”. Youtube Video, 1:00:46, from a lecture at The Royal Danish Academy of Sciences, Copenhagen, February 26, 2014, Posted By Videnskabernes Selskab, February 28, 2014, http://youtu.be/8I-Zkfshovs

Latour, B. (1993) We Have Never Been Modern. Cambridge, MA: Harvard University Press.

MacAuley, S, & Te Waru-Rewiri, K. (1996) Māori Weaving: The intertwining of spirit, action and metaphor” Textile Society Of America Symposium Proceedings, Paper 858: 195-204.

Mcdonough, W. & Braungart, M. Cradle To Cradle. (2002) Remaking The Way We Make Things. New York: North Point Press.

Manzini, E. Prometheus of the Everyday: the ecology of the artificial and the designer’s responsibility. Design Issues 9:1 pp 5-20.

Morris, W. (2000) News From Nowhere. London, GB: Elecbook.

Niuhans. (n.d.) About. [online] Niuhans.com. Available at: http://www.niuhans.com/about.php [Accessed October 30, 2016].

Papanek, V. (1984) Design for the Real World: Human Ecology and Social Change. 2nd ed. Chicago, Nl: Academy Chicago Publishers.

Paton, E. (2016) Fashion That Gets Under the Skin. The New York Times [online] Available at: https://www.nytimes.com/2016/07/19/fashion/leather-dna-alexander-mcqueen.html [Accessed Jul. 20, 2016].

Pearce, D. W., and Turner, R. K. (1990) Economics of Natural Resources and the Environment. Hertfordshire: Harvester Wheatsheaf.

Putterman, L. (2001) Dollars and Change: Economics in Context. New Haven: Yale University Press.

RSA. (2016) Designing for a Circular Economy: Lessons from The Great Recovery 2012 - 2016. London: RSA. Available at: http://www.greatrecovery.org.uk/resources/New-Report-Lessons-From-The-Great-Recovery-2012-2016/ [Accessed Jun. 3, 2016].

Schumacher, E. F. (1993) Small is Beautiful: A Study of Economics as if People Mattered. London: Vintage.

Shirres, M. (1997) Te Tangata: The Human Person. Palmerston North: Accent Publications.

Simmel, G. The Philosophy Of Money. (2004) 3rd ed. London: Routledge.

Singer, P. (2009) Speciesism And Moral Status. Metaphilosophy 40:3-4 pp 567-581.

Singer, P. (1972) Famine, Affluence, And Morality. Philosophy and Public Affairs 1:3 pp 229–243.

Smith, A. (1981:1776) An Inquiry into the Nature and Causes of the Wealth of Nations. London: Dent.

Smith, A. (1976: 1759) The Theory of Moral Sentiments. Oxford: Oxford University Press.

Tamagawa, H. (2006) Introduction. In Tamagawa, E. (ed) Sustainable Cities: Japanese Perspectives on Physical and Social Structures. Tokyo: United Nations University Press.

Tanizaki, J. (1977) In Praise of Shadows. New Haven, CN: Leete's Island Books.

Teiji, I., Ikko, T., & Tsune, S. (1993) Wabi, Sabi, Suki: The Essence of Japanese Beauty. Hiroshima: Mazda Motor Company.

Teijin Frontier. (n.d.) Ecological Materials. [online] Teijin Frontier Co., Ltd. Available at: http://www2.Teijin-Frontier.com/english/sozai/04.html [Accessed Oct. 3, 2016].

Tezomeya. (n.d.) Index. [online] Tezomeya.com. Available at: http://tezomeya.com/en/Index.html [Accessed Oct. 30, 2016].

Walker, R. (1990) Ka Whawhai Tonu Matou: Struggle Without End. Auckland: Penguin.

Wrap. (2013) Textile Flows and Market Development Opportunities in the UK. London: Oakdene Hollins.

Yglesias, M. (2013) Different Places Have Different Safety Rules and That's OK. Moneybox Blog [online] Available at: http://www.slate.com/blogs/moneybox/2013/04/24/International_factory_safety.html [Accessed Aug. 05, 2016].

Yoshida, F. (2005) The Cyclical Economy of Japan. Sapporo: Hokkaido University Press.

CENTRE for CIRCULAR DESIGN

CIRCULAR TRANSITIONS

23 – 24 November 2016

A Dematerialised Approach to Sustainable Fashion Design

Jade Whitson-Smith (University of Huddersfield, UK)

Abstract

The role of the fashion designer could be developed beyond material garment design, and their skills and influence could be applied to dematerialised approaches. Research into post-purchase garment behaviour suggests that a dematerialised approach could have a more significant impact on consumer behaviour than material-focused sustainable garment design.

Introduction

The intention of this paper is to explore the case for a dematerialised approach to sustainable fashion design. The case is made as one outcome of a study into post-purchase consumer behaviour. Examining how consumers interact with their garments post purchase is a burgeoning area of research, as consumer behaviour first needs to be understood before change is considered. This paper discusses how the results of the study support a dematerialised approach, and what this could mean for fashion design.

It is increasingly important for all disciplines to consider their impact on the environment; fashion design is no exception, as garment consumption behaviour has significant environmental impacts (Tukker & Jansen 2006). Initially, efforts into making the fashion industry more sustainable were focused on the impacts of material production (Fletcher 2008). More recently, life cycle thinking has grown in prevalence, and there is an increasing awareness of the environmental impacts that occur at other phases in a garment's life (Chapman 2010). This has increased research activity in the post-purchase phase, which is currently not well documented or understood.

Within the post-purchase phase certain behaviours have been identified as environmentally desirable. Environmentally desirable behaviours are the consumer behaviours that, based on the knowledge available, we currently understand to be preferable for the environment. Within the post-purchase phase examples include behaviours that extend the life of garments, such as repair, and behaviours that lead to re-use and recycling, such as donating unwanted garments to charity (Allwood et al. 2006). Influencing consumer post-purchase behaviour could have a significant impact on developing a circular economy in the fashion industry.

Fashion designers have begun to work with a range of design approaches to changing the impacts of the garment life cycle. Many of these approaches attempt to influence consumer behaviour; examples include design for durability, design for modularity, and design for reuse (Gwilt 2014). This is summarised in the life cycle diagram by Gwilt (Figure 1). However, despite considering the garment life cycle, these approaches often still rely on the design and production of new garments, rather than working with existing materials and garments.

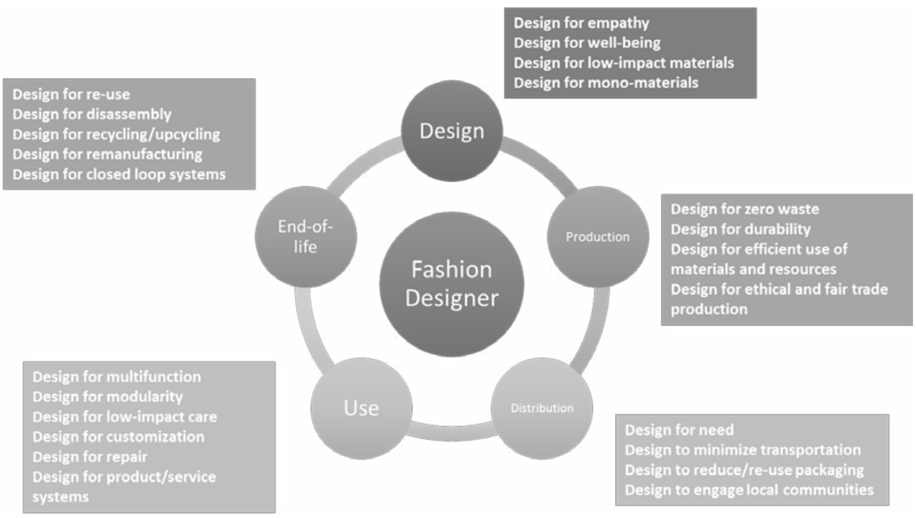


Figure 1: Design strategies focusing on specific phases of the garment life cycle (Gwilt 2014)

There is a significant opportunity to rethink how consumers behave with their existing garments. There are an estimated £89 billion worth of clothing in the collective British wardrobe (WRAP 2012). This is an existing resource that could be utilised to increase material efficacy, and develop a circular economy. In addition to existing materials, existing user practices could be nurtured and developed; but this would require a development in the understanding of post-purchase behaviour.

This paper looks to dematerialisation as a further approach to reducing the environmental impact of fashion design. Dematerialisation in product design refers to using less, or no, physical material to deliver the same functionality to the user (Thackara 2005). In the context of fashion, functionality comprises of a complex interlacing of physical and psychological needs. Within this context dematerialisation could refer to a range of practices including service design and social marketing, which promotes ideas and behaviours rather than material products (Geller 1989). Dematerialised fashion is not a new concept. Fletcher introduced the idea of Negademand in fashion in 2008, which advocated system and service design (Fletcher 2008), and 'Design to Dematerialise and Develop Systems & Services' was included in TED's strategy toolbox for textiles designers (TED n.d.). However, relatively few have adopted these strategies in their practice.

Method

The aim of the study into post-purchase garment behaviour was to gain insight into the factors influencing consumer behaviour. More specifically, the motivations and barriers to environmentally desirable behaviour were examined. The study was undertaken with a non-representative sample of women living in the UK. Seventeen women, aged between 18 and 65 years old, took part.

The study was conducted in the format of a 'wardrobe study'. There were 3 stages to the wardrobe study: a questionnaire, a wardrobe audit and a garment interview. Details of each stage are given in Table 1.

1. Pre-Audit Questionnaire	The pre-audit questionnaire collected information on the participant's demographic information (e.g. age, ethnicity, income), garment purchasing habits, and environmental viewpoint. The pre-audit questionnaire was used to categorise participants, and examine the influence of contextual factors.
2. Wardrobe audit	Following the pre-audit questionnaire an audit pack was posted to participants. Participants were asked to complete a wardrobe audit worksheet at home. This involved self-auditing the garments that they wore regularly using a wardrobe audit worksheet. The worksheet asked them to record garment type, brand, fibre content, fabric, colour, pattern, details, cut, age & damage.
3. Interview	Participants were asked to bring 6 garments from their wardrobe: i. A garment they have owned for a long time ii. A garment that they are emotionally attached to

	iii. A garment that they never wear iv. A garment that they wear frequently v. A garment that they recently purchased vi. A garment that they are likely to discard soon These garments were selected to give an overview of the wardrobe including active (frequently worn) and inactive (infrequently or never worn) garments. Participants were questioned regarding the wardrobe audit before being asked open-ended questions about each of the garments they had brought to the interview.

Table 1: The three phases of the wardrobe study method

Results

It was observed during the study that a complex, and highly individual, set of factors influence post-purchase behaviour. Personal context factors, such as age, occupation, family situation, relationship status and recreational activities, were one group of factors that had a significant influence on post-purchase behaviour. Such factors are inherently changeable, transient and varied widely between participants. Changes in any of these factors could result in changes in garment use, which may, or may not, be environmental desirable. For example, an individual who retires from work would have a change in personal context that could act as a barrier to them continuing to wear the garments they previously wore for work. This may result in discard of garments. Conversely, they may have more available time, which allows them to engage in repair.

It was interesting to note that a change in garment preference based on style was more likely to be based on personal context than the wider context of fashion change. This supports the findings of other consumer studies that suggest that fashion change does not have as much of a bearing on consumer behaviour as previously thought (Klepp & Laitala 2015; Woodward 2015).

The physical characteristics of garments did impact on consumer behaviour, but as a subsequent influence to other factors. In terms of longevity of wear, it appeared that the style of a garment did not just have to be liked; it had to be right for the context of the individual's life and physical characteristics. In some cases, garments were kept for aesthetic value, but these garments were not necessarily worn. The physical characteristics of a garment could motivate a behaviour such as repair, but only if context and personal capability were supportive.

Habits	Routinely undertaken behaviours
Context	Community expectations, social norms, material costs, laws, social context, political context, economic context, capabilities of technology
Personal capabilities	Behaviour specific skills and knowledge, availability of time, social status, income, age
Attitudes	Values, norms, beliefs

Table 2: Stern's causal variables from the Attitude-Behaviour-Context theory

Habits	Routinely undertaken behaviours
Context	Community expectations, social norms, material costs, laws, social context, political context, economic context, capabilities of technology *Personal context: occupation, family situation, relationship status, recreational activities, housing situation, physical characteristics*
Personal capabilities	Behaviour specific skills and knowledge, availability of time, social status, income, age
Garment characteristics	*Size of garment, style of garment, age of garment, condition of garment*
Attitudes	Values, norms, beliefs

Table 3: Adapted causal variables for post-purchase garment behaviour

The results of the study build on Stern's Attitude-Behaviour-Context theory (Stern 2000). This theory suggests that behaviours are influenced by four types of causal variables; habits and routines, contextual factors, personal capabilities, and attitudinal factors (Table 2). These variables are hierarchical; certain variables have more influence on the resulting behaviour than others. For example, if an individual does not have time to repair (context), they will not, regardless of the intent to do so (attitude). From the results of this study the theory was developed to make it more applicable to post-purchase garment behaviour (Table 3). Two changes were made; the context of the behaviour was expanded to include personal context factors, and another type of variable, garment characteristics, was added.

Discussion

The results of the study indicate that post-purchase behaviour is influenced by a range of variables, many of which are antecedent to the physical characteristics of a garment. This indicates that changing the physical characteristics of a garment at the design stage would only have a limited impact on influencing consumer behaviour. A range of approaches to change are needed in order to foster a more sustainable fashion industry (Fletcher 2008). However, as previously mentioned, many design strategies still aim to change the physical characteristics of new garments, rather than influencing other factors such as personal capability.

One of difficulties in using garment design to change behaviour are it is difficult to predict changing contextual factors, such as the economy, which impact on use (Bras 1997). Garments are trapped in their physical fabric from the point of construction (Chapman 2005), whereas dematerialised fashion could be responsive and adaptive dependent on changes in context. It would be very difficult to change or influence the contextual factors and personal capabilities influencing garment use, but dematerialised fashion design could develop an awareness of these factors and work with them.

Current perceptions of what constitutes fashion design need to be expanded into a more diverse breadth of approaches, including dematerialised fashion design. The findings of the consumer study support a dematerialised approach to fashion design because many of the factors influencing consumer behaviour went beyond the material characteristics of their garments. Although garment design can impact on how a consumer uses a garment, other, dematerialised approaches, may be more successful in overcoming the barriers to environmentally desirable behaviour.

It is perhaps understandable that the dominant approach in sustainable fashion design is to design garments. The approaches outlined in Figure 1 do not prescribe a garment outcome, but for fashion designers who might be accustomed to solving design problems with garment outcomes, this might be their instinctive response. Of the causal variables impacting post-consumer garment behaviour (Table 3), garment characteristics are also the easiest the change, so an obvious choice when considering influencing consumer behaviour. However, sustainable fashion design will not be able promote and maintain environmentally desirable consumer behaviour without considering the other variables influencing behaviour.

Designers in any discipline have specialised materials knowledge, skills and creativity that are needed both to understand the complexity of consumer use, and to apply this understanding with new innovative approaches to sustainable design (Mellick Lopes & Gill 2015). Utilising the designer's inherent skills for problem solving has been recognised in the field of design thinking. Design thinking uses the designer's intuitive sensibilities and methods to solve problems (Brown 2008). Apart from being creative and imaginative, designers have skills in empathy that can be applied to thinking about situations other than garment design; they are used to approaching things from different perspectives, and they are observant and notice details that others may not (Ritchie 2015). Dematerialised fashion design still values material understanding, and may be part of a mixed-approach method.

Dematerialised fashion design could include the design of workshops, experiences, events, campaigns and services. Examples include the Leeds Community Clothes Exchange, and the work of the Stitched Up cooperative in Manchester, who organise events such as repair cafes and film screenings (Van Der Zee 2014; Stitched Up n.d.). Dematerialised fashion design could utilise existing and emerging technologies, such as mobile technology apps, to rethink consumer interactions with garments. Such technologies have changed the way individuals experience 'products' in industries such as film and music. Dematerialised fashion could also build on the sharing economy; clothes exchanges, peer-to-peer resale, and garment rental schemes are examples of existing garment 'sharing' that increase material efficiency.

Fashion designers may find it challenging to move away from the design of garments. Many designers will be motivated by the physical characteristics of garment design, the sensory experience of working with fabric, aesthetics and a sense of accomplishment from the creation of a physical output. Fashion design education also encourages this focus on the physical garment as the assessed outcomes of projects are often physical garments (Grose 2013). Expanding the definition of fashion design needs to be pervasive throughout the industry, including fashion design education, in order to work towards creating a circular economy.

Conclusions

Despite the prevalence of life cycle thinking in sustainable fashion design, the design of new garments remains the dominant strategy in consumer behaviour change. In order to change consumer behaviour factors beyond the physical design of garments needs to be addressed. Designers working within sustainable fashion design could be applying their skills in alternative ways to work with existing garments and behaviours; dematerialised fashion design is one way they could do this.

Not all fashion designers will be attracted to working in a dematerialised way, and it would not be appropriate for all fashion designers to stop designing garments. But, it is necessary and timely to expand the thinking about sustainable fashion design beyond simply the design of garments.

This paper recommends that further research needs to be undertaken to investigate how dematerialised fashion design may be applied in practice, and to determine its impact on consumer behaviour.

References

Allwood, J. et al. (2006) *Well dressed? The Present and Future Sustainability of Clothing and Textiles in the United Kingdom*. Cambridge

Bras, B. (1997) *Incorporating Environmental Issues in Product Design and Realization.* Industry And Environment, 20(1), pp.1–19.

Brown, T. (2008) *Definitions of Design Thinking*. Available at: http://designthinking.ideo.com/?p=49 [Accessed February 2, 2016].

Chapman, A. (2010) *Mistra Future Fashion – Review of Life Cycle Assessments of Clothing*. MISTRA, Sweden.

Chapman, J. (2005) *Emotionally Durable Design*, London: Earthscan.

Earley & Politowicz (2010) TED's Ten: 9 - Design to Dematerialise and Develop Systems & Services. Available at: http://www.tedresearch.net/9-dematerialise-and-develop-systems-services/ [Accessed November 2, 2016].

Fletcher, K. (2008) *Sustainable Fashion & Textiles. Design Journeys*., London: Earthscan.

Geller, E.S. (1989) *Applied Behavior Analysis and Social Marketing - an Integration for Environmental Preservation.* Journal of Social Issues, 45(1), pp.17–36.

Grose, L. (2013) *Fashion Design Education for Sustainability Practice: Reflections on Undergraduate Level Teaching*. In M. A. Gardetti & A. L. Torres, eds. Sustainability in Fashion and Textiles: Values, Design, Production and Consumption. UK: Greenleaf Publishing.

Gwilt, A. (2014) *A Practical Guide to Sustainable Fashion*, London: Fairchild Publications.

Klepp, I.G. & Laitala, K. (2015) *Consumption Studies: The Force of the Ordinary.* In K. Fletcher & M. Tham, eds. Routledge Handbook of Sustainability and Fashion. Oxon: Routledge, pp. 121–130.

Mellick Lopes, A. & Gill, A. (2015) *Reorientating Sustainable Design: Practice Theory and Aspirational Conceptions of Use.* Journal of Design Research, 13(3), pp.248–264.

Ritchie, J. (2015) *The What, Why and How of Design Thinking*. Unpublished.

Stern, P.C. (2000) *Toward a Coherent Theory of Environmentally Significant Behavior.* Journal of Social Issues, 56(3), pp.407–424.

Stitched Up, Stitched up - About. Available at: http://www.stitchedup.coop/about/ [Accessed November 4, 2016].

Thackara, J. (2005) *In the Bubble: Designing in a Complex World*, Cambridge: MIT Press.

Tukker, A. & Jansen, B. (2006) *Environmental Impacts of Products: A Detailed Review of Studies.* Journal of Industrial Ecology, 10(3), pp.159–182.

Woodward, S. (2015) *Accidentally Sustainable? Ethnographic Approaches to Clothing Practices.* In K. Fletcher & M. Tham, eds. Routledge Handbook of Sustainability and Fashion. Oxon: Routledge, pp. 131–138.

WRAP (2012) *Valuing Our Clothes : The Evidence*, Available at: http://www.wrap.org.uk/content/valuing-our-clothes.

Van Der Zee, B. (2014) *Swap till you drop: why a clothing exchange beats London fashion week.* The Guardian. Available at: https://www.theguardian.com/lifeandstyle/2014/sep/15/swap-till-you-drop-clothing-exchange-beats-london-fashion-week.

Mundane Matters: Laundry, Design and Sustainability

Emma Dulcie Rigby (University of the Arts London, UK)

Abstract

Laundry is known to be a highly resource demanding and polluting practice. Many approaches to reducing impacts from laundry do not recognize the diverse reasons why laundry is carried out. Drawing on a subset of findings from a longitudinal laundry study this paper considers design opportunities to challenge laundry behaviours.

Introduction

Hidden away from public view and set within the privacy of the home, laundry has been consistently documented as a highly resource demanding stage in a garment's lifecycle (Allwood *et al*., 2006; Fletcher, 1999; Franklin Associates, 1993). Major impacts arise from burning fossil fuels to generate the electricity needed to heat the water and air in washing machines and tumble dryers (Maden *et al*., 2007). Further to this, laundering clothes is a direct cause of microfiber pollution in aquatic environments (Bruce, *et al*., 2016). While the challenges of laundry have become more widely documented in recent years (WRAP, 2012), in the field of fashion and textiles design research, laundry remains a largely underexplored area with exception to Fletcher (2008:74-92; 2001; 1999) and Earley and Fletcher (2003).

In considering the role of design in support of a circular economy and principles of resource efficiency, this paper considers some of the challenges and opportunities in designing to mitigate against impacts from laundry. It does so through examining how the routines and behaviours which help to construct laundry practices are influenced by garment design. In particular, it draws from a one-year laundry study to explore elements that influence laundering frequency and elements that influence laundry processes and methods.

Mundane Matters

Laundry is a mundane, habitual and highly routinized social practice. At the same time, it is an inconspicuous act of resource consumption that occurs in the private and domestic realm. As a collective activity, it annually uses up massive quantities of finite resources such as energy and consumes valuable fresh water, and in the process, contributes towards greenhouse gas emissions, global warming and climate change. Within a garment's lifecycle, continual washing and drying is estimated to account for 25% of the overall carbon footprint (WRAP, 2012). Beyond resource use, laundering can also be linked to a range of other environmental impacts such as solid and hazardous waste generation, air and water pollution including eutrophication, toxicity impacts and biodiversity loss (Bain *et al*., 2009:6).

Of particular significance to resource flows, a growing body of research has shown that clothes washing also causes massive scale microfiber pollution in oceans and other aquatic environments across the globe (Browne, *et al*., 2011). Synthetic microfibers (a subcategory of microplastics) derived from materials such as polyester, nylon, acrylic etc., are drawn out of clothing during washing machine cycles and then travel to waste water treatment plants where a large amount are removed but a significant proportion flow into marine habitats (Browne, *et al.,* 2011). A single polyester jacket can shed between 26 mg to 4,300 mg of microfibers per wash, depending on the wash cycle, jacket type and garment age (Bruce, *et al.,* 2016:40). Amongst other reasons, this is significant because synthetic microfibers are easily able to enter the food chain due to their size.

In addition to the embodied impacts of laundering as a process, it is also implicitly connected to overall garment quality, durability and lifespan (WRAP, 2015). How a garment is cared for, for example, how it is washed, sorted and separated from other garments, what temperature it is washed at and how it is dried all have varying degrees of impact on not just the fibre quality of a garment, but also the colour fade and overall shape and structure of the garment during active use. The more a garment is washed, the more exposed it is to degradation. Highest damage risks come from when garments are not sorted and separated appropriately, and when garments are put into inappropriate cycles. However, despite the risk of damage, most people do not spend much time sorting their laundry. An Ipsos MORI survey of 7,086 adults in the UK found that only 28% always sort their washing between those that require a longer wash and those that do not and only 36% always sort between hot and cold washes (WRAP, 2012).

As a social practice, the scale of impact from clothes washing is closely connected to individual laundry routines and behaviours within the home, however previous research into reducing impacts from laundry has been cautious to directly explore this due to complexities in social behaviours (Bain, *et al*., 2009). As such, many initiatives that seek to reduce impacts from laundry focus on technology efficiency and small scale changes in behaviour - rather than possibilities for challenging the more deeply rooted social and cultural reconstructions that laundry is understood to represent (Shove, 2003). From the perspective of fashion and textiles design, options to challenge laundry behaviour on deeper social and cultural levels emerge when laundry practices are better understood in terms of the reasons why people launder.

In research on laundry conventions and cleanliness, Jack (2013) concluded from a study in which 31 people were tasked to go without washing their jeans for three months, that shifting collective conventions is more effective for making environmental savings than challenging individual routines. Jack (2013:20) found that alternative laundry practices developed as the new routines of not washing set in and further noted that recognition should be given to 'individuals ability to embrace awareness and reflexivity in the reproduction of consumption practices'. Further to this, in a different piece of research that focuses on sustainable clothing design, Laitala and Boks (2012) argue that there is great potential for designing clothing to encourage more sustainable use and laundry, however more innovation is required into clothing design and research on attitudes, values and motives linked to laundry behaviour.

Longitudunal laundry study

Reducing the frequency of laundry by wearing clothes for longer between washes would help to reduce resource consumption and the associated impacts (Bruce, *et al*., 2016; WRAP, 2012). To further understand how fashion and textiles design can challenge the construction of laundry practices and related behaviours, further research into the connection between garment design and laundry behaviour is needed. A one-year laundry study was set up to explore how and to what extent the design characteristics of eight garments, as visualised in Table 1 and referred to as laundry probes, influenced the way in which they were laundered. The eight garment designs were developed from previous research by the author (Rigby, 2010) and duplicated to create two sets as a basis for comparison. The study involved sixteen female participants, eight located in Bristol and eight located in

London. The participants were asked to wear the study garments as and when they wished without special consideration or treatment, and to record the use and laundry of each in a diary whilst also comparing it to a similar garment they already owned. The participants were recruited from responses to notices placed in online platforms, community noticeboards and existing networks, and selected after completion of a questionnaire to ensure the study garment they would be given was appropriate to their lifestyle and clothing preferences. Each participant was given an information sheet about the study which explained the intention to understand more about laundry behaviour, however the specifics of linking laundry behaviours to sustainable design were not mentioned to avoid bias in behaviour. The identity of each participant in the study was anonymised through the use of a data coding key. The results discussed here draw on a subset of findings from the study where there is a dual focus on elements that influenced laundry frequency and elements that influenced laundry processes and methods. A qualitative and empirical approach to analysis is used to enable focus on the experiential and sociocultural aspects of laundry as a practice which are less accessible through quantitative and statistical analysis.

Sensing cleanliness

Physical elements as motivators to launder were chiefly associated with senses, i.e. when the garments appeared visibly dirty or developed an odour. Freshening garments emerged as one of the key motivators to launder; it was connected to confidence and satisfaction. This is in keeping with wider laundry behaviours beyond the study, in which research shows that 75% of adults put items in the wash to freshen them, even if not visibly dirty (Caines, 2011). Whilst this is unsurprising, it is significant to note that despite how often a garment was worn, when garments did not appear dirty because soiling was hidden by colour, texture or grain of the material, and when they did not develop odours, perhaps because they were not in direct body contact, laundry was less likely to be performed. Responses to sensory perceptions were underpinned by feelings, as B5 commented ‘when it didn’t look dirty I felt better about not washing it’. This indicates that how cleanliness in clothing is understood is subjective and relational to how garments are perceived. It also suggests that it is a concept which evolves and redevelops across cultures and generations. This is supported by the view of Douglas (1966:8) who states ‘our idea of dirt is compounded of two things, care for hygiene and respect for conventions. The rules of hygiene change, of course, with changes in our state of knowledge’.

Image	Description	Image	Description
	Navy blue sleeveless shirt with a centre front opening made from waxed cotton.		Cream three quarter length sleeve top made from merino wool jersey.
	Navy blue apron with adjustable popper fastening, made from wax cotton.		Navy blue trousers, dropped crotch point and relaxed fit on waist, made from merino wool serge and half silk habotai lining.
	Black skirt short in length with a concealed pocket and elasticated waistband, made from wool tweed and lining with silk habotai.		Cream hand knit tank top made from Wensleydale wool.
	Navy blue and black wrap around cardigan made from boiled wool jersey with a ribbon made from duchess silk satin, raglan sleeves.		Black three quarter length dress with cotton funnel neck, made from duchess silk satin and lining with silk habotai.

Table 1: Laundry probes

Aesthetics and longevity

During the study, laundry was not only influenced by concepts of cleanliness - the aesthetic of a garment also played a large part in how often it was laundered. For example, when a garment was no longer physically pleasing because it had stretched, a seam had twisted or bodily imprints were left in the material, it was more likely to be washed because it looked 'not quite right'. Participant B8 commented, 'sometimes I just washed it when it stretched a bit and I wanted to make it feel tight again', while participant B1 noted, 'I wash it mainly because it loses shape more so than anything else. I know it sounds weird but I don't like it when garments begin to sag in places. In this top it begins to sag in the elbows and through the width of the body…'. Participants laundered to remove traces of use and restore their garments to near original condition. In contrast, when garments did not appear 'worn' and retained their aesthetic they were less likely to be washed. Similar findings were reported by Gwilt *et al*. (2015:128) in a recent survey with focus on practices of care where garment maintenance was found to be influenced by a desire to keep garments in their original conditions. This suggests scope for designers to focus on working with materials, styles and silhouettes that resist stretch and preserve the original shape and fit of the garment.

Perception and Association

Motivators for laundry processes were easier to understand than motivators for laundry frequency because they are more pragmatic and rooted in convenience, and mainly responded to the physical elements of the garments. Fibre properties and material characteristics of a garment was one of the chief physical motivators to instigate or avoid particular laundry processes. In the study, the garments made from waxed cotton (aprons and shirts) and the sateen silk dress were most obviously affected by this. They were unsuitable for machine washing and tumble drying as the shirt and apron had a wax coating, and the dress was made from delicate silk, and during the year they were not machine washed. Indeed, the also *looked* unsuitable for machine washing. The materials they were made from looked specific and occasional and less likely to be used for casual every day dress.

Yet in contrast to this, the wool skirts in the study were also unsuitable for machine washing because of the particular quality and weave of the wool they were made from. However, the material looked less occasional and more suited to casual every day wear, and participant L2 did machine wash it, which she explained that this was linked to habit. Likewise, participant B8 machine washed a wool jersey cardigan which was hand wash only.

It was made from wool jersey and was also more suited to every day dress than occasional dress. Yet, it is likely that if these materials looked more occasional, as did the waxed cotton garments and silk dress, the participants would have made a clearer mental distinction between more suitable laundry processes, and would have been inclined to not machine wash them and to seek alternative methods. As in the cases of the participants who were given the wax cotton garments and silk dresses, their alternative laundry routines for these garments led to lower impact laundry routines in relation to the study garments. This insight from the study evidences that the way in which materials and textiles are perceived and associated plays a significant part in the way garments are laundered. This makes a case for further research into the relationship between garments, the materials they are made from, how materials are perceived and how material perception is linked to laundry knowledge. It also highlights opportunities for designers to innovate around perceptions of material types of encourage alternative laundry practices. As discussed earlier, Jack (2013) found credit should be given to the ability of alternative laundry practices to develop when existing routines are challenged.

Conclusions

Transitioning towards a circular economy requires systemic changes in the way resources are managed and used in the fashion and textiles industry. Clothes laundry plays a significant part in this scenario as an inconspicuous yet highly resource demanding practice. Despite this, research into how designers can address this issue has been limited and many approaches to reducing impacts from laundry do not recognise the diverse range of social reasons why laundry is carried out. This paper has taken a closer look at laundry practices and shows that when laundry is understood in a one-dimensional sense as a process for removing dirt and odour, strategies to reduce environmental impact can overlook some of the major elements that shape laundry practices and influence laundry behaviour. Likewise, in focusing exclusively on the consequences of laundering in terms of impacts, attention bypasses the nuanced details of human behaviour and the reasons why laundry routines evolve in environmentally significant directions (Shove, 2003). Thus, the way in which laundry is conceptualised bears great influence over the tactics taken that seek to reduce impact, and by extension approaches towards design for sustainability.

To conclude, this paper has discussed three key areas where designers can engage more closely with laundry behaviours to develop design ideas that are more relational to laundry as an integrated and embodied social practice. In the first instance, it has highlighted that cleanliness of clothing is individually constructed and closely connected to the design of a particular garment. This suggests opportunities for designers to work to challenge conventions associated with cleanliness. For example, the idea of using design to intervene in laundry practices was explored by Earley and Fletcher in the 5 Ways Project (Earley and Fletcher, 2003). They developed the No Wash top which was designed to never be laundered and responded to laundry as a cultural convention. The No Wash top conceptualised a design idea for sustainability and challenged notions of cleanliness and appropriately clean clothing.

Secondly, this paper has discussed how laundry behaviours are influenced by a desire to remove evidence of wear and use, and to preserve a sense of newness. Here there exists potential for designers to innovate around aesthetics which retain the original shape, finish and fit of a garment, or in contrast, to innovate around aesthetics which constantly change through use. This could be achieved through greater use of materials that develop a patina through use, for example using wax finishes on certain garments, or it could be developed through more experimental techniques in pattern cutting everyday garments that respond to movement. Finally, this paper has discussed material perception and how this is linked to laundry knowledge. It has shown how laundry practices are influenced by how a material is understood, and how laundry 'know-how' becomes part of laundry practices. In doing so, this insight provides further opportunities for designers and retailers to innovate around perceptions of material types to encourage alternative laundry practices. This might involve focused communication campaigns beyond care labelling to engage customers more closely with the materials that their clothes are made from. Future research is recommended into areas that seek to understand more about complex laundry behaviours and how design might be used to further challenge laundry conventions.

References

Allwood, J., Laursen, S., Malvido De Rodriguez, C., & Bocken, N. P. (2006) *Well Dressed? The Present and Future Sustainability of Clothing and Textiles in the United Kingdom*. Cambridge: University of Cambridge Institute of Manufacturing.

Bain, J., Beton, A., Schulze, A., Dowling, M., Holdway, R. and Owens, J. (2009) *Reducing the Environmental Impact of Clothes Cleaning*. London: Defra.

Browne, M., Crump, P., Niven, S., Teuten, E., Tonkin, A., Galloway, T. and Thompson, R. (2011) 'Accumulations of Microplastic on Shorelines Worldwide: Sources and Sinks', *Environmental Science & Technology*, 45(21), pp. 9175-9179.

Bruce, N., Hartline, N., Karba, S., Ruff, B., Sonar, S. and Holden, P. (2016) 'Microfiber Pollution and the Apparel Industry', University of California Santa Barbara, Bren School of Environmental Science & Management. [Online] http://brenmicroplastics.weebly.com/uploads/5/1/7/0/51702815/bren-patagonia_final_report.pdf (Accessed 4.9.2016).

Caines, R. (2011). *Laundry Habits – UK – November 2011*. Mintel. [online]. http://academic.mintel.com/sinatra/oxygen_academic/search_results/show&/display/id=575171 (Accessed 4.9.2016).

Douglas, M. (1966) *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*, London: Routledge & Kegan Paul.

Earley, R. and Fletcher, K. (2003) *5 Ways*. Available at: http://www.5ways.info/docs/intro/intro.htm (Accessed: 4.9.2016).

Fletcher, K. (1999) 'Clean and Green?', *EcoDesign*, 7, 34-36.

Fletcher, K. and Goggin, P. (2001) 'The Dominant Stances on Ecodesign: A Critique', *Design Issues*, 17(3), pp. 15-25.

Fletcher, K. (2008) *Sustainable Fashion and Textiles: Design journeys*. London: Earthscan.

Franklin Associates. (1993) *Resource and Environmental Profile Analysis of a Manufactured Apparel Product: Women's Knit Polyester Blouse.* Washington DC: American Fiber Manufacturers Association.

Gwilt, A., Leaver, J., Fisher, M. and Young, G (2015). 'Understanding the Caring Practices of Users', *Product Lifetimes and The Environment: Conference Proceedings.* Nottingham Trent University, Nottingham, 17-19 June, 2015. Nottingham: Nottingham Trent University: CADBE. 125-129.

Jack, T. (2013) 'Nobody was Dirty: Intervening in Inconspicuous Consumption of Laundry Routines', *Journal of Consumer Culture*, 13(3), pp. 406-421.

Laitala, K. and Boks, C. (2012) 'Sustainable Clothing Design: Use Matters', *Journal of Design Research*, 10(1/2), pp. 121-139.

Madsen, J., Perumalpillai, B., Selby, S. and Aumônier, S. (2007) *Mapping of Evidence on Sustainable Development Impacts that Occur in the Life Cycles of Clothing: A Report to the Department for Environment, Food and Rural Affairs*. London: Defra.

Rigby, E. (2010). *Clean by Design. Investigating the Relationship Between Design, Consumer Behaviour and Laundry: A Social and Practical Study*. Masters dissertation. London College of Fashion, University of the Arts London.

Shove, E. (2003) *Comfort, Cleanliness and Convenience: The social organization of normality*. New York: Berg.

WRAP (2012) *Valuing Our Clothes: The Evidence Base* [Online]. Available at: http://www.wrap.org.uk/sites/files/wrap/VoC%20FINAL%20online%202012%2007%2011.pdf (Accessed: 4.9.2016).

WRAP (2015) *Clothing Durability Report* [Online]. Available at: http://www.wrap.org.uk/sites/files/wrap/Clothing-Durability-Report-final.pdf (Accessed: 4.9.2016).

Acknowledgements

This research was carried out as part of the authors doctoral study, undertaken at the Centre for Sustainable Fashion, London College of Fashion. It was supported with funding from London College of Fashion Artscom Progressive Studentship Award and Buckinghamshire New University.

An Exploration of the Sustainable and Aesthetic Possibilities of 3D Printing onto Textiles as an Alternative to Traditional Surface Decoration

Kirstie Burn, Samantha Vettese (Edinburgh Napier University, UK), John Shackleton (University of Glasgow, UK)

Abstract

Embellishment, in a fashion and textile context, can be considered an extraneous decorative process that has a significant detrimental impact on the environment. However, aesthetic and cultural theories, in addition to consumer appeal, show that it is a worthwhile endeavour. This PhD project intends to address the ecological impact of the waste that can be caused by discarded, embellished textiles by creating a 3D-printed alternative, utilising biodegradable cellulosic materials that may return to the soil as 'food'. The outputs were also tested for their strength of adhesion, in addition to their potential visual attributes. Initial findings from the research at this stage show that there is potential to develop this technique, aesthetically and structurally, for wider use within the mainstream fashion and textiles industry.

Introduction

Textile embellishments are a small percentage of a finished product yet contribute a significant ecological impact. They can draw on the mining industry (metals for zips, poppers and electroplated studs for jeans) and the oil industry (plastic buttons, sequins and beads), with their associated impacts on global warming, land degradation, human health, air emissions and toxic contamination of water. In addition to this, at the end of a garments life cycle, in large scale textile recycling plants, items must be free of all trims to facilitate reprocessing. They can be difficult and labour intensive to detach or remain on the garment meaning that otherwise recyclable yarns or fabrics are passed by and sent to landfill.

According to Fletcher and Grose (2011), sustainably led innovation involves using renewable source materials and rapidly renewable fibres; materials with reduced processes such as water, energy and chemicals, fibres produced under improved working conditions for growers and processors and materials produced with reduced waste such as biodegradable and recyclable fibres from both consumer and industry waste streams.

From this standpoint, this research looks at an alternative approach to both the way that we embellish textiles and the materials used, at this time concentrating on the renewable source materials of PLA or Polylactic Acid – a biodegradable polymer derived from vegetable starch (Fletcher and Grose, 2012).and Tencel. This is a low-impact, regenerated cellulose fibre made from wood pulp. The raw cellulose is dissolved directly in an amine oxide solvent, substantially reducing pollution levels in water. It requires no bleaching prior to dying and is coloured with low chemical, water and energy techniques. 3d printing also offers an approach with little waste, which is less labour intensive than hand sewing. The full potential of this technique, in a textile context, is yet to be fully exploited.

Although 3D printing is occasionally used in a fashion context at this time, it is usually for 'novelty' rather than to approach any issues around sustainability in the textile industry. In addition to this, Tencel is utilised by several companies, including Marks and Spencer, H&M and Esprit, but they have not made enough of an impact to displace the use of more unsustainable fabrics such as cotton. This project intends to look at new ways to use Tencel and PLA used as embellishment on the textile. This project also utilises woven, non-woven and knitted Tencel, all provided by Lenzing. While most composite materials are not ideal, PLA and cellulose both biodegrade in a way that provides eventual nutrients to the soil. In addition to this, 3D printing is being used in a particular way, to provide the appearance of laborious hand printing and sewing techniques with the controllability of digital printing. There is no waste in the materials used in 3D printing – the equipment uses just what it needs and there is no water used in the process.

The embellishment and the material on the whole product would therefore be generally more sustainable for a number of reasons, as highlighted. Through this practice led investigation, there will also be emphasis on the technique's aesthetic appeal, usability and structural integrity of the processes, so that it may be a real alternative to current provision and practices. This research forms part of a wider ranging PhD study where it is intended that the visual success, usability, laundering and longevity will be tested through observational methods looking at designer and consumer responses to prototypes and the new methods of embellishment in this study.

The sustainable credentials of the processes and materials available, while not without challenges, show promise in their lesser environmental impact, compared to traditional provision. Material choices, particularly Tencel fabric and PLA, 3D printed onto it, are not only possible with the techniques developed, but, if widely adopted, have potential to add to circularity to fashion and textile design practice. An understanding of the concept of the circular economy has been crucial to the research, with the fashion industry making efforts to make its profile more social and environmentally responsible. The popularity of ‘Cradle to Cradle’ and closed loop fibers (Black, 2013) has become ever more profound in the industry. Early results from this research show that the technique could readily be adopted by textile designers without a significant change in their skills, while the visual results could either relate to their current designs, or innovatively push them forward.

It has become apparent that to enable the concept of McDonough and Braungart’s ‘Cradle to Cradle', all industrial products must be designed to conform with one of their next life cycle approaches – bio gradable or industrial [recycling]. (Fletcher, 2014) The thoughts of many is that these approaches are currently blocked by technology barriers and waste management (Black, 2013) The key challenges to the biodegradable approach in the fashion industry is that all components including the thread need to adhere to this. (Fletcher and Grose, 2012). This aspect triggered the research as embellishment is traditionally made with various materials. Cradle to Cradle need to enable new forms of thinking to necessitate sustainability. (Fletcher, 2014) Behavior may take time to change however developments within the field will enable these. (Black, 2013) The potential creation of this process would facilitate circular economy design allowing for changes to behavior and thinking patterns within industry.

Literature Review

As a response to many of the challenges in the relationship between fashion, textiles and sustainability, such as their impact on 'climate change; adverse affects on water and its cycles; chemical pollution; loss of biodiversity; overuse and misuse of non-renewable resources; waste production; negative impacts on human health and damaging social effects on producer communities' (Fletcher and Grose, 2012:13), it could be concluded that minimising processes that are not completely utilitarian, including 'embellishment', 'decoration' or 'ornament', would be a sensible reaction. The 'correctness' of minimalism and disdain for 'superfluous adornment' has been debated throughout the history of fashion and design, even before its unsustainable attributes were considered or understood. In his lecture 'Ornament and Crime' in 1910, Adolf Loos went as far as to say that 'the evolution of culture marches with the elimination of ornament from useful objects' and that it was 'a crime to waste the effort needed to add ornamentation, when the ornamentation would cause the object to soon go out of style'. Loos talked about the 'immorality' of ornament, describing it as 'degenerate' and its suppression as necessary for regulating modern society. (Loos, 1998) These tenets (and the phrase 'form follows function' by American architect Louis Sullivan in the 1930s) were followed throughout Modernism, by designers and schools including the Bauhaus. The influential Functionalist industrial designer Dieter Rams went further with his phrase ‘less, but better’ and in his iconic ‘ten principles for good design’, he says that good design is ‘as little design as possible’. (Rams, 2014)

This research begins with the stance that to embellish, in a fashion context - particularly decorative print and structural embroidery techniques - are positive cultural and communicative devices, for designers and the public who choose to buy and wear such decorative items. Decoration can also add to emotional attachment between the owner and the garment and therefore extend its lifespan.

McRobbie (1998:6) defines fashion as ‘the application of creative thought to the conceptualisation and execution of items of clothing so that they can be said to display a formal and distinctive aesthetic coherence which takes precedence over function’. This aesthetic factor is often the decorative elements added to the functional garment shape including printed motifs, patterns or embroidered shapes. If one follows the rationale that fashion and clothing are ‘forms of nonverbal communication' and that fashion can be ‘semiotically’ read (Barthes, 1983) to ‘make sense of the world and the things and people in it, that they are communicative phenomena; that they imply that the structured system of meanings, a culture, enables individuals to construct an identity by means of communication,’ (Barnard, 1996 : 32) it would follow that ‘symbols’ and ‘motifs’, provided by print and embellishment, are among the most direct devices. Printed or embroidered motifs and added symbolic ‘meaning’ can, ‘challenge or contest existing class and gender identities as a way in which people may transform their circumstances and conditions’. (Barnard, 1996:127) Norman’s research talks about the affirmative attributes of ‘fun and pleasure’ in design. (2004:101)

This pleasurable, obviously ‘prettified’ aspect of fashion decoration can be seen as ‘trivial’ and ‘irrelevant to serious minded persons.’ (Wilson, 1992:34)

Norman breaks down the 'fun' of aesthetic objects as being 'enticing by diverting attention; delivering surprising novelty; going beyond obvious needs and expectations; creating instinctive responses; espousing values or connections to personal goals; promising to fulfil these goals; leads the casual viewer to discover something deeper about the experience thy would normally have with a designed object and fulfilling these promises.' (2004 : 114) Well designed embellished garments can create a combination of 'surprising novelty', that are 'useful and believe[d] to be beautiful' (Morris, 1880) and are treasured because of their personal meaning.

Embellishment eschews 'novelty' and personal meaning, and, as it is natural for people to 'change their minds' and mediate their identities through their designed possessions, garments can, therefore, be discarded. It is this projects intention to provide a 'circular' solution, through the use of low energy processes and biodegradable materials where 'waste equals food' (Braungart and McDonough, 2008:92) This approach mirrors Braungard and McDonough's 'cradle to cradle' 'manifesto'. In their own project with a fabric that was 'safe enough to eat' (108), they said, 'as a biological nutrient, the fabric embodied the kind of fecundity we find in nature's work. After customers finished using it, they could simply tear the fabric off the chair frame and throw it onto the soil or compost heap without feeling bad – even, perhaps, with a kind of relish. Throwing something away can be fun, let's admit it; and giving a guilt-free gift to the natural world is an incomparable pleasure.' (109)

In the process of 'flocking', fabrics can be printed with glue then heat-pressed with flock paper. The flock adheres to the glue, creating as raised 'felt' effect glitter and foil can by similarly applied to produce special effects. (Udale, 2008)

The majority of printing inks are water based and much of the impact from processes involved in printing come from the disposing of inks and waste materials including rags, clean up materials, empty containers, used film and cardboard boxes. (Marshall, 2014) Along with this there is the water consumption used within the whole process and pollution from the fixation process. Due to the print residue it is more complicated to return the material back to a reusable state. (Marshall, 2015)

Other ways of adding surface decoration to embellished is by using beading and sequinning with 'beads made from glass, plastic, wood, bone and enamel" (Udale, 2008:108) It has been shown that the plastic used in beads have the potential of spending up to four hundred and fifty years in land fill without braking down (Headifen, 2015). The negative impacts come from what the embellishments are made of rather then the process itself. Polyester thread is the main fibre used to attached the beads and sequins, however the base fabric is normally made of silk and cotton, then the beads and sequins are made of one of the above materials (Udale, 2008). This means a large amount of different fibres left at the end of the garments life.

In contrast to this, using a 3D printer for embellishments could mean that designs are printed on demand without the need to build-up inventories of new products and spare parts (Lipson, 2013). A 3D printing facility would be capable of printing a huge range of types of products without retooling—and each print could be customized without additional cost, unlike screen-printing in where new screens would be required for every design (Shillito, 2013). Production and distribution of material products could begin to be de-globalized as production is brought closer to the consumer. (Lipson, 2013) Manufacturing could be pulled away from 'manufacturing platforms' like China back to the countries where the products are consumed, reducing global economic imbalances as export countries' surpluses are reduced and importing countries' (Lipson, 2013) reliance on imports shrink. The carbon footprint of manufacturing and transport, as well as overall energy use in manufacturing could be reduced substantially and thus global 'resource productivity' greatly enhanced and carbon emissions reduced. (Lipson, 2013) Reduced need for labour in manufacturing could be politically destabilizing in some economies while others, especially aging societies, might benefit from the ability to produce more goods with fewer people while reducing reliance on imports. Reduced need for labour in manufacturing could be politically destabilizing in some economies while others, especially aging societies, might benefit from the ability to produce more goods with fewer people while reducing reliance on imports. (Lipson, 2013)

3D printing generates shifts in labour patterns, as the process is highly automated. (Lindemann et al., 2012; Petrovic et al., 2011). Labour related implications show different patterns in developed and developing countries. The high degree of automation could be economically beneficial for developed countries with ageing societies, but destabilize developing countries if the production and there by the production volumes re-shift to consumer countries (Campbell et al., 2011). 3D printing has the potential to significantly lower life cycle energy demands of goods and their CO2 emissions (Reeves, 2012). Manufacturing-related energy demands and CO2 emissions are lowered through shortened processes and more direct manufacturing. 3D printing lowers manufacturing-related resource inputs as it solely requires the amount of material which ends up in the printed good without too many losses (Reeves, 2008).

3D print modelling can be labour intensive. It is necessary to select the appropriate 3D printing software to allow the designer to create a simple but effective way to turn 2D designs into 3D designs. Having an approach to produce work effectively and efficiently but leaving enough creative flexibility to experiment and exploit accidents. (Shillito, 2013) There is a possibility that once the 3D printing file is produced it can be used in several different ways to create embellishment. Variations can occur by slight changes including change of design thickness and scale; multiplying it in repeat and changing the filament colour. With the access to open source file sharing, any suitable files could be adapted to be used within this process. This system of working would generate more files, going forward, allowing for a less labour intensive approach.

The PLA used in 3D printing is known to have properties that mean it can be broken down into 'compost'. According to Lunt (1997), with PLA, hydrolytic degradation is primarily temperature and humidity dependent. In the primary degradation phase, no 'micro organisms' are involved. In 'commercial' composting environments, with controlled high humidity and temperatures of 55-70 degrees Celsius, PLA polymers will degrade rapidly. With 'home composting', which would allow a more accessible way for PLA to biodegrade, temperature is a still a key parameter determining the success of composting operations. Physical characteristics of the compost ingredients, including moisture content and particle size, affect the rate at which composting occurs. Other physical considerations include the size and shape of the system, which affect the type and rate of aeration and the tendency of the compost to retain or dissipate the heat that is generated. Compost heat is produced as a by-product of the microbial breakdown of organic material. A typical home compost system of more than 10 gallons in volume, will heat up to 40-50°C in two to three days. (Trautmann, 1996) This slight difference in temperature between commercial and home systems, added to the success of the addition of certain microorganisms, appear promising for increased use of PLA.

At this point in the author's PhD research, there are several projects of note that look at 3D printing in a fashion and textile context. However, at this time, many projects look at the 'novelty' of the process rather than addressing the challenges of the industry and proposing tangible, mass-producible solutions. Innovative projects that have caught media attention include Nike's 'Vapor Laser Talon 159-gram shoe' which involved a 3D printed, customisable nylon sole that was shown to improve athlete's performance. (Nike News, 2013) Michael Schmidt and Francis Bitoni's one-off 'fully articulated 3D printed gown, also printed in nylon by Shapeways, an open-access printing facility, gained widespread coverage. (Duann, 2013) Arguably, the first use of 3D printing in more 'mainstream' fashion and textiles was Richard Beckett's project for Pringle in 2014 where he used 3D printed 'laser sintered nylon elements' that were integrated into fabric (rather than 3D printed onto fabric). (Beckett, 2014)

Designers Meg Grant and Lynsey Calder (separately and together), have developed '3D printed, wearable origami' that involves PLA that is 3D printed onto several different textiles types (based on the applicability of the bond and flexibility of the ensuing print. Fabrics that were experimented with include iron-on interfacing (with the glue up side printed onto) and organza. (Calder and Grant, 2015) (see figure 1.)

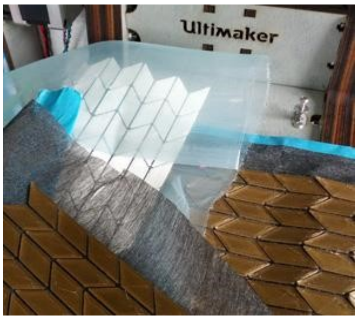



Figure 1 (left). 3D Printed 'Origami' by Meg Grant, 2015. Figure 2 (middle). 3D printing onto textile by Diego Zamora, 2014. Figure 3 (right). 3D printed garment utilising designs by Cubify, 3D System's printer and Fabricate application, 2015.

Ziego Zamora's research also looked at the 'flexible bonds' that can be created between natural fabrics and digital objects with an emphasis on how, even at this time in the development of 3D printing, any printable file can become wearable. (Zamora, 2014) (see figure 2.)

In 2015 3D Systems introduced the 'Fabricate' application which involved a series of ready made designs by Cubify (triangles, spikes and squares that could be [printed into 'special fabric' that would then be sewn or glued onto items of clothing. (Kira, 2015) (see figure 3.)

Methodology

At this point in the research, the reasons for looking into 3D printing utilising cellulosic materials as embellishment have been adequately established and so a test was set up to determine if 3D printing onto Tencel fabrics could perform as well as traditional embellishment, compared with information found on safety standards in the apparel industry. This project has been set out to provide an alternative to surface design techniques including screen printing, flocking and embellishment techniques including embroidery, applique, beading and sequins. The initial secondary research looked at the features of the embellishment techniques in comparison to 3D printing onto textile.

Various aspects from the fields of both design and engineering have so far influenced the research. These have included quantifying results using the Material Science lab's testing equipment at Edinburgh Napier University. The research has also produced designs using software, originally for 3D product design. In addition to this, there were engineering adaptions made to the 3D printer while printing, made by the technical staff in the engineering department such as holding the fabric in place using a customised clamp. Observational 'qualitative' visual analysis and 'field notes' of these undertakings have been recorded by the PhD candidate.

In the PhD candidate's choice of materials, Tencel was chosen, based on secondary research into its sustainable credentials. Woven, knitted and non woven textiles were printed onto with PLA. Once a technique was developed so that the PLA adhered to the textile in a visually acceptable way, initial tests were undertaken to test their structural integrity which would have implications for safety, usability, laundering and longevity. The samples then underwent a 'peel test', using a Lloyd Instruments LRX 01/2005 pull-testing machine, more commonly used within engineering than textile and garment design. This quantitatively tested the bond between the textile and the printed PLA and the results were collected to be compared to applicable industrial standards.

Initial Findings

The following images (figures 4 – 6) show the initial experiments with PLA 3D printed onto Tencel (with woven drill being visually the most successful). The author experimented with designing software for the Ultimaker 2 3D printer (Cura) to create a shallow print of several millimetres high. To enable the strength tests to take place, 'dots' were printed onto the textile that could be gripped by the machinery.

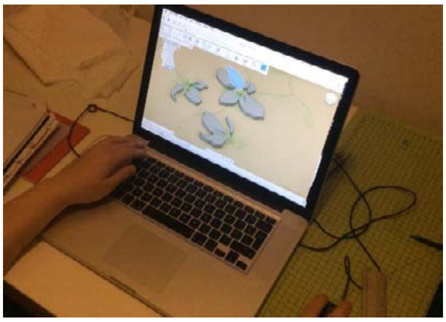


Figure 4 (left). Designing process for the 3D printer utilising 'Cura' software, Kirstie Burn, 2016. Figure 5 (middle). 3D printing onto textile from designs created on 'Cura', using an Ultimaker 2 3D printer, Kirstie Burn, 2016. Figure 6 (right). Floral design development for 3D printer, printed using an Ultimaker 2, Kirstie Burn, 2016

Peel Tests

Although the foregoing provides the motivation for its use, if 3d-printing is to be applied in the proposed context, it is important to establish that the technique produces a satisfactory bond between the printed embellishment and the textile. For this purpose, a series of peel tests were carried out on samples of PLA ‘buttons’ printed onto four different Tencel textile structures; drill, plain woven, knitted and non-woven.

The printed buttons were nominally 10mm in diameter by 5mm high, and attached to the textile over the full area of their circular base. The samples were set up individually in a Lloyd Instruments LRX 01/2005 pull-testing machine (see figure 8), using suitable grippers, and positioned axially such that the peel angle was 90° as the traversing peel line coincided with the button diameter. This was done to ensure that the maximum force would be measured as per the standard right-angle peel test. Five individual samples of each were tested in order to give a measure of the consistency of the process. The results are shown in Table 1, and presented as box-plots in Figure 7.

It can be seen that the textile structure has a significant effect on the strength of attachment. The strongest bond achieved was with the knitted textile, but this also exhibited the most variability. The reasons for this are not immediately clear, but may be because of the multiple fibre orientations presented at the textile-polymer interface, in contrast to the bi-directional nature of the woven fibres, largely parallel to the plane of the bond. Whilst this may lead to an expectation that the random orientation of the fibres in the non-woven textile would lead to an even stronger bond, this is not evident in the peel test results. Inspection of the samples post-test, however, reveals that the bond remains intact and the failure mode is that of the textile tearing.

Tencel drill	Tencel plain woven	Tencel knit	Tencel non-woven
13.65	12.55	31.71	6.35
13.55	9.48	17.30	8.52
13.82	8.98	18.91	5.56
14.21	7.39	25.05	7.12
13.31	3.16	24.16	6.27

Table 1: Maximum peel force measured for all samples.

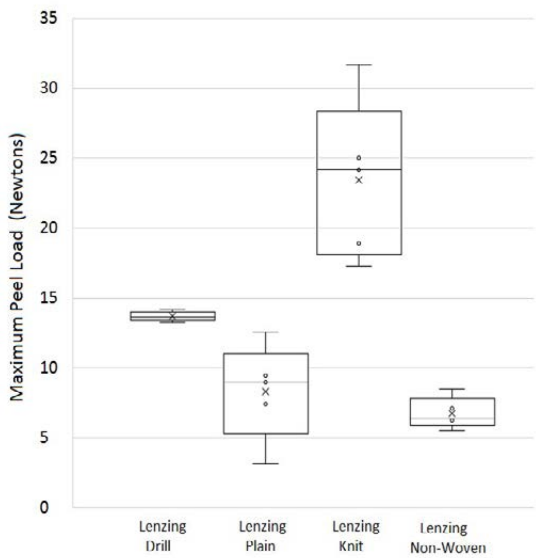


Figure 7 (left). Box plot of peel forces by textile structure. Figure 8 (right). Peel test equipment and 'button' samples using the Lloyd Instruments LRX 01/2005 pull-testing machine, 2016

The woven drill samples are notable for the consistency of the bond strength, albeit at little over half the mean strength of the knitted samples. Such consistency would be needed should the process be adopted on a production basis. The reasons for the outstanding performance in this regard is the subject of further enquiry. Furthermore, that the bond strength of the printed polymer approaches that of the textile itself in some cases is supportive of the potential viability of the technique. However, further work is to be carried out to investigate a variety of other polymer/fabric combinations.

Embellishment itself, as a process, could be considered extraneous in a climate that looks to ways that products can be made in a 'leaner and greener', more minimalistic way. Historical precedents and theoretical underpinnings question decoration's societal, cultural and personal purpose and show that it can be of value. Taking as inspiration Braungart and McDonough's theories on circularity, that waste can be 'good' if it becomes 'food', the availability of Tencel and PLA, and the positive aspects of the 3D printing process, this project proposed the tackle the challenge of embellished textile waste in a new way.

At this time, there are some projects that look at how 3D printing can be applied in the fashion and textiles industry, primarily as an exciting new aesthetic process. This project, however, wishes to address and an 'issue' in the fashion industry and create a technique that can be useable for fashion and textiles designers, rather than remaining in the 'lab'. Utilising pre existing 3D printing software in a textile design context and modifying the Ultimaker 2 to hold down textile with customised clamps, to give successful usable result, points to the potential usability of the technique within sustainable fashion. In addition to this, and initial strength tests undertaken show that 3D printing, as an alternative to traditional embellishment techniques, utilising Tencel and using PLA, can be a feasible, robust, usable material.

This PhD research is at a relatively early stage and there are opportunities, challenges and limitations that have been identified. The visual attributes of the materials produced will be assessed, recorded and reappraised using a combination of the PhD candidate's tacit knowledge and more quantitative notes on shape, line, colour and texture. It is anticipated that different textile types will be used and different versions of PLA, including more flexible filaments which, at this time, were not successful. The resulting samples will also be tested for usability using different methods, building on the peel tests undertaken.

At this time, the ease of 'usability' of this method is promising and, therefore, testing not only its outputs but the process itself, with other design practitioners, will be a further stage in this study. In addition to this, the biodegradability of the resultant materials and designs, and energy usage of the 3D printing process will be more clearly defined as the research progresses, through primary analysis. While the research is relatively early stage, the techniques and material outcomes show promise to not only add to a portfolio of production modes, but to change paradigms in the way that fashion can be designed, purchased then discarded.

References

Barnard, M. (1996) *Fashion as Communication*, London: Routledge.

Barthes, R. (1983) *The Fashion System*, Paris: Farnar Straus and Giroux.

Beckett, R. (2014) *3D Printed Knitwear* – Pringle of Scotland AW 2014 [online] http//:www.richardbeckett.com/pringle-3d-fabrics.html [Accessed 30.07.2016].

Black, S. (2013). *The sustainable fashion handbook.* London: Thames and Hudson.

Braungart, M. McDonough, W. (2002) *Cradle to Cradle, Re-Making the Way We Make Things,* London: Vintage Books.

Campbell, T., Williams, C., Ivanova, O. and Garrett, B., (2011) *Could 3D printing change the world. Technologies, Potential, and Implications of Additive Manufacturing,* Washington: Atlantic Council.

Calder, L. Grant, M. (2015) *The Pop Up Workshop* [online] Available at http://thepopupworkshop.wordpress.com/tag/e-textiles [Accessed 30.07.2016].

Duann. (2013) *Reveaing Dita Von Teese in a Fully Articulated 3D Printed Gown*, [online] Available at http://www.shapeways.com/blog/archives/1952-revealing-dita-von-teese-in-a-fully-articulated-3dhttp://www.shapeways.com/blog/archives/1952-revealing-dita-von-teese-in-a-fully-articulated-3d-printed-gown.htmlprinted-gown.html [Accessed 30.07.2016].

Fletcher, K., Grose, L. (2011) *Fashion and Sustainability*: Design for Change, London: Lawrence King Publishing.

Fletcher, K. (2014). *Sustainable Fashion and Textiles*. London: Routledge.

Headifer, R. (2016) *Plastic Litter* [online] Available at http://www.plasticwastesolutions.com/plasticlitter [Accessed 30.07.2016].

Kira. (2015) *Project Runway and 3D Systems Present 'Fabricate' 3D Printed Wearable You'll Actually Want to Wear* [online] Available at http://www.3ders.org/articles/20151016-project-runway-3d-systemshttp://www.3ders.org/articles/20151016-project-runway-3d-systems-present-fabricate-3d-printed-wearables.htmlpresent-fabricate-3d-printed-wearables.html [Accessed 30.07.2016].

Lindemann, C., Jahnke, U., Moi, M., Koch, R., (2012) Analyzing product lifecycle costs for a better understanding of cost drivers in additive manufacturing. In 23th Annual International Solid Freeform Fabrication Symposium–An Additive Manufacturing Conference. Austin Texas USA 6th-8th August.

Lipson, H. (2013) *Fabricated: The New World of 3D Printing*, London: Wiley.

Loos, A. (1998) *Ornament and Crime*, Paris: Ariadne Press.

Lunt, J. (1998) *Large scale production and commercial applications of polylactic acid polymers,* Polymer Degradation and Stability, Volume 59, Issue 1, pp 145 – 152.

Marshall, J. (2015) *Sustainability in Screen Printing* [online] Available at http ://www.printwearmag.com/features/sustainability-screen-printing [Accessed 30.07.2016].

Marshall, J. (2015) *How to do Eco-Friendly Screen Printing* [online] Available at http://www.ryonetblog.com/eco-friendly-screen-printing [Accessed 30.07.2016].

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

Morris, W. (1974) *The Beauty of Life: An Address Delivered at the Town Hall Birmingham in 1880*, London: Bentham Press.

Nike News. (2013) *Nike Debuts First-Ever Football Cleat Built Using 3D Printing Technology* [online] Available at http://news.nike.com/news/nike-debuts-first-ever-football-cleat-built-using-3d-printinghttp://news.nike.com/news/nike-debuts-first-ever-football-cleat-built-using-3d-printing-technologytechnology [Accessed 30.07.2016].

Norman, D.A. (2004) *Emotional Design: Why we Love (or Hate) Everyday Things,* New York: Basic Books.

Petrovic, V., Vicente Haro Gonzalez, J., Jorda Ferrando, O., Delgado Gordillo, J., Ramon Blasco Puchades, J. and Portoles Grinan, L., (2011) *Additive layered manufacturing: sectors of industrial application shown through case studies.* International Journal of Production Research, 49(4), pp.10611079.

Rams, D. (2014) *Less but Better*, Cologne: Die Gestalten Verlag.

Reeves, P., (2008) *Could Additive Manufacturing contribute towards environmental sustainability and carbon reduction across the supply chain?* Econolyst: the 3D Printing & Additive Manufacturing People Available at http://www.econolyst.co.uk/resources/documents [accessed 16.10. 2016].

Shillito, A.M. (2013) *Digital Crafts*, London: A&C Black.

Tratmann, N. (1996) *Compost Physics* [online] Available at http://compost.css.cornell.edu/physics.html [Accessed 16.10.2016].

Udale, J. (2008) *Basics Fashion Design*, London: AVA Publishing.

Wilson, E. (1992) *Chic Thrills: A Fashion Reader*, London: Pandora.

Zamora, D. (2014) *Diego Zamora PhD Candidate* [online] Available at http ://www.designinaction.com/research/individual/diego-zamora [Accessed 30.07.2016].

CENTRE for CIRCULAR DESIGN

CIRCULAR TRANSITIONS

23 – 24 November 2016

Laser Moulding for Textiles: Supporting Sustainability in Design and Manufacture

Laura Morgan (Loughborough University, UK)

Abstract

This paper considers the potential for digital laser technology to facilitate sustainable innovation in the field of textile design and manufacture enabling transition towards a circular economy. Using recent design research as a case study, it discusses a newly developed laser moulding method and its significance in relation to circularity.

Introduction

This paper presents a case study from the author's doctoral research (Morgan, 2016), which aimed to develop new laser processing techniques for coloration, patterning and three-dimensional surface design of textiles. The research examined laser technology as a tool to support sustainable innovation through science and design. The use of laser technology as a multipurpose tool for textile design and garment finishing offers environmental and economic benefits. Lasers offer digital control with potential to support sustainability through efficiency and direct-to-garment processing opportunities.

The case study details one of the developed processes: laser moulding for textile design. The aim of the paper is to discuss the abilities and application opportunities of the laser moulding technique, summarising the advantages for sustainability, design and manufacture. Laser moulding builds on mono material processing for synthetic fabrics, adding value and form to textiles through use of a new processing technique. The technique can be used to create multiple effects and can be combined with dyeing procedures to enable digital *Laser Shibori* effects.

While textile design as a subject may require an interdisciplinary mindset, it can often be difficult for designers to access the scientific and technical facets of textiles, production or technology without a technical background. Typically, areas of textile design and textile engineering operate separately within the textile industry. However, it has been recognised that collaboration and connections between fields can facilitate innovation. A report for the Crafts Council (KPMG 2016) notes the ability for craft to support cross sector innovation and discovery in the UK. This places textile designers in a significant position to balance craft, design and technology to facilitate material innovation. Literature and research that bring together practical, scientific and aesthetic strands in equal depth are infrequent. The research presented in this paper summarises an in-depth study that brings together these features, discussed in this paper as an important feature of the work.

Material choices have a significant impact at a textile's end of life. A report by Forum for the Future (2007) notes the importance for designers and developers to consider designing clothing for recycling or disassembly. Further to this is the Cradle-to-Cradle principle, by which zero waste is considered from the very inception of a new product or material with an aim to create a closed loop of manufacture and use (McDonough and Braungart 2002). McDonough and Braungart propose that a product that has reached the end of its lifespan should be returned to the industrial cycle as a raw material for new products, with no decline in quality. This system encourages materials to be used in a pure state. Without contamination, the materials can either be returned to the industrial cycle easily, or if the material is biodegradable, it can be returned to the earth to decompose. Goldsworthy (2014) discussed design for cyclability in relation to laser processing for textiles, proposing that synthetic textile products should be designed for recovery at end of life; that is, they should remain uncontaminated for repeated cycles of use and recycling. The design for cyclability proposal has relevance to this research project, through the development of laser techniques for creating three-dimensional textiles that negate additive processes, such as stitching. Keeping fabrics pure to one fibre type only allows outcomes to be recycled responsibly, vastly increasing the overall sustainability of the end products.

Emergent technological and engineering advancements are adding to sustainable improvements in manufacture. Scaturro (2008: 475) highlights the 'significance of technology's role in the evolution towards a more sustainable fashion system.' Literature in the field suggests new technologies are one way to boost sustainability of production. For example, in the realm of fashion and textiles, Scaturro (2008) referred to the use of sustainable technology as Eco-Tech Fashion. She reasoned that advances in technology could be used as a fundamental aid to the development of environmentally friendly processes, describing an ideal where future technological systems are more sustainable than those that currently exist in manufacturing. Allwood *et al*

(2006) propose a number of alternative scenarios by which the processing of a garment, from raw fibre to finished product could be changed to offer a commercially viable and more sustainable form of production. She suggests the impact of new specialist technologies on the textile industry could bring areas of production and manufacture back to the UK, where higher labour costs could be offset by a less intensive level of manpower required.

As well as the environmental benefits, digital technology and production systems may also offer other commercial benefits: such as allowing production of smaller batches, including made-to-order production of individually designed and sized garments, and pattern customisation at supplier or even consumer level, without the need for expensive setup costs (Allwood, et al 2006). Cie and Joseph (2010) describe this as ‘nimble manufacturing’. The laser is one such *nimble* or *agile* technology that has sustainable potential. It is a digital technology that offers dry processing and potential for combining processing stages, for example, laser cutting combined with laser processed surface design could reduce the number of separate steps necessary to produce garments.

Combining the environmental, economical and practical processing advantages of laser technology with new techniques for textile design that adhere to circular material systems has potential to support sustainability in the field of fashion and textiles.

Three-Dimensional Textiles

In the design and construction of commercial and industrial textiles, three-dimensional surfaces are often used to provide beneficial properties to the fabric. Many traditional constructed, woven and stitched textile patterns exist for the enhanced properties they can offer for textile end-use: for example, increased absorption and insulation properties. Functional finishes for textiles that were originally designed for high performance have become synonymous with high quality style, leading to their adoption in fashion and trend led textile products for aesthetic appeal (Braddock and O’Mahony, 1998).

Traditionally, three-dimensional effects can be added during the construction of textiles such as weaving, or in the finishing phases through additive embroidery and stitching techniques. Some wet-techniques such as devoré, flocking, felting and shibori can also provide three-dimensional effects. Heat and heat-setting methods have long been used for creating three-dimensional forms on synthetic substrates. Textile practitioners who have investigated heat or laser effects to produce three-dimensional textile outcomes include: Nigel Marshal's vacuum formed textiles (Braddock and O'Mahony, 1998); Isabel Dodd's (1999) sculptural velvet accessories; Janette Matthews' (2011) laser assisted origami textiles; and Kate Goldsworthy's (2014) laser bonded synthetics.

The potential to use a CO_2 laser to heat set pre-determined shapes in a synthetic textile had not been previously explored. The study presented in this paper examined the potential to use photothermal energy from a CO_2 laser to induce a heat setting effect on polyester and nylon substrates, investigating three-dimensional effects through controlled tension and targeted laser irradiation. The dry laser process negates requirement for additional materials, such as thread for stitching. Elimination of additional materials offers potential ease of recycling at end of life, thus complimenting a circular textile lifecycle.

Laser moulding for textiles

The practice-based, interdisciplinary study drew on scientific knowledge frameworks used within optical engineering and dye chemistry, as well as design and craft based approaches familiar to textile design. Using a combination of material-led approaches and design practice in addition to technical and scientific enquiry, the synthesis of approaches ensured rigor across the interdisciplinary fields of study and were found to be essential in developing the three-dimensional laser moulding technique. The author's background in woven textiles provided a familiarity with achievable design effects facilitated by altering tension in the production of constructed textiles. It was hypothesised that three-dimensional surface design effects may be achieved by laser irradiation of a fabric substrate under strain.

Figure 1: Laser Moulded Polyester Samples (Morgan, 2016)

A CAD controlled CO_2 laser was used to create three-dimensional forms on polyester and nylon fabrics under tension. On release from tension the marked areas created three-dimensional protrusions from the surface of the cloth as shown in Figure 1. Important parameters were identified and explored through experimentation, leading to a system for predicting the three-dimensional effects to enable controlled design outcomes. Altering these parameters offered a range of three-dimensional textile design features and opportunities. These included;

1. Measuring extension to plan and control the resulting size of moulded forms.
2. Using directional (uniaxial or biaxial) tension to control gathered or uniform moulded effects.
3. Designing with consideration for pattern spacing to allow dimensional stability of the fabric to remain intact.
4. Altering laser energy density within a given range to control the intensity of the moulded forms.
5. Altering scale and shape of designs to achieve a range of aesthetic, textural and functional three-dimensional effects.
6. Combing laser moulding with coloration techniques to achieve three-dimensional multi-tonal patterning: *Laser Shibori*.

The scientific approach used in this study provided a measurable means to calculate, predict and control the laser moulding effects for designing three-dimensional textile surfaces. The purpose of this short paper is not to detail technical information, rather, it will provide a summary of achievable effects from utilising the above parameters to manipulate scale and shape of three-dimensional textile surfaces. In addition, it will discuss the potential to offer new or enhanced fabric properties, design features and application opportunities.

The surface effects that can be achieved have been categorised into four types including: weave and stitch-inspired effects; shaping effects; texturing effects; and *Laser Shibori*.

Weave and Stitch Effects

The use of weave and stitch inspired effects present a rich library of aesthetic and tactile patterning opportunities borrowed from traditional textiles structures as well as the potential performance benefits they may offer, including thermal insulation, airflow, breathability and tailoring functionality.

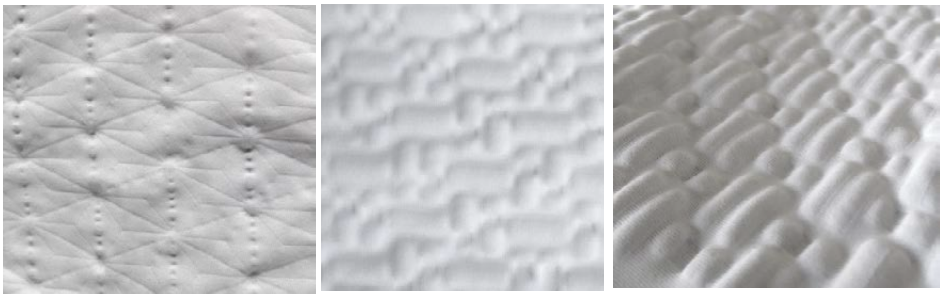


Figure 2: Laser Moulded Geometric, Embossed Hopsack and Basket Weave Patterns (Morgan, 2016)

The laser moulding technique enabled embossed textures on polyester and nylon textiles. Geometric patterns including hopsack and basket weave (Figure 2), showed optical illusion effects, emulating traditional woven textures.

Laser moulded honeycomb and quilted effects are shown in Figure 3. Honeycomb structures, traditionally used to provide increased absorption and insulation properties in textiles also make strong insulators due to the pockets of air that can be trapped between the honeycomb areas of pattern. In a similar way, quilted surfaces trap air and padding between textile layers for insulating properties. Laser moulding on a large scale can be used to create dramatic three-dimensional moulds and surface qualities akin to quilting as shown in Figures 3 to 4. The laser moulded samples could provide quilted textures for an aesthetic effect, or be layered to supply thermal insulation.

Figure 3: Laser Moulded Honeycomb Pattern and Quilted Triangle Pattern (Morgan, 2016)

Figure 4: Laser Moulded Large Scale Three-Dimensional Moulding (Morgan, 2016)

Figure 5 shows an example of a laser moulded seersucker effect. This structure can also offer increased functionality in textile products. Seersucker is often used in clothing to offer heat dissipation in hot weather garments. The rippled areas of the textile remain loose, preventing fabric from touching the skin during wear, which in turn facilitates air circulation.

Figure 5: Laser Moulded Seersucker Effect and Zigzag Seersucker Pattern (Morgan. 2016)

Laser moulding effects could offer additional decorative or functional effects in the design and tailoring of garments. For example, gathered or ruched finishes as shown in Figure 6. These effects have potential to add visual interest to a textile product, or add functionality such as ease of movement or ‘no sew’ darts.

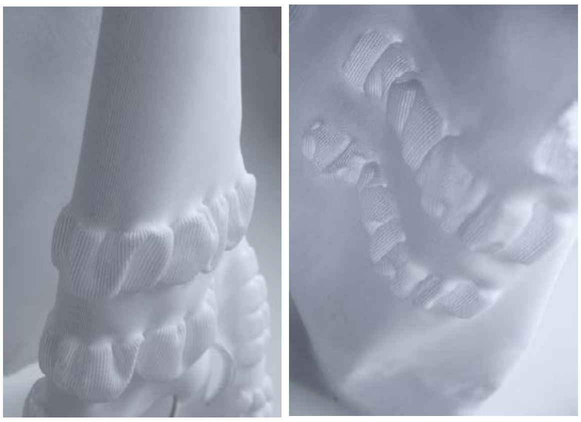


Figure 6: Laser Moulded Gathered Bands (Morgan, 2016)

Shaping Effects

Shaping effects have the potential to offer benefits for finished textile product applications such as ease of movement at joints or engineered fitting opportunities. Further investigation could explore the potential of applying the laser moulding technique for engineered design offering targeted functionality and fitting.

Figure 8: Large Scale Laser Moulded Circles (Morgan, 2016)

Figure 8 shows an example of a laser moulded circle design. The circles have a diameter of 10cm resulting in large-scale moulds on a polyester textile. The substantial three-dimensional forms show potential for shaped product or garment applications. For example, laser moulded garment-pattern pieces could be engineered to fit the body. Circular shapes, such as those shown, could be used to laser mould cups onto a textile for intimate apparel.

Pleats are another form used in textile product applications to provide freedom of movement to the wearer. The sample shown in Figure 9 has an all over pleated, accordion effect. The images demonstrate the sample draped in a bent and a relaxed position exhibiting the properties of a soft spring which could have possible relevance for clothing, architectural or medical textile applications.

Figure 9: Laser Moulded Pleated Fabric (Morgan, 2016)

Texturing effects

Texturing effects add visual interest, changes in tactile qualities, and offer the potential for sweat wicking and aerodynamic properties. The sample in Figure 10 shows an example of small-scale patterning with a circle diameter of 0.5cm, resulting in a dimpled fabric texture. Patterns of this nature have been used within performance wear to provide aerodynamic texturing. A similar surface is used in the design of Nike’s TurboSpeed performance sportswear where textured surface patterns are placed on specific areas of the athlete’s body. Nike (2012) claim the textured surface uses the same principle of dimples on a golf ball that reduce drag allowing it to travel further and faster.

With a beam size of 0.03cm there is the potential for laser moulding on a microscopic scale. Micro-patterning or micro-texturing has the potential to provide added or enhanced tactile properties: a subject for further investigation.

Figure 10: Laser Moulded Dimpled Fabric Texture (Morgan, 2016)

Laser Shibori

Figure 12 shows a dyed three-dimensional relief surface pattern. The samples show that dyeing techniques can be successfully combined with laser moulding. The design opportunities provided by combining the two processes increases design flexibility. For example, multi-coloured imagery and pattern could be enhanced by three-dimensional elements in targeted areas of the design. The results could be compared to shibori dyeing; a resist dyeing process where dyeing and three-dimensional effects are combined. The *Laser Shibori* provides its own unique aesthetic effect, offering control and digital image making, with a level of precision and repeatability that cannot be achieved with existing shibori processes or alternative textile production techniques.

Figure 12: Laser Shibori: Laser Moulded Dyed Sample (Morgan, 2016)

Discussion

Reflections on an Interdisciplinary Approach to Textile Design Research

Interdisciplinary collaboration in this research took the form of hand and digital textile design practice, quantitative scientific experimentation and qualitative industry feedback. In order to achieve this, the research was carried out across engineering, chemistry and art departments as well as visits to industrial stakeholders within contract interior textile manufacturing and performance swimwear. This crossing of disciplines led to a thorough investigation of the subject maintaining rigor across all straddled fields.

The approach used to develop and examine laser moulding made use of what has been referred to as ‘craft intervention’ (Woolley and Huddleston 2016). A craft-led approach in the initial stages of the research provided proof of concept that was developed and tested with technical and scientific procedures to measure and explain the process. Quantitative data and mathematical interpretations were used to predict and control the effects, without which, the results achieved would remain ‘happy accidents’ or one-off effects that could not be replicated. Instead, command of the necessary parameters for predicting the three-dimensional effects enabled design flexibility through controlled design outcomes suitable for technology transfer across industrial laser systems. Design practice was used to develop and test the aesthetic and tactile qualities that could be achieved. Examining varied laser moulded shapes and their resulting forms on textile substrates identified a library of decorative and functional design and application opportunities.

Advantages for Sustainability and Manufacture

In this study, the laser moulding technique was shown as an effective method for creating three-dimensional forms on polyester and nylon knitted textiles. The technique could be used for surface design and to engineer functional properties such as breathability, insulation and aerodynamic texturing to textile goods. Combining three-dimensional laser moulding with dyeing processes resulted in an effect akin to shibori. The *Laser Shibori* provided a unique aesthetic effect, offering control, with a level of precision and repeatability that cannot be achieved with existing shibori processes or textile production techniques.

The use of laser technology to create three-dimensional textile forms presents processing advantages over traditional methods. Unlike regular textile embossing equipment, the laser does not require moulds or plates to be cast for each new design. Unlike the relief effects created through weaving, the laser does not require complicated loom set up to produce three-dimensional forms and offers ease of pattern change through digital generation of designs. This in turn would allow targeted, direct-to-garment processing opportunities on textile ‘blanks’ or engineered garment pattern pieces, adding additional properties to a textile, post-construction.

The opportunity for digital laser processes to move the design stage further down the production cycle can allow for late stage decisions and design flexibility, providing a responsive approach to design and manufacture. For manufacture and supply chains, responsive or agile manufacturing can offer reduced lead times and minimum orders to reduce surplus stock and to minimise or eliminate the creation of excess waste of textile goods; in addition, it may facilitate bespoke or customised production opportunities.

The design of systems to compliment and facilitate circular material processing that have additional efficiency benefits for manufacture may encourage uptake of more sustainable technologies and processing techniques in the textile industry. Laser moulding is a dry and efficient process that can make use of existing CO_2 laser processing equipment and does not require additional materials, such as thread for stitching. Therefore, using the technique for surface design effects could eliminate the need for additional embellishment for decorative and functional textiles. The use of synthetic mono materials, such as polyester used in the presented study, can facilitate circularity in the textile industry, allowing textile products to be recycled effectively in a closed loop lifecycle.

Further Work

Further work to develop and improve the discussed technique lies in expanding the three-dimensional design effects that can be achieved, examining engineered design opportunities and the potential for micro-patterning or micro-texturing as discussed in the following paragraphs.

Additional three-dimensional design effects, specifically furthering *Laser Shibori,* could enhance multi-coloured patterns and create three-dimensional imagery. Alternate pleated forms and graduated moulding could provide an expanded range of achievable shapes.

Placement of moulding could be furthered through engineered fitting or shaping for moulded garment pattern pieces. This could offer an exciting opportunity to develop custom fitting with the goal of starting from a blank standard fabric and adding targeted properties or shaping based on requirement.

The work examined macro-scale moulding, however with a laser beam size of 0.03cm, there is the potential for laser texturing on a microscopic scale. Micro-patterning has the potential to provide added or enhanced textile properties. Technical textile testing could be used to quantify changes or enhancements to fabric comfort properties such as air permeability and thermal conductivity after laser treatment. Emulating the tactile qualities of natural fibre fabrics such as cotton or wool is a desirable feature for manufacturers of synthetic textiles. If micro-patterning using the laser moulding technique can alter tactile properties of synthetic stretch fabrics, a potential valuable avenue for further investigation has been identified.

Conclusion

This paper summarised a new method for moulding synthetic stretch textiles, developed by the author. A selection of laser moulded samples was presented, discussing the functional and aesthetic possibilities for textile design and avenues for further investigation. The technique, which uses the photothermal properties of the CO_2 laser, allows accurate three-dimensional moulding of synthetic fabrics without the use of pattern moulds.

The laser moulding technique can be used to design accurate surface architectures providing three-dimensional design features for textile product applications. Combining the technique with dyeing processes resulted in an effect akin to shibori. Unlike the traditional craft practice, *Laser Shibori* offers precise control, repeatability and a unique aesthetic. Designs are created digitally and can be changed effortlessly. The method allows decoration to emerge from the structure of the cloth without contaminating the mono-material fibres. This in turn would allow the cloth to be recycled easily and adheres to a closed-loop system for a sustainable textile lifecycle.

The study demonstrated the benefit of interdisciplinary study, synthesising design and science to support sustainable innovation for textiles. The synthesis of the scientific and creative approaches proved essential in creating the laser technique as a design tool with potential to support efficiency, agility and circularity in textile processing. Working in this way created a platform for innovation beyond creativity as discussed through potential functional application ideas and sustainability benefits.

References

Allwood, J., Laursen, S., Malvido De Rodríguez, C. & Bocken, N. (2006) *Well Dressed? The Present and Future Sustainability of Clothing and Textiles in the United Kingdom*. Cambridge: University of Cambridge.

Braddock, S & O'Mahony, M. (1998) *Techno Textiles: Revolutionary Fabrics for Fashion and Design*. London: Thames & Hudson.

Cie, C. & Joseph, F. (2010) *New Dimensions: Sustainability in Digital Design and Print for Textiles*. Sustainability in Design Now: Learning Network on Sustainability (LeNS) Conference. Bangalore, India. 29 Sept – 1 Oct 2010.

Dodd, I. (1999) *Velvet Scarf with Hand Printed Large Spot*. Crafts Council. Web: 30 November 2015. <http://collections.craftscouncil.org.uk/object-t151>

Forum for The Future. (2007) *Fashioning Sustainability; A Review of the Sustainability Impacts of the Clothing Industry*. London: Forum for The Future.

Goldsworthy, K. (2014) *Design for Cyclability: Proactive Approaches for Maximising Material Recovery.* Making Futures Journal, 3 (2014) 249.

KPMG. (2016) *Innovation Through Craft: Opportunities for Growth: A Report for the Crafts Council.* London: KPMG.

Matthews, J. (2011) *Textiles in Three Dimensions: An Investigation into Processes Employing Laser Technology to Form Design-Led Three-Dimensional Textiles*. Doctoral Thesis: Loughborough University.

McDonough, W. & Braungart, M. (2002) *Cradle to Cradle: Remaking the Way We Make Things*. New York: North Point Press.

Morgan, L. (2016) *Laser Textile Design: The Development of Laser Dyeing and Laser Moulding Processes for Sustainable Design and Manufacture.* Doctoral Thesis: Loughborough University.

Nike. (2012) *Nike Unveils Track and Field Footwear and Apparel Innovations.* Nike. Web: 10 January 2016. <http://news.nike.com/news/track-field-nike-pro-turbospeed-uniforms-and-nike-zoom-spikes>.

Scaturro, S. (2008) *Eco-Tech Fashion*. Fashion Theory*,* 112-4 (2008) 469-488.

Woolley, M. & Huddleston, R. (2016) *Maintaining the Human Touch- Exploring 'Crafted Control' Within an Advanced Textile Production Interface.* In *Crafting Textiles in The Digital Age*. Eds Nimkulrat, N., Kane, F. & Walton, K. London: Bloomsbury.

Acknowledgements

The author would like to thank her PhD supervisors, Dr Faith Kane and Prof John Tyrer from Loughborough University and Prof Jinsong Shen from De Montfort University. With thanks to the Arts and Humanities Research Council (AHRC contract number: AH/J002666/1) and industrial partners Speedo, Camira Fabrics and Teresa Green Design for their funding and support towards the LEBIOTEX Project, a collaborative venture with Loughborough University and De Montfort University.

CIRCULAR TRANSITIONS

23 – 24 November 2016

A Closed Loop Model for 3D Printing Fashion

Emma Grain (University of Huddersfield, UK)

Abstract

This paper discusses the 2 Way Closed Loop Model using recycled polyester (PET polyethylene terephthalate) developed by the author (in 2014) and its relativity to the development of sustainable practices in fashion and 3D printing in fashion. Bringing together sustainability and innovative technology, the focus of this practice based study aims to evaluate the early possibilities of such a model through design and exploring manufacturing methods as well as interviewing Fashion and Technical experts from academia and industry for their views on the model, methods, final usability, constraints and opportunities.

Introduction

Closed Loop systems are the pinnacle of sustainable models and one of which the Fashion industry could benefit more from to help reduce the 350,000 tons of textile waste that goes to landfill each year in the UK alone as well as the pre-consumer textile waste from factory floors. Recycled PET has been used for many years by outdoors clothing companies such as Patagonia who have been the pioneers of using old polyester clothing and recycling it back into new yarn to make more clothing. Working with Teijin a Japanese high-performance material developer since 2005 they have been able to advance their environmental responsibilities further into more of their products.

Since 2010 3D printing has emerged as a new method of manufacture for fashion, this is mainly evident in experimental sculptural forms for women as seen by Iris van Herpen. In moving forward with experimental fashion designs and venturing into the unknown, a lot of waste can be created and the end of life of these items need to be considered as with any other fashion piece. This newly developed closed loop model hopes to help solve this by using rPET and become an option for future 3D printing fashion designers to employ by bringing together sustainability and innovative technology in practice.

3D Printing in Fashion

3D Printing, a popular term for what is now known as additive manufacturing (AM), refers to various processes where successive layers of material are formed under computer control to create the object. Notable 3D print creatives making fashion pieces include, Neri Oxman of MIT university and founder of the Mediated Matter group who collaborated with Iris van Herpen to produce the Anthozoa Cape and Skirt in 2012 on a multi material printer. Richard Beckett an Architect, Lecturer and designer in 2014 worked with Pringle to produce some 3D designs integrated into the ready to wear pieces of knitwear and outerwear for both the men's and women's wear collections all produced by SLS (Selective Laser Sintering) in Nylon. It has become quite common for collaborations to involve designers from backgrounds such as architecture due to the digital aspect lending itself to the 3D fashion printing.

3D Prints for fashion come in many different structures, varying from chainmail like links, to hinged pieces and mezzo structures that stretch. Due to the nature of the materials which these fashion pieces are printed from, the structures that form them must have certain properties to allow movement.

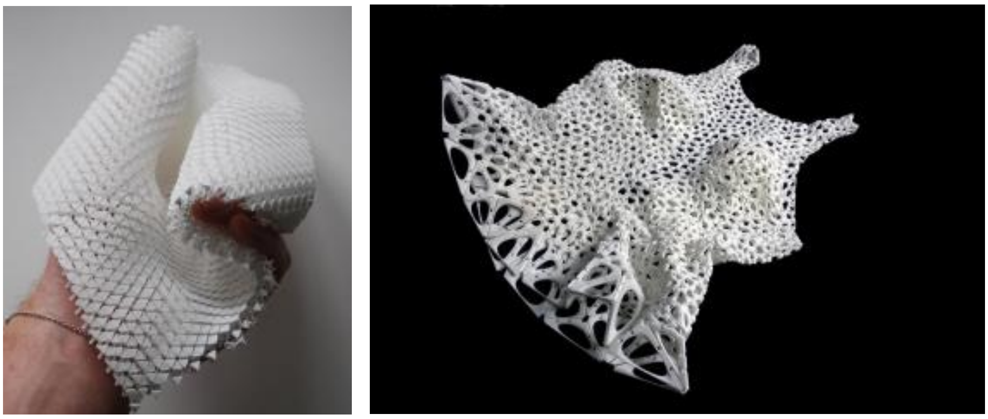
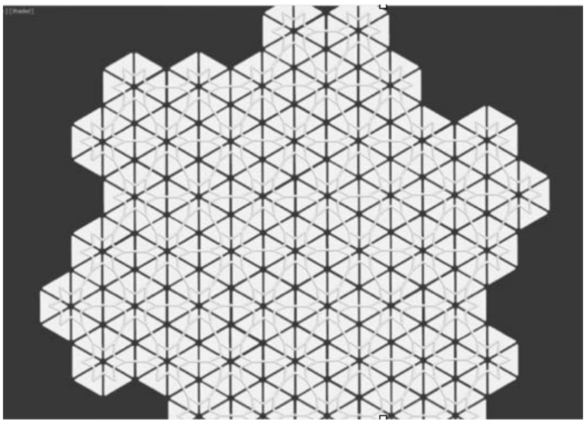


Figure 1 & 2: Richard Beckett for Pringle. Kinematics top by Nervous Systems

The researchers most recent study involves designing new 3D printed textile structures, working with the properties of rPET 3D printing filament for FDM (Fused Deposition Moulding) printers. The Filament used was made from recycled PET bottles and gave a clear aesthetic to the finished piece (Fig 1). All though the material is still fairly rigid the chosen Mesostructure textile design allows it to bend and curve in multiple directions.



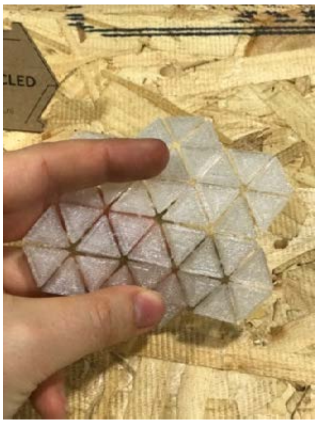


Figure 3 & 4: Skinspiration 3D Textile CAD design Grain. E 2016. rPET Print

Sustainability and rPET in 3D Printing

3D printing has been known as a throw away fad and one which can produce lots of waste itself as with both novice and amateur makers there are often mistakes which end up in the bin. In the last 50 years alone plastic production has increased by 500% and when discarded often ends up in the rivers and sea creating ‘plastic soup’. Finding new ways to recycle this into new things is infinitely better than creating new as it saves on CO2 emissions and the ever-decreasing resource of oil it starts out as. C.A. Griffiths et al (2016) noted this means that the design stage must consider constraints of time and cost and to furthermore consider sustainability and the need to seek to reduce scrap. Due to the nature of 3D printing, it only uses the material needed for a product with exceptions of small supporting pieces during additive manufacturing, rather than the subtraction approach in manufacturing which involves controlled material removal but involves a lot of waste.

Refil

Refil is founded by Rotterdam based design agency Better Future Factory (BFF), founded by five alumni from the Delft university of technology. BFF is a multi-disciplinary design and engineering company. BFF finds and develops creative yet realistic and sustainable solutions by incorporating the essential principles of the circular economy. They have many projects running but most famously the recycled filament for 3D printing called Re-filament. They believe: “3D printing is todays trendiest industrial revolution. At Refil we aim to make is a sustainable one as well. Why continue to use new plastics, when there is so much old plastic we can re -use?”

Refil produce 4 types of 90-100% recycled filament, they are ABS filament made from car dashboards and PET filament made from old PET bottles, each sold on their website and most recently HIPS filament made from recycled refrigerator insides and PLA made from recycled food packaging most commonly yogurt pots. Refil are at the forefront of this area and are a leading enterprise in terms of new materials and sustainability.

Figure 5: Refilament recycled 3D printing filament from http://www.re-filament.com

Ekocyle/Cubify Will.I.Am

In a wholly collaborative move towards sustainable fashion, W ill.i.am has teamed up with Coca-Cola to make new things in part from recycled materials (Ekocycle, 2015). This high profile colab has brought together some of the biggest names in fashion and retail to make this possible and the products range from clothing by Adidas and Ecoalf to lifestyle products by Globe Trotter and footwear by Keds all sold online and in the prestigious Harrods of London. The products are all made from partly recycled materials mainly including a percentage of PET bottles and this information is clearly displayed on their website adding transparency to the brand's impressive attributes. In an interview with GQ Will.i.am discussed that the project will continue to launch new products throughout the year, from everyday pieces to luxury items, with Will.I.Am at the helm as creative director – producing the type of recycled clothing we can all get on board with (Conner 2015). The quest for making sustainable living cool does not stop with clothing, but reaches over into 3D printing. Using an average of 3 post-consumer PET bottles per printing cartridge this enables the consumer to use their 3D Systems Ekocycle Cube printer for home use with sustainability in mind. Will.i.am explained that the goal is to partner with the most influential brands around the world and use technology, art, style and inspiration to change an entire culture. We will make it cool to recycle, and we will make it cool to make products using recycled materials. This is the beginning of a more sustainable 3D-printed lifestyle. Waste is only waste if we waste it. (Ekocycle ,3D Systems, 2014). Although this printer is part of a wider range by Ekocycle that includes clothing made from recycled materials including bottles, the printer itself has not made and of the fashion pieces or accessories but is merely sold as part of the offer of sustainable goods.

Figure 6: Ekocycle + Harrods ,3D Systems, 2014

3D System's (3DS) continues to support the many facets of 3D printing with its new program rollout called Fabricate. The program works in tandem with existing products, such as the Cube, to offer both amateurs and professionals the chance to design or modify their own apparel (3DS 2015) This is not using recycled materials but shows 3DS creating's and accessible technology allowing creative people the anility to accessorize fabric and clothing. Seemingly this program is no longer being run on their website and design downloads are no longer available, the reason is unknown.

B-PET

B-PET is another recycled filament manufacturer based in Argentina who has produced 100% recycled filament from PET bottles and claims to have 100% recycled PET powder for use on Selective Laser Sintering machines in the near future which will mean a greater clarity of print and an ability for much finer detailing in designs.

Figure 7: B-PET at http://bpetfilament.com

Proto Cycler

The Proto Cycler is a new innovative tool which allows consumers to recycle plastic waste themselves by using the built-in grinder, filament extruder and spoolers to create new 3D printing filament. Previous machines have been available in recent years but none so consumer friendly that does the job start to finish with such ease of use. Such a machine allows there to be an industry driven by creation and not driven by consumption. "Whether it be the cost of buying new feedstock, or the waste generated as you finalize your design to perfection, true creative freedom is being held back by the consumable nature of the industry." Redetect.com. PROTOCYCLER claims it can grind and extrude any none toxic plastic within the melting range of 260' such as ABS and PLA most frequently used in 3D printing and they are working on being able to support the recycling of more plastics soon.

Closed Loop

A Closed loop system is one where the waste or by product of one process or product is used in making another product, this is a theory which more and more industries are adopting and a leader in spreading the word on this is the Ellen McArthur Foundation.

Figure 8 & 9: The Proto Cycler and Protocycler diagram

Ellen McArthur Foundation

Set up in 2010 with the aim of accelerating the transition to a circular economy and putting it on the agenda of key decision makers in the areas of business, government and academia. The foundation provides and amazing set of resources that help educate towards a more circular economy and has produced many reports, graphics and publications which make it very easy to understand. The below image identifies the two material flows, biological and technical. The foundation points out that: *In the technical cycle, the closer the loop is to the user, the more profitable is the action. Thus, repairing products is a more profitable action than, say, recycling."*

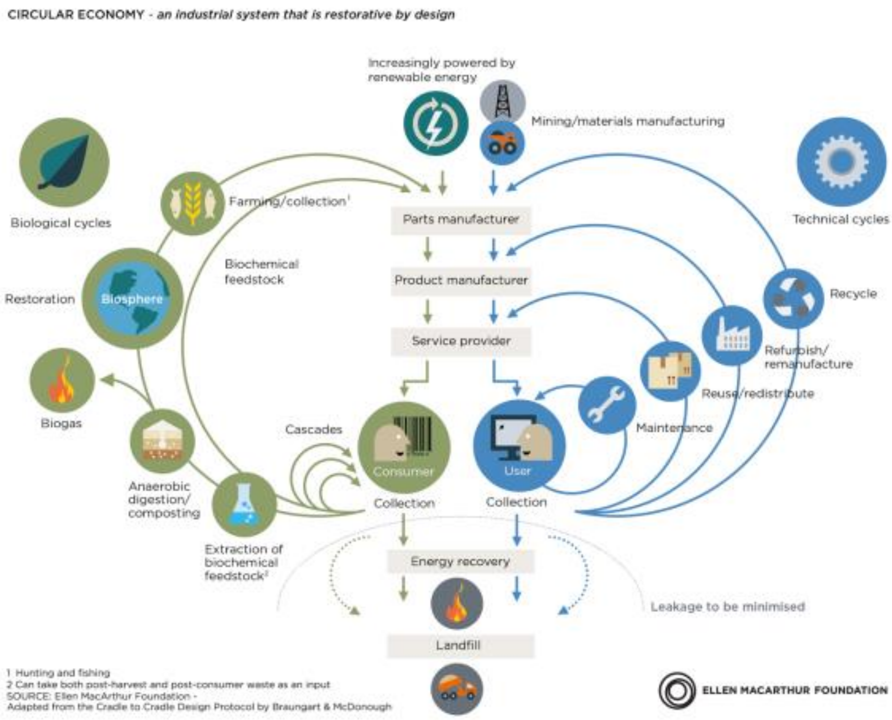


Fig 10: Ellen McArthur Foundation 2016

Closed Loop thinking: Recycled Polyester/ Pet – Case Studies

Polyethylene Terephalate (commonly abbreviated PET, is the most common thermoplastic polymer resin of the polyester family and is used in fibers for clothing, containers for liquids and foods, thermoforming for manufacturing, and in combination with glass fiber for engineering resins. The prefix (r) to rPET is recycled.

TEIJIN – Japan

Teijin's mission statement is 'Human Chemistry, Human Solutions' to respond to various global issues and needs, focusing on technological innovation in their strengths of high-performance materials (Teijin, 2014). They are the global leader in chemical recycling of materials into fabric including polyester. The current global annual production of major fibers is approximately 78.11 million tonnes. Synthetic fibers account for more than half of this amount, approximately 45 million tons, of which approximately 80% is Polyester (Teijin, 2014). The two main materials which Teijin have developed from post-consumer pet or polyester products are as follows:

i. Eco PET

A mechanically recycled polyester fabric which is made from 100% recycled PET bottles called which was first established in 1995 after Teijin had already been manufacturing recycled Pet bottles into new bottles so this was naturally the next step.

ii. Eco Circle

Alternatively, in 1999 ECO CIRCLE TM utilizes Teijin Fibers innovative chemical recycling technology for polyester products. Its unique recycling technology is a world first in this field (Fig.6). The technology enables decomposition of used polyester products using chemical recycling, followed by reproduction of new polyester fibers. This process can be repeated multiple times (Japan for Sustainability, 2009). This method can produce fabrics that are so purified through this process that the quality is equivalent to that of freshly produced polyester from petroleum (Teijin, 2014). This method is popular with both Patagonia and The North Face and allow a totally closed loop cycle.

Figure 11: EcoCirlce Polyester Recycling Process www.ecocircle.co.jp

Repreve by Unifil – USA

Repreve by Unifil an American based leading producer and processor of multi-filament polyester and nylon textured yarns. Providing innovative, global textile solutions and unique branded yarns for customers at every level of the supply chain. (Repreve & Unifil, 2009)

Under the Repreve label 2 types of recycled polyester are produced, Repreve filament fibers and Repreve staple fibers. The latter is further processed to produce the physical properties required of a spun yarn and the former is in the form of yarn.

Both these types of Repreve polyester are used by brands such as The North Face, Quicksilver, Patagonia, Timberland, New Balance to name a few. These top brands are safe in the hands of a certified sustainable fiber manufacturer and can rely on 100% traceability in their products composition.

The 2 Way Closed Loop Model

Below is a Model developed in 2014 by the author, a Fashion Lecturer, Menswear Designer and 3D Printing and Fashion Sustainability Researcher at Huddersfield University. In the Two Way Closed Loop Apparel Cycle (Fig.11) Grain. E has theorized that by recycling all PET products, whether it is bottles, clothing or 3D prints, the existing recycling process of clothing and bottles into textiles can be mirrored but into 3D printing filament and vice versa. This stands to reason through exploring the methods existing polyester recyclers use and noting the early stages up to the pellets stage is identical to that of recycling into printing filament.

The current research focuses on designing and 3D printing textile structures from rPET made from recycled PET bottles which is readily available. In testing this material in various structures and designs, the parameters of end product can be examined as to what properties it may have and lack.

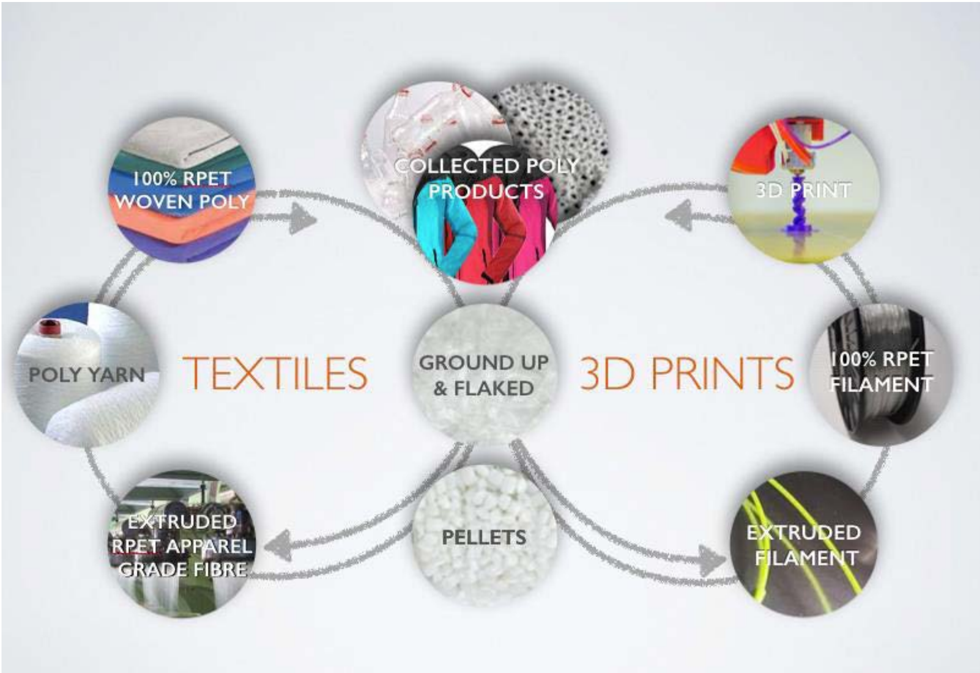
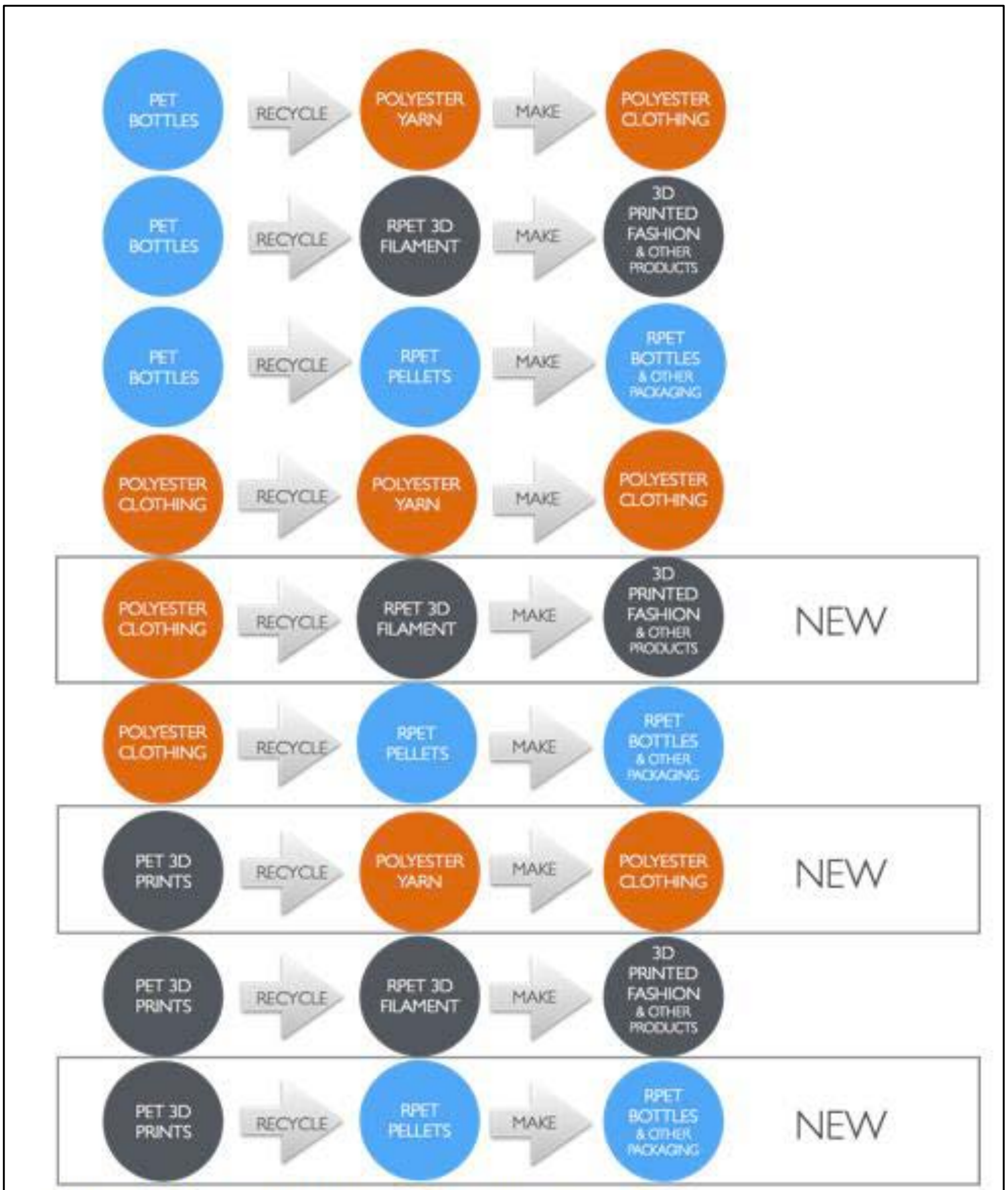


Figure 12: Two Way Closed Loop Model by Grain. E (2014)

From this model a number of outcomes can take place:

- Polyester Clothing > Recycled = new polyester Yarn > new clothing
- Polyester Clothing > Recycled = rPET Filament
- Polyester Clothing > Recycled = rPET Bottles/Packaging
- PET 3D Prints > Recycled = new polyester yarn > new clothing
- PET 3D Prints > Recycled = rPET Filament
- PET 3D Prints > Recycled = rPET Bottles/Packaging
- PET bottles > Recycled = new polyester yarn > new clothing
- PET bottles > Recycled = rPET Filament
- PET bottled > Recycled = rPET Bottles/Packaging



Grain.3. 2016 2 Way Closed Loop possible Outcomes

Figure 13: Two Way Closed Loop Model by Grain. E (2014) with potential outcomes

Feedback on the Model

Four industry experts in the fields of Fashion Academia, 3D printing, 3D printing Filament Recycling and Sustainability, and in relation to this research they were asked what they thought about the 2-way closed loop model and their initial reactions brought up some interesting points of discussion.

From fashion academia, Catherine Brenannd, Fashion Lecturer at Huddersfield University, brings up the point on educating consumers on the methods and theory in order to make the process viable and also noted problems that may be faced in terms of geographic locations of the two parts of the process.

An expert in 3D printing Chris Charlesworth from the University of Huddersfield thought the the 2-way closed loop model was certainly viable but would need vigorous testing and referred to his experience in using recycled ABS filament.

A leader in recycled PET 3D printing filament Casper Van Der Meer of Refilament commented on the need to convert PET-A to PET-G in order to use for 3D printing, and showed an interest of future collaboration and expansion of Refilament's current portfolio if this 2 way closed loop went into practice.

Both a WRAP and end of life and standards committee member Charles Ross points out that although some major companies have already started working towards this the main issues will be initial cost and changing consumer behaviour in order for it to work and then the issue of how it will make money to maintain it.

Design Obstacles

Learning how to use 3D software to enable you to 3Dprint your designs is a difficult set of skills to grasp. There are many tools and techniques you need to learn in this virtual studio before you can show your ideas in 3D. One of the reason the designers that 3D print fashion always collaborate with other industries is because there are so many technicalities involved in the process and it allows them to share resources and pool innovative ideas. Interdisciplinary partnerships such as Males and Tilbury of Studio XO bring together skills from engineering and Fashion and the Co founders of Nervous Systems, Rosenkrantz and Rosenberg who combine multiple disciplines including architecture, biology and Math. It is with more than one area of expertise like these that the combined skills allow hybrid creations such as 3D printed fashion to exist. Some things to be considered when designing for 3D printing are:

Material guidelines: There will be specific guidelines depending on what material you want to print in and the melting point of each material, this will also effect the strength and flexibility of each print.

Printing Technology: Different printing technologies have different capabilities as with materials so you must know what that specific technology can do before designing for it. Whether its SLS or SLA or FDM they would all react differently to the same design, one may need more support while the other may need the design to be made thicker or not interlinking.

Wall Thickness: Taking this into consideration means the print is less likely to fail. Creating a wall thickness that is too thin thus leaving a weak part or too thick so the desired flexibility is not achieved, this is one of the most common mistakes people make.

File Resolution: This will determine how pixilated your print will look. The high the resolution the design you send to print, the more detail and smoother it will be.

Software Guidelines: Depending on which software you use, different settings may need to be altered before you are able to print from your design, this may include, wall thickness or hollowing out (i.materialise, 2015).

Conclusion & Further Studies

This research has sought to outline several methods in which PET could be recycled in a Closed Loop system with the new addition of 3D printing within a Fashion context. It has theorised that by recycling polyester clothing it can be chemically processed in such a way not dissimilar to that of PET bottles, that it can be turned into 3D printing filament.

In terms of reducing clothing going to landfill, this is way to prevent its end of life and keep it in a closed loop. The filament could be 3D printed with and create endless amounts of designs with the potential to recycle again if needed. More opportunities need to be identified as to what is the most suitable structures for this material and how can we best work with the properties for it to work in fashion and fashion product.

Further research into the types of PET as mentioned by Casper van der Meer of Refilament, noting a conversion of PET-A to PET-G will be needed in order to 3D print from PET that originally came from clothing.

Moving forward into PhD the researcher plans to collaborate with both leading 3D printing and textile companies to combine the process to produce a filament made from recycled polyester clothing and then 3D print a garment from it, making this truly closed loop.

References

B-PET. (2016). *About B-PET*. Retrieved from http://bpetfilament.com. Filamentive. (2016). *About Us*. Retrieved from http://www.filamentive.com/about-us/.

Earley, R. & Goldsworthy, K. (2015). Designing for fast and slow circular fashion systems: exploring strategies for multiple and extended product cycles. *In PLATE Conference Nottingham Trent University*, Retrieved from http://www4.ntu.ac.uk/plate_conference/PLATE_2015_proceedings.pdf.

Ekocycle. (2014). *Will.i.am & The Coca-Cola Company's Journey Towards Zero Waste.* Retrieved from http://www.ekocyclemovement.com/will-i-am-the-coca-cola-companys-journey-towards-zero-waste/.

Goldsworthy, K. (2009). RESURFACED: Using Laser Technology to Create Innovative Surface Finishes For Recyclable, Synthetic Textiles. In *Cutting Edge Lasers and Creativity Symposium, Loughborough University,* Retrieved from http://cuttingedgesymposium.com/pdf/kate-goldsworthy-paper.pdf.

Grain, E. (2016). 3D PRINTING FASHION WITH RECYCLED POLYESTER: A SUSTAINABLE JOURNEY. In *IFFTI, Beijing, Beijing Institute of Fashion and Technology,*Retrieved from http://iffti2016.bift.edu.cn.

Griffiths, C.A., Howarth, J., De Almeida-Rowbotham, G., Rees, A., & Kurton, R. (2016). A design of experiments approach for the optimisation of energy and waste during the production of parts manufactured by 3D printing. *Journal of Cleaner Production,* 139 , 74-85. doi: http://dx.doi.org/10.1016/j.jclepro.2016.07.182.

I Materialise. (2015). 5 mistakes to avoid when designing a 3D model for 3D printing | 3D printing blog i-materialise. Retrieved from https://i.materialise.com/blog/5-mistakes-to-avoid-when-designing-a-3d-model- for-3d-printing

Kreiger, M.A., Mulder, M.L., Glover, A.G., & Pearce, J.M. (2014). Life cycle analysis of distributed recycling of post-consumer high density polyethylene for 3-D printing filament. *Journal of Cleaner Production,* 70 , 90- 96. doi: http://dx.doi.org/10.1016/j.jclepro.2014.02.009.

Livingston.B. (2003). Forward-Recycling of Synthetic Contract Textiles: A Vision of the Sustainable Future. USA: The Designtex Group

Oecotextiles. (2009). Why is recycled polyester considered a sustainable textile?.Retrieved from https://oecotextiles.wordpress.com/2009/07/14/why-is-recycled-polyester-considered-a-sustainable-textile/.

Patagonia. (2009, March 4). Closing the Loop – A Report on Patagonia's Common Threads Garment Recycling Program [Web log post].Retrieved from http://www.patagonia.com/blog/2009/03/closing-the-loop-a-report-on- patagonias-common-threads-garment-recycling-program/.

Polygenta.(2016). Polygenta Sustainability. Retrieved from http://www.polygenta.com/sustainibility.html. *Protoprint*. (2014). About

Us. Retrieved from http://www.protoprint.in/protoprint-ethical-fairtrade-3d- printing.htm.

Reflow. (2016). About Reflow. Retrieved from http://reflowfilament.com/about.html.

Refilament. (2016). About Refilament. Retrieved from http://www.re-filament.com.

Repreve. (2009). REPREVE: Our Story So Far. Retrieved from http://www.gounifi.com/pdf/utsc_repreve_eng.pdf Repreve. (2016). OUR UNIQUE PROCESS. Retrieved from http://repreve.com/our-process.

Teijin. (2015). Eco Circle Fibers. Retrieved from http://www2.teijin-frontier.com/english/sozai/specifics/ecopet-plus.html.

Unifi. (2016). What We Do. Retrieved from http://www.unifi.com/un_about_whatwedo.aspx.

WRAP.(2015). Sustainable Clothing A Practical Guide To Enhancing Clothing Durability and Performance. UK: WRAP.

A Space of Waste

Karen Dennis (Ketchup Clothes), Claire Evans, Charles Kahabi (University of Huddersfield), Alfred Lugallo (Independent Tanzanian Designer)

Abstract

Exported waste clothing, emanating from a western context, saturate indigenous African markets but satisfy local clothing needs. This produces a dichotomy in ways in which it is viewed and the necessary actions needed to address the issues of waste within a circular economy. Experiences and outputs from recycling clothing waste in a UK based context are applied to that of a Tanzanian context and methods for re-appropriating this waste back into manufacturing systems are explored. These include ideas for re-exporting remanufactured garments back to their place of discarding and of working cross culturally with local designers and businesses to address indigenous clothing and manufacturing capacities and needs.

Introduction

Ketchup Clothes, a remanufacturing social enterprise established by one of the authors (Karen Dennis) in 2004 and based in the North of England, was set up to transform garments and textiles that, through no fault of their own, had become viewed as waste and no longer required by their original owners. Through a process of transformation and remanufacturing, new garments were imagined, produced and sold, and insight gained into the social, political and environmental dimensions of garment rubbish (Dennis, 2008). Ketchup Clothes was essentially a one-person operation although assistance through student placements and collaborations with similar enterprises was also gained. In the time it maintained itself financially, and whilst there were not large profits, there was enough to put back into the enterprise to keep it going. The key sources of finance included sale of clothing (40%), payment for the delivery of workshops (30%) and external funding for business start-up (30%) (Shah, 2015). This implied that as a viable social enterprise it had potential to grow and when the opportunity arose to showcase the techniques and models of manufacture within a Tanzanian context it seemed the perfect place to further the debate as to whether the these could be developed for economies that are defined by the importation of clothing waste, have a failing mass production system but a thriving informal and small-scale sector. Similarities and differences could be drawn across the cultures in the ways in which products were manufactured and consumed. Of particular interest was the way in which 'circular thinking' undertaken within the context of co-design could be extended to foster an environment in which waste exported from one context could be reused in another. In August, 2016 a catalogue of these ideas and processes was produced and used, within a series of co-design workshops undertaken at the University of Dar Es Salaam, Tanzania (Shah, 2016a). These workshops were conducted under that auspices of a PhD by Kahabi and used to investigate perspectives on recycling and the value of western waste, experienced in the form of second-hand clothes (mtumba) (Shah, 2016a). This was part of a wider study into the development of a National dress for Tanzania where discussion centred upon the potential for using second-hand clothes (or mtumba) within the production process (Shah & Kahabi, 2016).

The purpose of this paper is to establish the extent which methods and techniques for transforming waste clothing from the streets of Leeds, UK could be applied to a global context, particularly that of Tanzania. The overall aim is to investigate and develop appropriate manufacturing and re-appropriation techniques that will have resonance on circular notions of production and tackle the mountains of clothing waste that we find spread across the globe. It will achieve this through a discussion and exploration of techniques used to date by the authors and primary empirical research gathered during the course of workshops. This will include practice-based outputs that have the potential to be up-scaled, applied to varying scales of production and potentially incorporated into CAD/Apparel Systems. In the course of this exploration aspects such as key spaces of waste will be critically evaluated and differing perspectives and discourses will be analysed.

Contextualising the Problem

A key hypothesis underlying this paper, and indeed wider research interests, is that something has gone array in our production and consumption systems in order to produce such a vast amount of waste and that this is having a detrimental impact on both intrinsic and extrinsic environments (Scanlan, 2005;Braungart & McDonough, 2008; Farrant et.al, 2010; Foote & Mazzolini, 2012) .We are spreading this waste across the globe where it enters systems that are not set up to receive it in a safe manner and there is the worry that this will have a lasting impact on our planet, psyche and well-being (Bauman, 2003; Ritzer, 2004; WRAP, 2012; BBC, 2016; Wheeler, 2016). A large part of the problem arises out of the need for companies to keep producing – not just to satisfy demand - but to remain profitable and create new demand. Forward and backward linkages within the fashion industry are complex but tend to be centred upon forward inertia in that everything is geared towards the end product. Materials and resources are pushed forward in the creation of an object and there they tend to finish. There are obviously incidences in which waste comes back into the same system from which it came but they can so small-scale or fragmented that they appear insignificant.

The export of second-hand clothes is one situation in which waste in one context is brought back to life in a new one (Cline, 2015; Brooks; 2015). The markets and streets of Tanzania are overflowing with piles of clothes that were once considered of no use, now seeming to perform an important function (Isla, 2013) (Figure 1).

Figure 1: Second-hand clothes stalls on the side of the road, Dar Es Salaam: Image: Dennis, August 2016

In the bustling second-hand markets, workspaces have been set up to repair and transform clothes, shoes etc. and vendors state that business is good and profitable (Shah, 2016b). Seen in this light the problem becomes a solution for a related activity – that of clothing our backs to satisfy both basic and complex social, environmental and cultural demands. Paradoxically many of the fixers also stated that they did not see the activity as an aspirational career for their children indicating that work is needed to raise the status of the occupation for the future. As positioned by Isla (2013), in relation to the various discourses we can use to investigate second-hand fashion trade and consumption, she argued that at one end is a noticeably modern and functional outlook and on the other is a distinctly postmodern and consumerist perspective. This was seen to give rise to the coexistence of both positive and negative orientations and connotations and she posited that:

"…while the United States and western Europe tend to frame second-hand fashion consumption almost entirely with the notion of constructed identity and other "postmodern" notions, African feelings could very well be located towards the middle of the continuum with their recognition of functional and rational socio-economic motivations in used clothing consumption, as well as consumption practices that are informed by local cultural norms and through which identities are constructed and contested." (Isla, 2013, p.222)

In this context second-hand clothes (SHC) serve a function and provide a much needed resource. They satisfy the need for affordable, available and quality clothing and the sorting, distribution and sale of the SHCs provide valuable income-generating opportunities for tailors, fixers and entrepreneurs. As stated by Brooks (2015)

"Poor people may have little agency in shaping used clothing systems of provision, but they can and do respond in creative and unanticipated ways to imports of used garments. Imports have diverse affects within different societies. Norms of dress are transmitted by the prevalence of Western clothing. Yet rather than everyone being passive receivers of clothing culture evidence shows how individuals give textiles a new lease of life and create their own creolized trends." (Brooks, 2015:145)

This represents the potential for second-hand clothing and the positive manner in which it can be adopted within a developmental context. It also provides insight into how indigenous designers could utilize second-hand clothes within national schemes of dress and creolized styles.

Pressures are now being placed on the export of waste clothing, with Tanzania being just one of the African countries seeking to ban its import (BBC, 2016). Thus inventive ways of utilizing second-hand clothing are needed that address measures to make its remanufacturing and processing more appealing to producers, governments and future generations. Consideration for both local and export markets would help to close the loop and highlight the issues that occur when waste exported from one context is subsumed within a different socio-economic location. In this way clothing waste become circular in the way in which it is reabsorbed and contributes to the development of both indigenous and export markets and local manufacturing capacity.

Means to a Solution

The means to the solution that is proposed through this research is to propose methods for reintroducing clothing waste back across the scale of manufacturing systems from small to large-scale production. Its presence within niche and designer markets has great value and potential but there is also an imperative to introduce clothing waste at a mass scale (Brown, 2014). The reasoning behind this is, that in the main, it is this system that has produced the waste in the first place and therefore it should shoulder more responsibility to re-appropriate it. Designer and couture pieces do end up within the global clothing redistribution system but these are far and few between. The bulk of that which is exported tends to come from high street names and brands. In manufacturing terms solutions are thus framed around current approaches to clothing production and of developing improved techniques that have resonance to both local and global manufacture. These include the development of a range of clothing made from second-hand clothes/mtumba that would be suitable for western markets, modern Tanzanian styles and the incorporation of waste clothing and textiles into a national dress for Tanzania.

Flow charts detailing the process of clothing recycling and its potential for re-appropriation into larger scales of production have been developed and these demonstrate the opportunities that exist for remanufacture (Dissanayake & Sinha; 2015). However, the emphasis on managerial structures and the limited design appeal of these investigations suggest that whilst re-appropriation of clothing waste into larger manufacturing has potential it needs a clearer design philosophy and aesthetic. Further consideration of cultural preferences, design tendencies and manufacturing capacities are also needed. Design research, by the author, Dennis, to date has centred upon the generation of garments utilizing pattern generation and shape development adopted by both mass production systems and designer one-off processes. This has resulted in a bank of design and pattern cutting methods from which to draw upon and hypothesise as to how they may be applied to a number of cultural and manufacturing scenarios. Within the context of this practice-based research fabrics such as denim (mainly from jeans), cotton jersey (mainly from T-shirts) and woven cotton (mainly from shirts and household linen) were utilized to produce a variety of design outputs.

Co-design

Co-design, as a concept for developing more meaningful design outputs for both consumers and producers would appear to have resonance to circular notions of design and consumption since an active dialogue is encouraged in order to produce design solutions. In the case of the transferral of methods for recycling clothes in a UK context to that of a Tanzanian context this process was actively pursued through the means of workshops in Dar Es Salaam University and the subsequent sharing of ideas via an online communication system, i.e. Whatsapp. Discussions as a result of the workshops revealed that there were definite correlations between small-scale activities set within a UK to that of the Tanzanian tailor and designer. Both were small-scale in operation and utilized waste clothing to a lesser or greater effect. For the Tanzanian tailor it was cited how they would often have a stock of second hand clothing to use for trims, buttons and for converting into alternative products such as pillowcases. Whilst there was not much evidence of tailors or designers making full garments out of second-hand clothes there was a sense that these practices were seeping into teaching practices. Observations during a visit to a second-hand market revealed a thriving undercurrent of fixing, mending and alterations but interviews revealed how these activities paid well but were not a profession that they would want their children to go into. Finding means through which these activities could be given a higher status through the production of upscaled outputs would therefore have resonance to circular manufacture.

Drawing on the experiences gained as a result of submersion in Ketchup Clothes, techniques and methods of recycling were developed and discussed with participants both in the workshops and via online and social media means (mainly Whatsapp). These centred upon the utilization of second-hand t-shirts, jeans/denim and traditional Tanzania 'kanga' fabric and all sought the need to address both export and local markets. (Figures 2-6) In addition feedback on a previous process, was introduced as a potential means of getting the fabric to lay flat and suitable for printing on and presenting for manufacture.

Figure 2 (left): Mtumba t-shirts with applied batik process & refashioned into western style garment (L: New Era Designs (NED); R: Dennis, 2016). Figure 3 (right): Western and Tanzanian Interpretations of Traditional Kanga Fabric (L: Dennis, R: NED, 2016)

Figure 4: Interpretations of National Identity in Kanga Design (L: Dennis, R: Kahabi, 2016)

Figure 5: Mixing Kanga fabric with recycled denim/jeans (Dennis, 2016)

Figure 6: Football Kanga designed by Dennis (L) and imagined as contemporary garment on illustration of Alfred Lugallo (Dennis, 2016)

Laying flat

This technique was developed as a potential solution for re-appropriating waste into production systems that necessitate the need for the fabric to be presented flat for textile finishing and manufacture (Shah, 2016b). One of the key characteristics of recycling is that there is little uniformity in either the size or quality of pieces of fabric and that an element of deconstruction needs to take place in order to extricate fabric from the original garment. Once this is done pattern pieces can be laid on the fabric or it can be presented to a mannequin to begin the design development and cutting out process. Contemporary mass production, on the other hand is characterized by its uniformity of inputs and outputs and thus waste inputs need to be formalized and in an appropriate state to be acceptable to systems of manufacture. Drawing on methods of dealing with animal skins in the fashion industry and series of fabric samples were developed that presented the fabric in a flat form ready for cutting and manufacture. In this process ‘patches’ of fabric were collected from the waste item (cutting out defects, stains and holes), butted together and then joined. This resulted in a skin of fabric from which a pattern could be laid on top and cut out. As a preliminary investigation collaboration was sought with a CAD/Apparel Systems company (Assyst Bulmer) who helped to visualize how the skin of fabric may be uploaded onto relevant systems prior to cutting out and manufacture and also how the garment would look. This gave significant results and showed that irregular shapes of fabric could be uploaded into the system and from there digitally manipulated to not only show the lay of the pattern on the fabric but also how the garment would go together (Figures 7–9).

Figure 7: Fabric ‘skin’ that has been produced from a number of discarded T-shirts and with superimposed pattern pieces for a simple T-shirt and resultant computer simulated top (Geoff Ward, Assyst Bulmer, 2016)

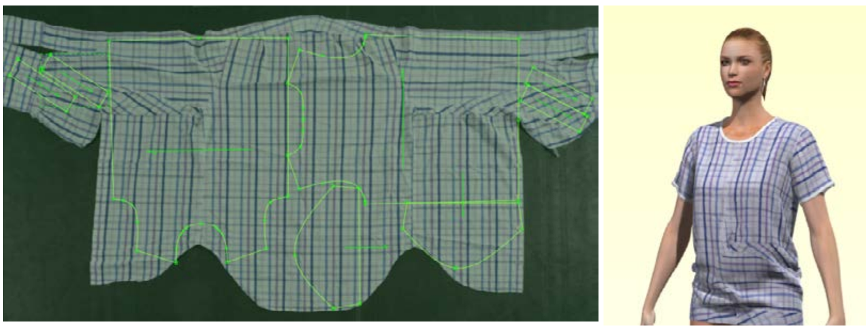


Figure 8: Pattern pieces superimposed onto flattened shirt and computer simulation of resultant top (Shah & Ward, 2016)

To take the research further more skins of fabric could be produced and investigation undertaken to apply print and seaming details to see if a range of designs can be produced that are appropriate for a number of manufacturing scenarios. One of the key issues in designing for traditional production is the need for consistency, standards and quality control – all of which become problematic when introducing a resource that is inherently inconsistent, of varying quality and un-uniform in both aesthetic, fibre composition and fabric structure. The focus for investigation will include the cotton jersey T-shirts, cotton shirts and household linen and jeans/denim items, after which efforts will be undertaken to connect with and foster production systems both in the UK and Tanzania.

Figure 9: Tailors at co-design workshop handling fabric and assessing fabric potential

Substantiation

The means through which ideas developed in the UK were measured for their feasibility and appropriateness in a Tanzanian context occurred during the course of the co-design workshop, and subsequent communication, concerned with whether it was possible and/or appropriate to use second-hand clothing in the development of a national dress for Tanzania. Participants of the workshop included local tailors, businesses, designers, teachers and researchers/students as well as representatives from the Textile Standards Board, Dar Es Salaam University, the Arts Council of

Tanzania and representative from an AIDS charity. Participants were organized in specialist and mixed groups and this provided the opportunity to share ideas and debate the key issues. Activities included focused presentations on varying topics, feedback presentations, a field trip and design and making tasks. Field visits to local markets, an interview with a prominent Tanzanian fashion designer Manjou, discussions with Kanga (fabric) sellers and a trip to a tourist market, all in Dar Es Salaam, formed the basis for design discussions and development. Analysis of interviews and observations helped to substantiate conclusions in terms of re-appropriation and the circular economy by devising the following hypothesis.

To move into a circular economy necessitates the development of circular manufacturing systems. These systems can operate on a variety of scales but are reliant on the closing of loops and of having appropriate resources in terms of quality and design appeal. In the case of the export of second-hand clothing to Africa, the remanufacture of SHC and its export back to western markets would appear to the joining of these two parts. It would generate income for the sender and an opportunity for the receiver to reflect upon their shopping habits. To facilitate this joining together certain conditions need to exist. These include a commitment by the western fashion system to address its overproduction and consumption and to more fully assess the impact of the export of second-hand clothes, many of which carry their labels, together with the development of African based remanufacturing to help convert waste. This would result in the generation of styles and designs that are more fully embedded with meaning and capable of being coveted for longer and having appeal to both indigenous and export markets.

Discussions with participants of the workshop revealed how second-hand clothing, as in the discarding of ones clothes, is not a common practice but that if they did find that they no longer required something that it was likely to be passed down through the family or taken back to their village when they returned for holidays. However, it was revealed that this was changing and that internal recycling of clothes existed through charities and certain networks. There was generally a very positive attitude towards the consumption of second-hand clothing saying that it offered individuality, quality, affordability and availability. The negatives being that the shopping environment was generally not conducive to trying on clothes and would entail sorting through large piles of clothes just in the hope that you would find something. It was also concluded that a National Dress was needed in Tanzania to satisfy the demand for items that could be worn at special events and to boost National identity. It was recommended that this should be acceptable to all, communicate notions of individuality and also of unity and be made of cotton (and possibly mtumba). In terms of manufacture it should link into both small/medium activities currently operating and also investigate the potential and feasibility of larger scale operations. It should take account of religious beliefs, with appropriate motifs related to nature, animals and relevant political symbols and iconography.

Conclusions

Embedding recycling practices, and utilizing second-hand clothes/mtumba in the development of products suitable for both local and export markets did at first appear a rather strange proposition to some of the participants of the workshops. There was a real concern that there were many health hazards in handling the mtumba and that alternative methods for dealing with the waste were needed. These included ragging and converting the materials back into polymers, areas of research that appeared to be developing at the University. Issues to do with capacity and equipment were also raised especially in relation to what was seen as a failing mass production system. However, it was concluded that the co-design process had been a success and rather than closing a loop in a circular way it had actually opened up a spiral. Cross-cultural communication is key to closing gaps and how we move forward in the development of circular practices. Social media platforms such as Whatsapp proved a liberating mechanism for the discussion with images, techniques and final outputs being able to be shared quickly and easily between related parties. Thus many activities need to function side by side in order to succeed with the sharing of design practices playing a large part to ensure the appropriateness of resultant outputs. Initiatives for processing materials and bringing them back into a circular manufacturing system will take time but could provide a great benefit to a country such as Tanzania. There is potential for the embedding of meaning into design outputs that will communicate not only aspects of nationality but also identity and aspirations. In developing garments for export an opportunity exists to send garments back from where they came and in the process use income as a source of investment for the indigenous clothing and textile industry. The development of a National Dress, based on recycling second-hand clothes, would generate interesting insight into the processes of design and how it may be used as a tool to convey complex political issues, social conditions and environmental concerns. The development of new cloth could also be used as a way of embedding meaning into items made from waste and of maintaining long held traditional modes of printing and construction. Lacuna and barriers do exist in the application of these ideas to the current manufacturing capacity but will cross cultural dialogue and collaboration in time these may be overcome.

References

Bauman, Z. (2005) 'Wasted lives: Modernity and its outcasts'. London: Polity Press.

BBC (2016) 'Why East Africa Wants to Ban Second-hand Clothes', www.bbc.co.uk/

Braungart, M. & W. McDonough (2008) 'Cradle to Cradle: Re-Making The Way We Make Things'. London: Vintage Books.

Brooks, A. (2015) 'Clothing Poverty: The Hidden World of Fast Fashion and Second-Hand Clothing'. Zed Books.

Brown, S. (2011) 'Eco Fashion'. London: Laurence King.

Brown, S. (2014) 'Refashioned – Cutting Edge Clothes from Up-cycled Materials'. London: Laurence King.

Cline, E. (2014) 'Where Does Discarded Clothing Go?' www.theatlantic.com/business/archive/2014/07/where-does-discarded-clothing-go/374613

Dennis, K. (2008) 'Sustainable Design and Development: A Personal Journey' in Design, Pedagogy, Research. Huddersfield, UK Jeremy Mills. pp 85-98 ISBN 978-1-906600-35-8

Dissanayake, G., & Sinha, P. (2015) 'An examination of the product development process for fashion remanufacturing'. Resources, Conservation and Recycling, 104, 94-102.

doi:10.1017/S0960777313000192

Farrant L, Olsen SI, Wangel A (2010) 'Environmental benefits from reusing clothes'. International Journal Life Cycle Assess 15(7):726–736.

Foote, S., & Mazzolini, E. (2012) 'Histories of the dustheap: Waste, material cultures, social justice'. US: MIT Press.

Isla, V. L. (2013) 'Investigating second-hand fashion trade and consumption in the Philippines: Expanding existing discourses'. Journal of Consumer Culture, 13(3), 221-240.

Ritzer, G. (2004) 'The globalization of nothing'. Thousand Oaks, California. London: Pine Forge.

Scanlan, J. (2005) 'On garbage'. Reaktion Books, London

Shah, K. (2015) 'Dilemmas of Development and the Reconstruction of Fashion.'In: Environmental Implications of Recycling and Recycled Products, London, UK. Springer. Pp 1-1-134 ISBN 978-981-287-642-3

Shah, K. (2016a) 'Ketchup clothes: a catalogue of ideas', https://designforinteractivity.files.wordpress.com/2015/05/part-1.pdf

Shah, K. (2016b) 'From Skip to Catwalk: An Investigation into Viable Pattern Cutting Techniques for Recycled Clothing.'. In: The Second International

Conference for Creative Pattern Cutting, 24th - 25th February 2016, University of Huddersfield, UK

Shah, K. & Kahabi, C. (2016) ‘Revolutions come in cycles: mapping new paradigms in fashion research and practice to social change’ in Fashion: Exploring Critical Issues 8th Global Meeting 5-7th September, Mansfield College, Oxford, UK https://designforinteractivity.files.wordpress.com/2016/09/revolutionscomeincyclesfinal.pdf

Wheeler, A. (2016) ‘Clothing Industry Wakes up to Sustainability in Recycling and Waste World: A Catalyst for Positive Change in the Resource Management Community’.

Whiteley, G. (2011) ‘Junk: Art and the politics of trash’, London: I.B.Tauris.

Wrap (2012) ‘Valuing our clothes: the true cost of how we design, use and dispose of clothing in the UK’ www.wrap.org.uk/clothes

CENTRE for CIRCULAR DESIGN

CIRCULAR TRANSITIONS

23–24 November 2016

Can Design-Driven Material Innovation Also Drive Circularity?

Marjaana Tanttu, Cindy Kohtala, Kirsi Niinimäki
(Aalto University School of Arts, Design and Architecture, Finland)

Abstract

Design-Driven Material Innovation is espoused as a win-win solution, for consumers, economies and circularity. However, there is little empirical research on its methods or outcomes. This paper presents the results of an ethnographic study that examined the first phases of a design-driven project in the field of textile fibre development.

Introduction

The resource intensity of the textile industry presents a pressing problem, exacerbated by overconsumption in Western countries and increased demand in emerging economies because of rising standards of living. Cotton, the most popular natural fibre, entails significant environmental and social problems, and polyester is petroleum oil-based. At the same time there is no efficient way of recycling these materials. There is a clear need for technological development related to recycling (Zamani et al. 2015).

But developing recycled and/or recyclable materials is not the only demand material developers are facing today. There is also increased emphasis to develop materials that increase the competitive advantage of European industries, meeting the needs of users and manufacturers (European Commission 2013a; 2013b). Integrating designers into early stages of material development has been suggested as one potential solution to these challenges, an approach sometimes referred to as Design Driven Material Innovation (DDMI). Recent research on material innovation processes, especially in the context of nanomaterials, also recommends adopting novel approaches (e.g. Linton and Walsh 2008).

Developing purposeful and commercially viable materials need not be limited to those produced from virgin resources; design-driven innovation can also be a tool in the development of materials for a circular economy. It even appears that a design-driven approach and developing systems for a circular economy have potential synergy, since they both require collaborative efforts targeted towards a material future. This study investigates the relationship of these two approaches through a project where designers and material scientists work together with market experts and the manufacturing industry to develop novel textile fibres from waste using chemical recycling.

Background

Recycling textile waste by developing new fibres and thereby higher value products is preferable to current practices, where much textile waste in Europe goes to landfill or to energy recovery (Zamani et al. 2015; Wang 2010). Increasingly, textiles and other materials are recycled into carpets, insulation materials, automotive components and other applications (Wang 2010; Valverde et al. 2013).

Such recycling processes can be made even more eco-efficient if the design phase considers recycling, remanufacturing and material recovery from the outset (Muthu et al. 2012). The emerging concept of Design for a Circular Economy (DCE) encompasses 'Design for X' practices that support circularity. The RSA's Great Recovery initiative, for example, has presented four design models or principles (RSA 2016) (Figure 1).

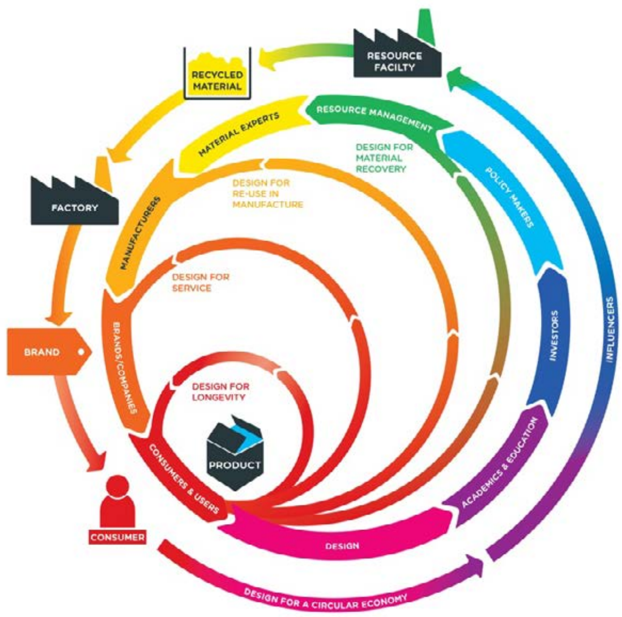


Figure 1: The Four Models of DCE (Source: RSA Great Recovery, used with permission.)

Furthermore, products and solutions could be developed that are novel and attractive to consumers: the principle behind Design-Driven Innovation (DDI) and Design-Driven Material Innovation (DDMI). While there are few academic studies on DDI,[1] its body of discourse in both policy and consultancy arenas is growing. This discourse is currently mainly divided into two branches. In the context of products, DDI as "innovation of meaning" is the most well-known approach, where developing appealing products creates new markets, in contrast to meeting current market needs (Verganti 2009). The second branch relates to European Commission policy and funding tools, where DDI is seen as a valuable strategy to increase European competitiveness (European Commission 2013a; European Design Innovation Initiative 2012). The aim is to enhance "European SMEs' ability to use design as a strategic tool in creating products and services with a higher value for their customers" (European Commission 2013a). Both branches endorse design being brought earlier into the value chain than is conventional.

The main focus in both DDI branches is on economic benefit and added value, but the EC's Horizon2020 Research and Innovation programme that funded the project studied here also highlights increased environmental sustainability as an explicit objective: funded projects should employ a DDI approach in order to strengthen creative industries by developing new materials from waste or by-products and new products with lower environmental footprint (European Commission 2013b). Verganti himself (2010) has also claimed the superiority of design-driven approaches to meet sustainability goals. However, the empirics of how design of this kind can contribute to circularity have been little articulated,[2] the actual tools and methods in DDI are neither widely known nor codified, and the inevitable trade-offs encountered in such processes are easily hidden by policy rhetoric.

How the DDI focus on added value encounters circularity ambitions requires careful examination. Our research question in this paper is the following: does the adoption of a design-driven innovation process appear to help or hinder circularity-oriented material development processes?

In this study we concentrate on the first phase of the project. We focus on the project workshops, the main means for working together where

1 the body of literature on DDMI is scarce and strongly reflects the discussion on DDI

2 including what may be important differences between material development and product development

otherwise geographically dispersed participants (usually about 30 people) meet face-to-face. The workshops provide the primary platform for collaborative project work and decision-making. We present our data and methods in the next section, followed by the key findings.

Methods

This study is based on data gathered with ethnographic methods in the first nine months of the project, entailing the first three workshops. The data set includes fieldnotes (8 sets), photographs (1240) and audio (32 hours) and video recordings (21 hours) taken by the first two authors as participant observers, as well as workshop materials such as presentations, worksheets, agendas and minutes. The various data materials were summarised in notes, and portions of the recordings seen as important were transcribed, those incidents conveying conflict, confusion, facilitation etc. In collaborative analysis sessions, two themes of added value and circularity and the research question for this study were identified. Accordingly, the notes, fieldnotes and transcripts were coded by the first two authors independently using thematic analysis (Braun and Clarke 2006). The three authors then discussed the coded documents in several analysis sessions.

All three authors have worked in the project as participant observers, with varying proportions of participation and observation. The main workflow of the project has been planned by other participants, but we have contributed to workshop planning by participating in meetings and giving feedback prior to and after the workshops. Participation in these in-between-workshops activities has also provided insights into the process for the authors, but this information has not been used as primary data.

Findings

In this phase of the project, the 'front end', the design-driven approach was actualised particularly in ideation (or envisioning) activities, such as brainstorming and scenario building. These activities were not carried out by designers alone but performed collectively in the workshops, an approach that was considered non-traditional by material scientists. In our observations, the designers appeared to push the boundaries of what was seen possible, to push the imagination and level of 'innovation' aspired to, while the manufacturing and technical experts tended to remind the others of realistic constraints. However, when the purpose of the 'high-flying' envisioning exercises was less clear to participants, and when the realistic 'grounding' in material circumstances was absent, some dismissed the scenario work as irrelevant to their own role and became disengaged. Another insight relates to collaboration on goal setting and what arose as important for the participants. Added value as an objective was discussed throughout the project workshops, which is not surprising considering the design-driven nature of the project. The number and diversity of partnering organisations may also have contributed to the frequent discussion on what exactly this added value of recycled material should be, and for whom to add value. As a special case of customer value, the concept of quality was constantly on the table.[3]

D1: "If you accept that the fibre and material will be weaker than this extreme strength, you have other benefits, the softness of it, a low level of pilling. You might have this origin, it comes from somewhere,
it might be authentic, you have this colouring and your clothes are different from others on the store shelf; in that case it might have a lower carbon footprint."

R & D1: "I guess for some products, people don't use them for so long, (….) [I]t doesn't matter if it looks good for only four washes, because some people maybe use it four or six times, (...) so I don't think high quality is important in all products."

D2: "There are some processes that don't take water when dyeing; it's not a matter of fibre, but just a process innovation (…) [I]n this case the benefit is not perceived by the end user, it's just a B2B benefit."

R & D2: "Bacteria very much likes to stay in this material more than on natural fibres for example. (…) (W)hen you take a shirt of polyester, after…"
M1: "The smell (…) of polyester."
D2: "For anti-smell treatment or another kind of treatment, it's necessary to work on the fibres, or no?"
R & D3: "It's really hard to work on the fibre level, you work on the fabric…"

3 In all quotes: D1, D2, D3 = designers; M1, M2 = manufacturing industry representatives; R & D1, R & D2, R & D3, R & D4, R & D5 = research and development experts, either in academia or a company

D2: “No, I mean, sorry, if I have to make an anti-smell treatment...”
R & D2: “Fabric, fabric.”
D2: “Just on the fabric. So it's not necessary to take the fibre into consideration?”
R & D3: “It depends, for example if you want to have this kind of effect permanent, for example antibacterial or anti-stain, you can work on the fibre level. But if you just use spin finish, plasma-treatment, after washing, several washes...”
D3: “It comes away.”
R & D3: “Yeah.”
D3: “So is that a question for us, is there a benefit for the end-user to engineer it into the fibre?” (…)
R & D2: “There is one limitation, that is the cost. Treatment on fibre is also more than one degree of magnitude more expensive than on the fabric.”

These excerpts illustrate not only the range of discussions on added value (for the end-user and the manufacturer), but also an almost constant challenge: it was not clear where certain properties should be added in the long value chain of fashion and textiles. As a result, the conversation bounced from the level of fibres to products, to fabric structure, to marketing, and back to fibres.

In addition, due to the aim of developing novel fibres from waste, circularity was explored through several lenses in the workshops. Challenges related to using recycled material were acknowledged, in sourcing, separation, recovery and consumer perception. Further recyclability of project outcomes, the required percentage of virgin material added into the loop and the possible number of recycling loops were mentioned several times. Especially the topic of dyes was frequently on the table, both in the context of current recycling practices and future needs:

R & D3: “It’s because they [a particular company] know what kind of pigment they dye the polyester with, so they know how to remove it easily. Also with spin finish and other finishes, it takes more energy to recycle if they don’t know what kind of finish is used. They will use more energy to recycle them, and it’s no longer an environmental process.”

M2: “For eco-products, new dyes must be developed which can be removable.”

However, instead of raising 'added value' issues and circularity issues as separate topics, they were most often discussed together and weighed against each other:

R & D2: "[I]f we want to have high quality and total recyclability, then we're pushing too much towards what we cannot have."

D3: "This one that is blended has a longer life, but the problem is we have to recycle it. So we have to be conscious of the lifetime of the product we are making; there are benefits to keeping it pure, but also drawbacks."

R & D4: "We are speaking now of recyclability, and then it competes with topics of durability, quality expectations, reusability."

R & D5: "What I see here about this discussion is a lot about how to increase the value, so how to make it even better, really exciting, but our problem is we are actually starting from (...) the pile of waste."
(…)
"[T]hinking ahead for the next generation, instead of now devoting all our efforts in making new and better materials, it's just the same materials but really intended for recycling, so that's what I personally would like to see there on this board."

M1: "I don't see that a recyclable product will have some additional characteristic, something more. But the idea is a recyclable product and people would like recyclable products, because they care about the planet."

These excerpts show how potential trade-offs and challenges were acknowledged and discussed, particularly tensions between added value and material circularity, and product longevity and circularity. These trade-offs were not limited to technical issues or 'silos' such as 'cost' and 'benefit', but involved many issues across the value chain. Moreover, over the timespan of the project phase we observed, the differing perspectives on goals, challenges and trade-offs were represented relatively equally in the discussions: no one perspective or set of interests clearly dominated. This appears to be due to the way the workshops were organised. Here, especially the manufacturing and technical experts were actively objecting if ideas drifted towards unrecyclable, unsustainable or unfeasible options. By the same token, technical research and development experts were exposed to end-consumer points of view that may not be represented in conventional material development; the majority of these comments were contributed by designers, manufacturing representatives or market experts. This study therefore emphasizes how such open discussions on trade-offs were fostered by the multi-professional interaction.

Discussion

As seen in the previous section, a significant part of the project discussions focused on topics of added value, quality and circularity. Such a plurality of goals may be seen as one of the potential benefits of DDMI in the context of circularity. Sustainability issues can easily be overruled by other priorities as a project progresses, but in this project concerns about customer expectations, economic viability and sustainability were equally raised in discussion. Sometimes participants had differing views about potential conflicts or synergy between added value and technical feasibility. These differences may result from diverging perceptions on quality and added value. Some project participants seemed to regard high quality as a standard product feature, whereas others may have expected it to be something better than the majority of existing options. In future phases and future projects, clarifying different aspects of customer value, such as tangible and intangible value (European Commission 2013b), may open up some issues that now appear to be trade-offs, making them more amenable to evaluation and prioritisation.

The high occurrence of concepts like quality and recyclability also suggests that two different DCE models emerge as important for the project. Discussions around quality, customer value and extended product lifetime, probably stemming from the design-driven origin of the project, have been described in the literature as elements of Design for Longevity (cf. Page 2014; Van Nes and Cramer 2005). On the other hand, Design for Material Recovery is obviously linked to material recovery processes and making products recyclable (cf. Rose and Ishii 1999). The fact that added value and recyclability were most often discussed together can be seen as a signal that these models compete with each other, at least to a certain extent. Some literature is emerging about the applicability of different DCE models to different product areas, such as suggestions to use short-life, closed-loop items to complement more durable and classic products (Earley and Goldsworthy 2015). Once the project proceeds, either a choice between these models needs to be made, or their compatibility needs to be solved. The latter possibility shows how DDMI has innovative potential in the context of a circular economy. As was raised in the workshop discussions, there are indeed some real-life challenges in making high quality products out of waste (the mid-grey arrow in Figure 2), at least in the field of fashion and textiles. And similarly, when designing products primarily for long life, for example by using blends and additional finishes, one will eventually have to deal with the recovery of these products at the end of their life (the darkest grey arrow in Figure 2).

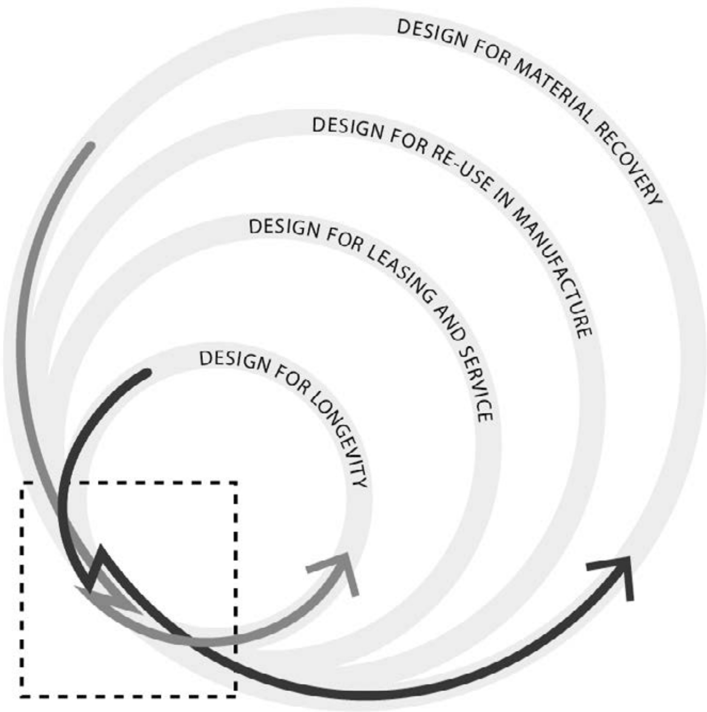


Figure 2: Challenges in reconciling two DCE models, as discussed in the project. Adapted from The Four Design Models (RSA 2016).

Conclusions

This paper contributes to existing literature by opening up the potential challenges and benefits of the Design Driven Material Innovation approach by observing what actually happens in such a process. Zooming into a particular context of DDMI work enables the evaluation of these challenges and benefits with respect to expected outcomes, in this case circularity of textiles. The results of this study suggest that a plurality of goals can prevent sustainability or end-user points of view being forgotten in the flow of the process. The design-driven approach can also contribute to circular solution development by enabling the recognition of important trade-offs early in the process. It can increase the discussion between different professional fields through more activities that are collaborative and 'visionary'. At the same time, more attention needs to be paid to communicating the meaning of these activities to all partners. If the aim of activities that are targeted outside participants' own professional area remain unclear, people are at risk of becoming disengaged. These results come from the early stage of the project, and the researchers will continue to observe the process to clarify their findings and contribute to academic knowledge about DDMI processes.

This study also pointed out topics for future research. For example, the vast amount of discussion about dyes and colour has already made clear that further research on this topic, from consumer, manufacturer and material recovery points of view, is needed. The dialogue on quality and recyclability showed that it is an opportune time for a richer discussion on the different design models for a circular economy, especially the ones focusing on product longevity and recyclability. It is not yet clear how these models are connected. Will these design models run in parallel in our fashion system, rather than integrated, and will they also contribute to different material cycles? Or can DDMI actually function as a tool for bringing these approaches together? Further discussion on these topics would help both material developers and designers to understand the actual professional challenges they will face when entering the era of a circular economy.

References

Braun, V. and Clarke, V. (2006) *Using thematic analysis in psychology.* Qualitative Research in Psychology, 3(2): 77–101.

Earley, R., Goldsworthy, K. (2015) *Designing for Fast and Slow Circular Fashion Systems: Exploring Strategies for Multiple and Extended Product Cycles.* Paper presented to PLATE conference, Nottingham Trent University, UK, 17/19 June 2015. Available at: http://ualresearchonline.arts.ac.uk/8352/2/PLATE15_Earley_Goldsworthy.pdf [Accessed October 24, 2016]

European Commission (2013a) *Implementing an Action Plan for Design-Driven Innovation* [Commission Staff Working Document SWD(2013) 380], European Commission. Available at: http://ec.europa.eu/growth/industry/innovation/policy/design/index_en.htm [Accessed July 3, 2016].

European Commission (2013b) *Topic: Materials solutions for use in the creative industry sector* [Horizon2020 Funding Call NMP-18-2014], European Commission. Available at: https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/226-nmp-18-2014.html [Accessed July 4, 2016].

European Design Innovation Initiative (2012) *Design for Growth and Prosperity: Report and Recommendations of the European Design Leadership Board,* Helsinki, Finland: DG Enterprise and Industry, European Commission.

Linton, J. D., Walsh, S. T. (2008) *A theory of innovation for process-based innovations such as nanotechnology.* Technological Forecasting and Social Change, 75(5), 583-594.

Muthu, S.S. *et al* (2012) *Carbon footprint reduction in the textile process chain: Recycling of textile materials.* Fibers and Polymers, 13(8), 1065–1070.

Page, T. (2014) *Product attachment and replacement: implications for sustainable design.* International Journal of Sustainable Design, 2(3), 265-282.

Rose, C. M., Ishii, K. (1999) *Product end-of-life strategy categorization design tool.* Journal of Electronics Manufacturing, 9(01), 41-51.

RSA (2016) *Designing for a circular economy: Lessons from The Great Recovery 2012-2016*, London, UK: RSA Action and Research Centre, The Great Recovery. Available at: https://www.thersa.org/globalassets/pdfs/reports/the-great-recovery---designing-for-a-circular-economy.pdf [Accessed April 21, 2016].

Valverde, I.C. *et al* (2013) *Development of New Insulation Panels Based on Textile Recycled Fibers.* Waste and Biomass Valorization, 4(1), 139–146.

Van Nes, N., Cramer, J. (2005) *Influencing product lifetime through product design.* Business Strategy and the Environment, 14(5), 286-299.

Verganti, R. (2009) *Design-Driven Innovation: Changing the Rules of Competition by Radically Innovating What Things Mean*, Boston, Massachusetts: Harvard Business Press.

Verganti, R. (2010) *User-Centered Innovation Is Not Sustainable*. Harvard Business Review, March 19. Available at: https://hbr.org/2010/03/user-centered-innovation-is-no [Accessed April 22, 2016].

Wang, Y. (2010) *Fiber and Textile Waste Utilization*. Waste and Biomass Valorization, 1(1), 135–143.

Zamani, B. *et al* (2015) *A Carbon Footprint of Textile Recycling: A Case Study in Sweden.* Journal of Industrial Ecology, 19(4), 676–687.

Acknowledgements

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 646226.

Towards a Quantified Design Process: bridging design and life cycle assessment

Kate Goldsworthy (University of the Arts London, UK), Sandra Roos (Swerea, Sweden), Gregory Peters (Chalmers, Sweden), Gustav Sandin (RISE, Sweden)

Abstract

In this paper the authors describe how design researchers and environmental researchers, in the ongoing Mistra Future Fashion programme (2011-2019), are making a joint effort in overcoming the disciplinary barriers for collaboration. By comparing existing processes and identifying potential opportunities arising from inter-disciplinary collaboration the aim is to propose methods for building a bridge between disciplines. A model for "quantified design" is generated, and explored, relevant for designers, design researchers as well as LCA researchers.

Introduction

There is broad consensus that the sustainability challenges of the fashion and textiles industry could be better met through a multi-disciplinary approach (Börjeson et al., 2014). Designers, design researchers and environmental researchers need to collaborate, but there can be difficulties in doing so, with scientific analysis and creativity seemingly at odds, even when both are aiming towards better environmental solutions. It is not unusual to design multi-disciplinary research projects, however, the administrative project set-up is seldom enough to bridge the disciplinary gaps (Sandin et al., 2014). There is also need for inter-disciplinary understanding to provide joint results. The overarching aim of the Mistra Future Fashion project is to attain 'systemic change' in the Swedish fashion industry leading to sustainable development. This aim requires collaboration from actors across multiple disciplines including design, material and social sciences. In order to combine the highest level of research across these disciplines towards a common goal it is essential to move towards a common language and means of combining insights in all areas. In this project researchers are attempting to find solutions and best practice towards this aim. This paper explores the interrelation of two stakeholders (design & environmental science) through proposing a pilot project to combine their processes into a singular and interrelated approach. The scientific theory development behind the design research process and the environmental science research process have both similarities and differences.

The LCA Model

The key environmental assessment process in use in Mistra Future Fashion is Life Cycle Assessment (LCA) as defined by the ISO 14040 standard (ISO, 2006). LCA is today an important holistic process for comparison of alternative solutions for environmental performance improvement, used by governments, industry and academia. The relevance for policy-making has increased the recent years, as the European Ecodesign Directive (European Commission, 2009) as well as the European Commission initiative for Product Environmental Footprint (PEF) are based on LCA (European Commission, 2013). LCA is commonly performed in multi-disciplinary research projects (Sandin et al., 2014). In using LCA for environmental research, the limitations of the method should also be known. LCA assesses exclusively to impacts that are potentially caused by physical inflows and outflows between the analysed system and the ecosphere, and caused during normal and abnormal operating conditions of the included processes, but excluding accidents, spills, and the like (European Commission, 2010). The environmental aspects that cannot be quantified are excluded, and important qualitative information may be lost. The absence of some important sustainability aspects in LCA has encouraged the development of other life cycle thinking processes such as social LCA and life cycle costing. The latter evaluates financial impacts of alternative products, while the former considers the social impacts associated with product design. As the application of SLCA to fashion design is relatively new (Zamani et al, 2016) and the methods are controversial (Arvidsson et al, 2014) it will not be discussed further in this article.

LCA differs from many other processes in the chemical and environmental sciences in that it is based on systems analysis (Baumann and Tillman, 2004). In systems analysis, method development is commonly based on empirical experiences from case studies (inductive or abductive perspective) (Miser and Quade, 1985). The classic chemical and environmental sciences are very often based on the deductive perspective, often using reductionism to test theories of cause-effect, though the biology branch of environmental science early discovered system-level effects (von Bertalanffy, 1968). Dubois and Gadde (2002) describes the abductive logic-based systematic combining approach as particularly useful for development of new theories, letting theoretical framework, empirical fieldwork, and case analysis evolve simultaneously, in case studies where when the boundaries between phenomenon and context are not clearly evident. As systems analysis methods are difficult to validate, case studies can also be used to provide proofs of concept (or calls for adjustments) of the developed method and theory (deductive perspective) (Miser and Quade, 1988).

The Design Model

Systems thinking is also at the centre of the design model adapted by design researchers in this project. However, unlike the LCA process the 'system' is explored and tested through the realisation of a 'prototype'. In many ways the whole iterative experience of designing can be described as prototypical. Although the prototype itself can take on different roles within the design research itself. Design researchers in Mistra Future Fashion have been using the 'prototype' as both a 'thinking process' (setting the future scenario) and as a 'proposal for evaluation' (a future product ready to be analysed).

Firstly, by building prototypes based on a future scenario towards a systemic ideal researchers are adopting a speculative design approach. This approach based on Dunne & Raby's vision (2013) of design as a 'tool to create not only things but ideas.' In this version of design, speculation can inform how 'things could be' to imagine possible futures. In order to propose 'systemic change' an understanding must be reached of the changes and impacts that can be affected. Both 'intended and unintended consequences' of design decisions must be considered throughout the 'whole' lifecycle of the product in close collaboration with scientific partners.

Tim Brown (IDEO), in Change by Design, cites the production of prototype in design, as a fluid system for the exploration of ideas: 'Design thinking is inherently a prototyping process. Once you spot a promising idea, you build it. In a sense, we build to think.'

'Innovation starts with a story about the future. Imagining and sharing desires and fears about the futures is a way for all of us to shape it… By articulating the changes needed to bring a preferred future to life, we can fix the shape of the future in a previously uncertain landscape.' (Bland & Westlake, 2013, p18)

'By creating scenarios around these 'what if' questions with tangible and realistic objects, designers can fabricate an experience of that possible future. Looking forwards in time allows us to imagine problems that might still be beneath the surface or factors that are unknown but plausible or possible.' (Nesta, 2016)

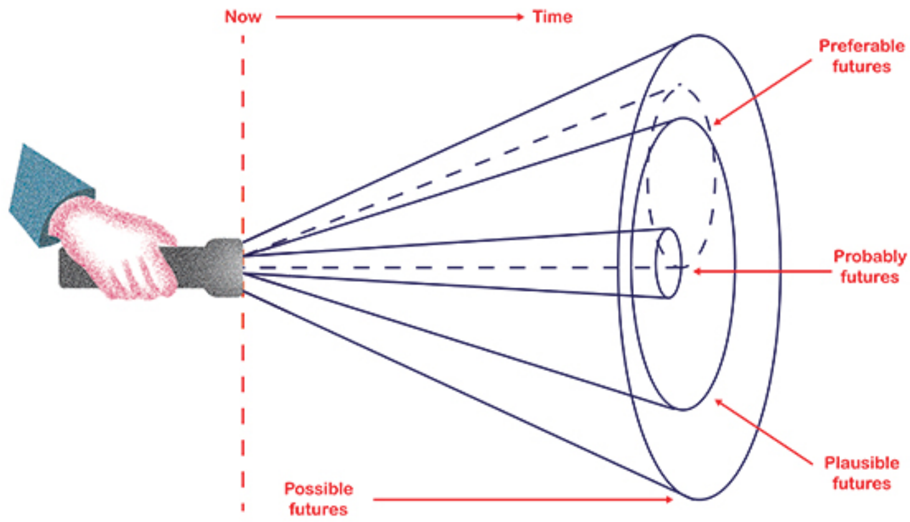


Figure 1. Nesta (2016) The Futures Cone diagram above imagined the cone as a torch beam. Available at http://www.nesta.org.uk/blog/speculative-design-design-niche-or-new-tool-government-innovation

Secondly, the prototype can act as a focus for cross-disciplinary discussion and communication of ideas, in the hope that these ideas will go some way towards changing mindsets, an essential aspect towards achieving systemic change.

To achieve sustainability through design, collaboration across disciplines can reduce the potential damage resulting from existing practices. A product can be redesigned to improve its overall performance, by understanding its context in a system. 'Re-directive practice' results in what Fry describes as design 're-coding': 'the exposure of the unsustainable and the declaration of means of sustainment.' When this is embodied in a prototype, the reflective 'conversation' takes place in a series of project revisions. As a result of surprise realisations or 'backtalk' from the prototype, the designer can test, redesign and collaborate with other disciplines and ultimately, with the consumer, who can become part of the prototype community. (Winograd.1996)

When the models clash and integration is needed

Experiences in the first phase of the programme (2011-2015) showed that practical integration of the work of designers and environmental assessors was an interesting challenge. For need for designers to be empowered by creative flexibility during the design project hampers the LCA analyst's desire to be as clear about the goal and scope of the LCA at the outset as possible. The focus on design principles and conceptual approaches to sustainability for example embodied in TED's TEN (http://tedresearch.net/teds-ten/) differs from the desire for numerical quantification of impacts, which is embodied in LCA and LCA-based ecodesign methods and tools. These different needs and desires lead to different vocabularies for expressing garment sustainability among designers and environmental assessors.

Current Combined Models

The list of available methods and tools for utilising LCA results in decision-making in product design processes, so-called 'ecodesign', is extensive. For example, Bovea and Pérez-Belis (2012) presented a summary of available environmental tools together with a taxonomy, and Pigosso et al. provided another overview of 112 ecodesign tools together with a scheme for diagnosis of the current maturity profile of a company's product development and proposal of the most suitable ecodesign practices to be applied (Pigosso et al., 2013). Some of the most famous ecodesign method developers relate to product design (Charter and Clark, 2008; Boks, 2006; Lindahl, 2006; Dewulf and Duflou, 2004; Luttropp and Lagerstedt, 2006; McAloone and Bey, 2009). Although the proposed ecodesign methods have a number of common elements, they do not occur in the same order. Important common elements include the process of transparently defining stakeholders in the design process, defining the product to be designed, identifying the supporting systems, detailed options analysis (for example, using lifecycle assessment tools) and synthesising strategy. These approaches provide useful guidance for the integration of LCA and design in Mistra Future Fashion.
The process of integrating the fashion design research and environmental science processes has however not been studied before. Many studies show that the implementation of ecodesign is not so simple as to make methods and tools available even if the tools are at hand the problem is rather that they are not used enough. The theories and research areas

about ecodesign implementation in both product development and research processes can be categorised as:

- frameworks for categorising companies maturity in incorporating sustainability considerations in their product realization (Alakeson and Sherwin, 2004; Pigosso et al., 2013).
- the role and challenges of integrating ecodesign in the early product development, the fussy front end, and the two different processes for development of new products on the one hand and incremental development of existing products on the other hand (De Medeiros et al., 2014).
- the main obstacles of successful integration of ecodesign include the same areas of concern that general organisational and product development issues but also in particular lack of motivation and competence (Baumann et al., 2011; Jönbrink and Melin, 2008; Sandin et al., 2014).
- addressing 'the soft sides of ecodesign' as an important area of research, increasing the knowledge of how to work with the weak link between attitudes and behaviour, motivation and responsibility in decision making (Boks, 2006)
- the language and communication playing a crucial role, and the under-researched link between ecodesign proponents and the executors (technical experts, decision makers and marketing experts especially) (Charter and Clark, 2007)

More work is needed to study how the particular characteristics of fashion design research and LCA research can be integrated.

Method

The proposed method for the study involves an integration of the design research and environmental science methods into a combined process which for the purposes of this paper is called 'quantified design'. It will involve a number of multidisciplinary workshops where both research processes are merged and responsive to one another, building a new understanding, whereby the impact on the environment acts as an integrated part of the design brief and informs each stage in the design concept development.

Process for Combined Model

The proposed 'combined model' can be broken down into the following steps:

Garment Level Case Study
(narrative development based on LCA factors)
Several prototype garments are under investigation in the second phase of the research programme), among them a paper jacket, a laser-finished recycled polyester dress and an upcycled polyester shirt, all from the 2015 'Textile Toolbox' exhibition (Earley & Goldsworthy, 2016) and will act as case study objects for this inter-disciplinary analysis. Typical questions around the prototypes will be posed from design researchers to LCA researchers based around the product lifecycle scenarios: what if they are worn more times, produced locally, require less washing etc. Typical questions from the LCA researchers to the design researchers might be: what are the prototypes meant to represent, what is the aim of the LCA study etc. This part of the proposed 'combined model' process will be used to highlight and record potential obstacles for collaboration such as the different perspectives, agendas, vocabulary etc.

The outcome of this stage in the process will be a fully developed 'lifecycle narrative' which is informed by the LCA metrics and allows our speculative design prototype to be assessed in terms of these impacts even before it is a physical product. Assumptions will of course need to be made about its production methods, material construction and use among others, but by deciding on these assumptions collaboratively with scientist and design bringing different perspectives it is hoped that the resulting narrative might be closer to an industry reality than might otherwise be achievable.

Assessment of Existing Case Study Narratives
Once these existing product scenarios are fully defined through the above process a second stage will involve an outline of the LCA implications of these case studies based upon the research carried our in the first phase of the project. These LCA narratives will then be further explored with the designers in order to refine and make sense of the case studies.

Scenario Development Based on Case Study Narratives (fast and slow adaptations)

Each case study narrative will then be developed further into alternative scenarios focussed on two main adaptations; one to extend the use phase of the garment through material and emotional durability qualities (extended life products) and another to shorten the use phase and focus on lighter production and efficient recycling (short-life products). These second-tier scenarios will be fully described as for the existing ones through a product narrative and specification.

LCA Implications of new Design Scenarios

The adapted product scenarios will then be reassessed by the LCA researchers in order to prompt discussions around where the key benefits of different design decisions may be. To what extent might these scenarios improve environmental impacts or create new ones at further stages along the lifecycle?

Realisations of new Design Scenarios (prototypes)

The final design concepts will be realised into creative material artefacts, or prototypes, which will act as communication and exploration of the combined process. The LCA insights become effectively part of the design brief and are responded to through this realisation process. This step may offer further insight which could lead to future developments.

Steps three to five may be rerun as cycles or iterations to refine both the narrative and the LCA analysis until it reaches a point of insight between both designer and LCA practitioner.

Results

Comparison of Research Processes

While science aims to explain how things are, design aims to explore how things should be by finding a solution to a problem and improving the current status quo. The problem itself can be something concrete like an unergonomic chair. But, the problem can also be as substantial as a public transport infrastructure or how a business should plan its goals. At either end of the scale, the aim of a design process is always to improve the future, which is why the future is often a dominant factor in different design activities.

Existing Separate Models

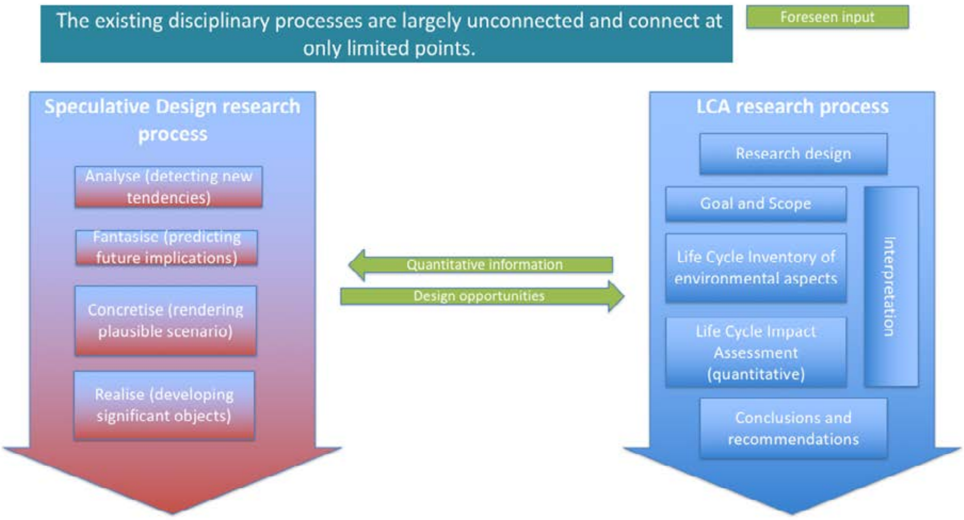


Figure 2. The Above figure demonstrates two existing but separate models for LCA and Design Research. These disciplinary processes are largely unconnected and interact only at limited points, whereby design outcomes might be used to influence the early stages of LCA modeling and LCA might be part of initial design inputs.

Proposed Combined Model

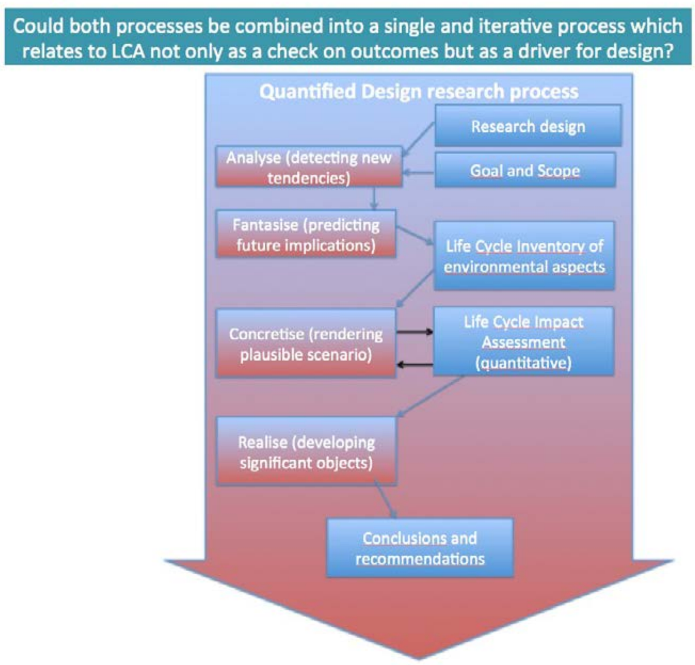


Figure 3. This combined model is a proposition for fully integrating the design and environmental science process into an iterative design & environmental process. To be tested through the Mistra Future Fashion programme Phase 2, 2015-2019

Discussion

The clash between the worldviews can perhaps be explained by the different perspective applied by design researchers and LCA researchers respectively regarding consequences. The consequential perspective can be divided into different orders (Sandén, 2012):

- 0 order consequences: direct physical effects
- 1st order consequences: linear systemic response (technical or physical mechanism)
- 2nd order consequences: systemic response governed by negative feedback (economic mechanisms)
- 3rd order consequences: systemic response governed by positive feedback (socio-technical mechanisms)

The zero order consequences are what LCA researchers generally put into the quantitative system model: resource consumption and emissions from real-life textile production processes. On zero order system level, the consequences of that a consumer buys a garment, are actually none. The garment is produced several months earlier and the effects on the environment have already occurred.

The first order consequences are often the main focus for the LCA researcher. Technical interventions in terms of new machinery, alternative chemistry and so forth, as well as physical interventions in terms of quantity of produced goods or new production locations are the focus for the LCA-based ecodesign guidelines. On the first order system level, the environmental gain is easily quantified and can be translated into the direct physical effects

The second order system level is where the design interventions begin to show. The garment design impacts the economic mechanisms, and depending on the size of the available stocks of products, the effects on first order system level arise at some point in time. At the second order system level, the consequences are no longer purely mechanistic, and LCA researchers part from the previous stricter physical process descriptions and begin to draw so called "scenarios" of possible first order consequences. The scenarios are more exploratory than descriptive and are aiming at capturing which decisions that might be environmentally beneficial or not

The third order consequences are systemic changes due to accelerating learning curves and institutional changes. Here is where the design researchers have their main focus. The fashion design development is no longer limited to incremental improvement of existing products but there is space for invention of fashion items with entirely new ways of meeting consumers' needs.

The proposed method for handling the clash of the models in the project is to visualize the differences. The two processes can then be combined into a single and iterative process of meeting and discussing the different worldviews in a set of workshops. The preliminary model generated for 'quantified design' is aimed to be inclusive enough to leave room for both engineering and artistic mindsets, and relevant for designers, design researchers as well as LCA researchers. This stands well in line with previous knowledge of ecodesign implementation seeing that the language and communication play a crucial role for success (Charter and Clark, 2007).

Conclusions

The sustainability challenges of the fashion and textiles industry could be better met through a multi-disciplinary approach. However, in the review of the literature on design models and ecodesign implementation, it was found that descriptions of practices for how design researchers and environmental researchers can overcome the disciplinary barriers for collaboration are scarce.

This paper aims to address this need by providing a practical example of the model in development by the authors. The background to this combined model has also been described, as it was performed in two steps. In the first step the literature on scientific theory development behind the design research process and the environmental science research process was investigated as a way to find similarities and differences that could contribute to mutual understanding. The disciplines were found to be quite far apart. While science aims to explain how things are, design aims to explore how things should be by finding a solution to a problem and improving the current status quo.

The second step was to combine the two different worldviews into a 'combined model for quantified design'.

Future work includes validating and improving the model by empirical case studies. Through the 'combined model/quantified design' process it is hoped that new insights may be drawn which relate scientifically based environmental impact research to the design process. By integrating these two models a new, iterative one emerges which places circular design at the centre of the design process and is backed up by scientific evidence. By developing scenarios which polarise the designed-in 'speeds' of a fashion product it is hoped that insight will be gained into the 'direction of travel' of impacts relating to fundamental design decisions. It is not intended that 'absolute' metric judgements will be made, rather that design decisions will be linked to impacts on a scale which a designer may understand and utilise in their process.

The project will be completed in 2018 and further results published through Mistra Future Fashion.

References

Alakeson, V., Sherwin, C. (2004) *Innovation for sustainable development.* Forum for the Future

Arvidsson, R., Baumann, H., Hildenbrand, J. (2015) On the scientific justification of the use of working hours, child labour and property rights in social life cycle assessment: three topical reviews. *International Journal of Life Cycle Assessment*, 20(2)161-173.

Baumann, H., Berlin, J., Brunklaus, B., Lindkvist, M., Löfgren, B., Tillman, A.-M. (2011) *The Usefulness of an Actor's Perspective in LCA,* in: Finkbeiner, M. (Ed.), Towards Life Cycle Sustainability Management. Springer, Springer Dordrecht Heidelberg London New York, pp.73–84

Baumann, H., Tillman, A.-M. (2004) *The Hitchhiker's Guide to LCA.* Studentlitteratur, Lund, Sweden.

Boks, C. (2006) *The soft side of Ecodesign*. J. Clean. Prod. 14, 1346–1356. doi:10.1016/j.jclepro.2005.11.015

Bovea, M.D., Pérez-Belis, V. (2012) *A taxonomy of ecodesign tools for integrating environmental requirements into the product design process.* J. Clean. Prod. 20, 61–71. doi:10.1016/j.jclepro.2011.07.012

Börjeson, N., Gilek, M., Karlsson, M. (2014) *Knowledge challenges for responsible supply chain management of chemicals in textiles – as experienced by procuring organisations.* J. Clean. Prod. 107, 130–136. doi:10.1016/j.jclepro.2014.03.012

Bland, J and Westlake, S. (2013) *Don't Stop Thinking About Tomorrow: a modest defence of futurology*, Nesta (available at http://www.nesta.org.uk/sites/default/files/dont_stop_thinking_about_tomorrow.pdf)

Charter, M., Clark, T. (2008) *Product sustainability: organisational considerations.* Int. J. Prod. Dev. 6, 251–275.

Charter, M., Clark, T. (2007) *Key Conclusions from Sustainable Innovation Conferences 2003-2006*, in: Sustainable Innovation Conference. Centre of Sustainable Design, University College for the Creative Arts.

De Medeiros, J.F., Ribeiro, J.L.D., Cortimiglia, M.N. (2014) *Success factors for environmentally sustainable product innovation: A systematic literature review.* J. Clean. Prod. 65, 76–86. doi:10.1016/j.jclepro.2013.08.035

Dewulf, J.R., Duflou, W. (2004) *Integrating eco-design into business environments: a multi-level approach,* in: Talaba, D., Roche, T. (Eds.), Product Engineering: Eco-Design, Technologies and Green Energy Sources. Springer, p. 539.

Dubois, A., Gadde, L.-E. (2002) *Systematic combining: An abductive approach to case research.* J. Bus. Res. 55, 553– 560.

Dunne, A., Raby, F (2013) *Speculative Everything: Design, Fiction and Social Dreaming*, The MIT Press (http://www.dunneandraby.co.uk/content/books/690/0)

European Commission (2013) *Commission Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations*. Off. J. Eur. Union 56.

European Commission (2010) *International Reference Life Cycle Data System (ILCD) Handbook—general guide for life cycle assessment—detailed guidance*, 1st ed. Publications Office of the European Union, Luxembourg. doi:10.2788/38479

European Commission (2009) *Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.* Off. J. Eur. Union 285, 10–35.

ISO (2006) *Environmental management – life cycle assessment – principals and framework.* International Standard ISO 14040. International Organization for Standardization – Geneva, Switzerland.

Jönbrink, A.K., Melin, H.E. (2008) *How central authorities can support ecodesign*. TemaNord, Copenhagen.

Lindahl, M. (2006) *Engineering designers' experience of design for environment methods and tools – Requirement definitions from an interview study*. J. Clean. Prod. 14, 487–496. doi:10.1016/j.jclepro.2005.02.003

Luttropp, C., Lagerstedt, J. (2006) *EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development.* J. Clean. Prod. 14, 1396–1408. doi:10.1016/j.jclepro.2005.11.022

Miser, H.J., Quade, E.S. (1988) *Validation*, in: Miser, H.J., Quade, E.S. (Eds.), Handbook of Systems Analysis. Volume Three - Craft Issues and Procedural Choices. John Wiley & Sons, Chichester.

Miser, H.J., Quade, E.S. (1985) *The context, nature and use of systems analysis*., in: Miser, H.J., Quade, E.S. (Eds.), Handbook of Systems Analysis. Volume One - Overview of Uses, Procedures, Applications and Practices. John Wiley & Sons, Chichester.

Mistra Future Fashion c/o SP (2016) Mistra Future Fashion [Document]. URL http://www.mistrafuturefashion.com (accessed 6.1.16).

Nesta (2016) http://www.nesta.org.uk/blog/speculative-design-design-niche-or-new-tool-government-innovation (accessed 12/08/2016)

Pigosso, D.C. a, Rozenfeld, H., McAloone, T.C. (2013) *Ecodesign maturity model: A management framework to support ecodesign implementation into manufacturing companies*. J. Clean. Prod. 59, 160–173. doi:10.1016/j.jclepro.2013.06.040

Sandén, B. (2012) *Standing the test of time: Signals and noise from environmental assessments of energy technologies.* Based on a paper presented at the Symposium on Life Cycle Analysis for New Energy Conversion and Storage Systems, Materials Research Society Symposium Proceedings Vol. 1041. Boston, MA, 2008.

Sandin, G., Clancy, G., Heimersson, S., Peters, G.M., Svanström, M., (2014) *Making the most of LCA in technical inter-organisational R&D projects.* J. Clean. Prod. 70, 97–104.

Textiles Environment Design (2014) *Textile Toolbox* [Document]. URL http://www.textiletoolbox.com/exhibits/ (accessed 6.1.16).

Von Bertalanffy, L. (1968) *General System theory: Foundations, Development*, Applicatio GeorgeBraziller, New York.

Zamani B, Sandin G, Svanström M, Peters G. (2016) Hotspot identification in the clothing industry using social life cycle assessment – opportunities and challenges of input-output modelling. *International Journal of Life Cycle Assessment*, article in press, DOI:10.1007/s11367-016-1113-x

Designing Cycles: An Interdisciplinary approach to coloured fashion & textiles

Dawn Ellams (University of the Arts London, UK)

Abstract

The interdisciplinary research presented was conducted at the design/technology interface. The research focused on the use of design thinking as means to explore the life cycle and end of life relationship between fibre, colour and design to address the challenges and limitations in reducing the environmental impact of coloured fashion and textiles through a cyclical approach to design.

The research evolves the traditional linear design process into a cyclical model; life cycle thinking and technical inquiry were incorporated within the design process to balance aesthetic value with environmental value. Design research was under-pinned by experimental research methods for textile and coloration technology, interweaving the creative outcomes with technical inquiry. Through this method of 'Cyclical Design' innovative approaches to colouring textiles were developed, examples of which are presented within the paper.

Introduction

The global textile industry faces significant challenges in addressing its responsibility towards a wide range of environmental issues. In aiming towards economic success, the industry has developed a dependency on non-renewable resources, consumes large quantities of chemicals, energy, and water, and generates large volumes of waste during production. Annually in the UK alone, 2.35 million tonnes of textile and clothing become waste, of this waste 13% goes to material recovery, 13% to incineration and a huge 74% (1.8 million tonnes) to landfill (Allwood et. al., 2006). Due largely to the chemicals used in production, especially at coloration and finishing stages, textile waste sent to and buried in landfill sites is not 100% biodegradable. As textiles degrade there is potential for harmful toxins to be released into the earth. It is reported that any textile derived from natural Consumer demand for low cost fast fashion drives the cycle of waste (Bhardwaj and Fairhurst, 2010). Waste is created at two key stages, firstly from industrial manufacturing processes then secondly when garments are discarded by consumers and sent to landfill. In developing solutions for sustainability within the fashion and textile industry this current linear model; produce, use, dispose, needs to evolve into a cyclical model where waste streams are utilized, product life times extended and end of life materials recaptured.

It has been suggested that decisions made at the design stage are responsible for 80 to 90% of product life cycle impacts (Graedel et al 1995). This estimate, based on the idea that design determines between 70-90% of product manufacturing costs is regularly used to highlight the role of the designer and the design process in reducing environmental impact. The idea that the design process can determine these financial and environmental costs was formalised in the Theory of Dispositions and is used by the European Union within the Eco Design Directive (Directive/ 2009/125/EC). Though an important framing for the role of design in creating environmental savings, methods and tools to support designers in the interdisciplinary understanding of the implications for material and process choices they make at design stage are vital in enabling them to make more sustainable decisions. This paper demonstrates the complexity of the challenge in creating sustainable coloured fashion and textiles where design is informed by science and technology through a through a developed interdisciplinary research model that crosses, is emerged within, and explores the ‘space between’ disciplines.

The research focus is on the designer understanding the life cycle relationship between fibre, colour and garment so to enable them to not only design the product, but connect the product to the processes within which it is produced and the life cycle within which it exists. Decisions made at the design stage not only determine the environmental impact of products but also whether the materials used for production exist within a technical or biological life cycle (Braungart & McDonough & 2002). The technical cycle involves a cycle of materials or products designed to be continuously returned into the cycle so as to create new materials or products. The biological cycle is the cycle of materials or products designed to be returned to nature through safely biodegrading after use.

It is argued that the highest impacts on the Life Cycle Analyses (LCA) of textile is due to fibre choice were the environmental impact of the clothing and textile industry begins (Allwood et al.,). During much of the twentieth century, we have relied heavily on fibres that have a detrimental environmental impact, namely the natural cellulosic fibre, cotton, existing within a biological cycle and the man-made synthetic polymer based fibre, polyester, existing within a technical life cycle. Cotton production requires extensive use of both arable land and fresh water during production as well as the use of fertilizers and pesticides (Ferrigno, 2012). Polyester production is heavily reliant on the naturally-occurring non-renewable resource, oil. (Hallet and Johnston, 2010).

Traditionally fibres were categorized as either man-made filament fibres (synthetic fibres), derived from petrochemical sources, or natural staple fibres. Natural fibres are fibres that exist in their natural state as either plant-based cellulosic fibres, animal-based protein fibres, or mineral fibres (Wilson, 2011). Concerns over diminishing oil reserves, which impact on the availability and price of petrochemical-derived (synthetic) fibres, and growing awareness of the pollution caused in producing cellulosic and protein fibres has driven research into the investigation of alternative more environmentally sustainable sources and methods of production for fibres. Developments in this area and the launch of alternative fibre types within the commercial market have required an expansion in the way that fibre types are categorized, especially by designers. The category of man-made (synthetic) fibres includes not only the traditional synthetic polymers but also a section for natural polymers, of both animal and vegetable origin that involve an element of synthetic processing. This latter sub-category has been proposed as encompassing regenerated cellulose fibres, such as, the fibre chosen for use in this study, made from sustainable farmed wood pulp.

Within the interdisciplinary cyclical model presented examples of work developed within the authors doctoral research (Ellams, 2016) using this framework are presented. The two examples ‘Sustainable colour’, utilizing the natural by-products of fibre production and ‘responsible colour’, where the biological cycle is disrupted through the introduction of synthetic dyestuff are based around the biological lifecycle of the regenerated cellulose fibre lyocell.

Lyocell

Lyocell is a regenerated cellulosic fibre that has strong environmental credentials (Taylor, 1998; Mather & Wardman, 2011). Lyocell was chosen for use within this study due to the biological cycle it exists within and its closed loop production process, the lyocell process, that increases its environmental performance when compared to other cellulose fibres such as Cotton. The manufacturing process uses, as its raw material, wood pulp derived from eucalyptus species, particularly *Eucalyptus Grandis, Urophylla, Nitens and Dunnii*, all of which are hybrids. These species are farmed on land described as 'marginal', i.e., unable to sustain agricultural crops. They are fast growing and have low requirements for water and pesticides. The manufacture of lyocell involves dissolving the pulp in N-methyl morpholine-N-oxide (NMMO) containing a small amount of water. The fibres are formed by a dry-jet wet spinning process in which the viscous, concentrated solution of cellulose is extruded through a spinneret into a water bath. The solvent, which is claimed to be essentially non-toxic and biodegradable, is recovered at a rate of 99.5% (Mather and Wardman, 2011). Unlike other regenerated cellulosic fibres, such as viscose, there is no chemical conversion involved, and the cellulose content of the pulp used to feed the lyocell process remains chemically unchanged in the final product. The lenzing lyocell process is illustrated in figure 1.

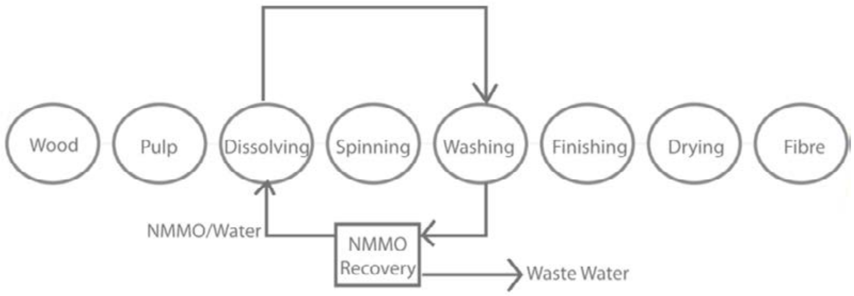


Figure 1. Lenzing AG closed loop Lyocell Process

The Interdisciplinary Research

It is recognized that to design future fashion and textiles that aim to be sustainable, informed design decisions based on both aesthetic and tactile qualities of fabrics and finishes as well as the environmental credentials of the raw materials being used are required (Hallet and Johnston, 2010). To achieve this sustainable design vision, a need for an interdisciplinary approach to research is recognised. The strength of interdisciplinary research is in the uniting of discipline areas in answering a question, or solving a problem that is too complex to be addressed by one single discipline (Darbellay et al, 2014; Thompson, Klein and Newell, 1997). Research within sustainable coloured fashion and textiles have largely splintered into two separate discipline approaches, either scientific or design based.

Developing the Interdisciplinary Relationship for the Research

The interdisciplinary research relationship was driven by the primary research question; can colour for fashion and textiles be sustainable? The areas of largest environmental impact within the production of coloured fashion and textiles were identified through existing research and life cycle assessment data and categorized within this research as life cycle 'hotpots'. Fibre production, coloration and finishing stages and final garment use/end of life were the key 'hotspots' identified as mapped and illustrated in figure 2.

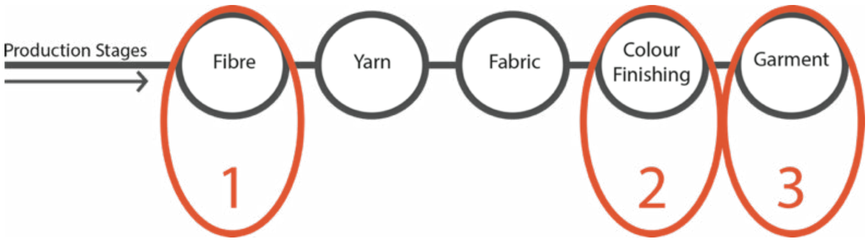


Figure 2. Life cycle 'Hotspots' identified then mapped to inform the interdisciplinary research relationship.

The lifecycle 'hotspots' were used to inform the interdisciplinary relationship required for the primary research question. This method established the discipline boundaries to be merged and explored within the research were; textile technology (hotspot stage 1), colour chemistry (hotspot stage 2) and garment/textile design (hotspot stage 3). The new interdisciplinary space, the space in-between these disciplines the research explored is illustrated in figure 3.

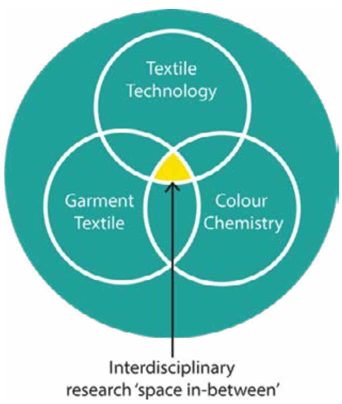


Figure 3. Interdisciplinary research relationship.

Discipline Organisation within the Space In-Between

A criticism of the organisation and undertaking of interdisciplinary research can be of the interaction across discipline borders (Sandin et al., 2014). Repko (2006, 2008) identifies the need for the devepment of interdisciplinary understanding within the design of the research process, suggesting a logical linear progression with the overall aim being to establish an interdisciplinary understanding of the complex question or problem being addressed through the research. Repko's process begins with the definition of the problem and disciplinary insights, leading to the integration of these insights within the separate disciplines and finally concludes with a general understanding of the problem. The framework developed within this research recognised, though establishing interdisciplinary understanding is an important stage, if the research aims not to conclude with only an understanding of the primary research question but to provide new solutions in response to the question then gaining understanding is only a stage within the process and not the purpose of the research. The purpose of interdisciplinary research relationship and process within this study aimed to answer a research question by providing new solutions/knowledge. To achieve this the researcher who was also the designer would be required to gain interdisciplinary knowledge as an outcome of the process.

Cyclical Design; An Interdisciplinary Methodological research approach formulated based on Design and Science

In developing the interdisciplinary framework for the research that would provide the required 'interdisciplinary knowledge', the creative and intuitive nature of the design process & creative experimentation was interwoven within the factual nature of the science established by technical experimentation to create an iterative loop in which one stage informed another. This framework was essential to establish 'interdisciplinary knowledge' in both the researcher and research outcomes, ultimately it is the knowledge gained through undertaking the process that is fed back into the research cycle and ultimately achieve the research outcome. The framework was structured into three sections, stage 1: interdisciplinary foundational, Stage 2: interdisciplinary research, stage: 3 interdisciplinary knowledge. The interdisciplinary framework developed for 'interdisciplinary knowledge is presented in figure 4.

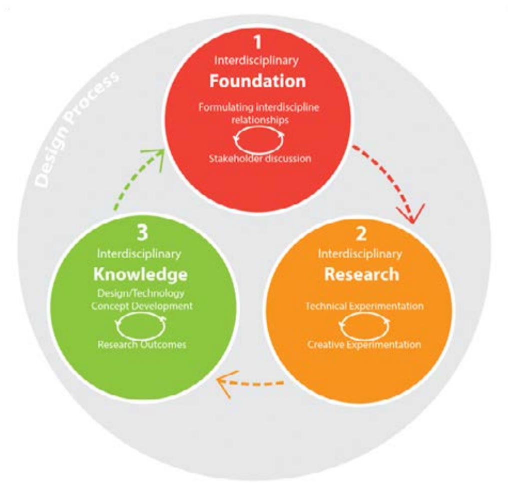


Figure 4 'interdisciplinary framework'

The 'mixed method' approach, the combining of varied quantitative and qualitative methods within the framework are shown in figure 5. These stages of research were used to draw technical conclusions that through critical reflection and technical analyses informed the designer and the choices made within the design process.

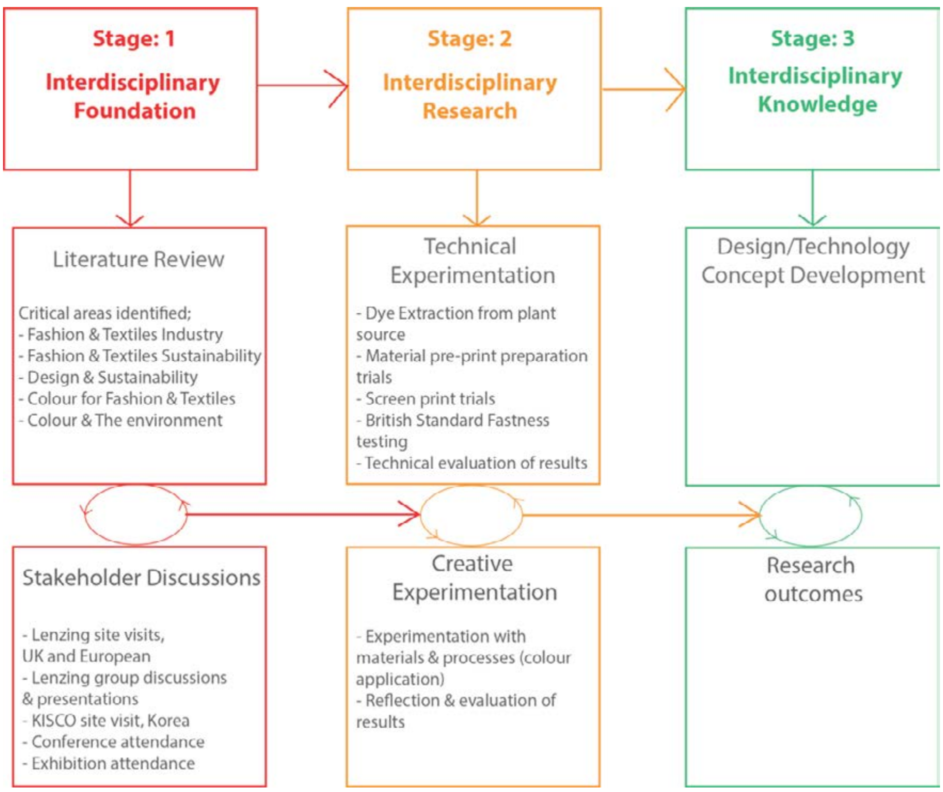


Figure 5. Interdisciplinary Research Stages

The framework can be used at varying intersection points to further inform/develop research findings. For example, having acquired interdisciplinary knowledge the researcher may be required to re-formulate the interdisciplinary relationship, or use the acquired new knowledge to feed back into the research and technical/creative inquiry within the same interdisciplinary relationship to create an alternative research outcome, examples of the various ways the framework can be explored once the first cycle is completed and 'interdisciplinary knowledge' is developed presented in figure 6.

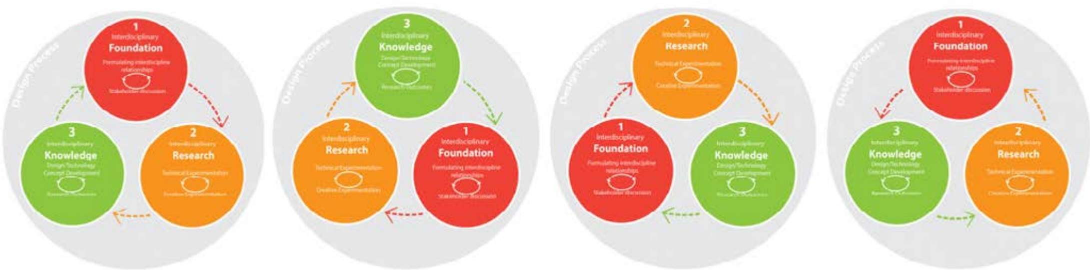


Figure 6. Development of framework

Designing Cycles: Using the Research Framework

Research outcomes, 'sustainable colour' and 'responsible colour' developed by working within the interdisciplinary space and research framework are presented. An overview of the framework process is given in figure 7.

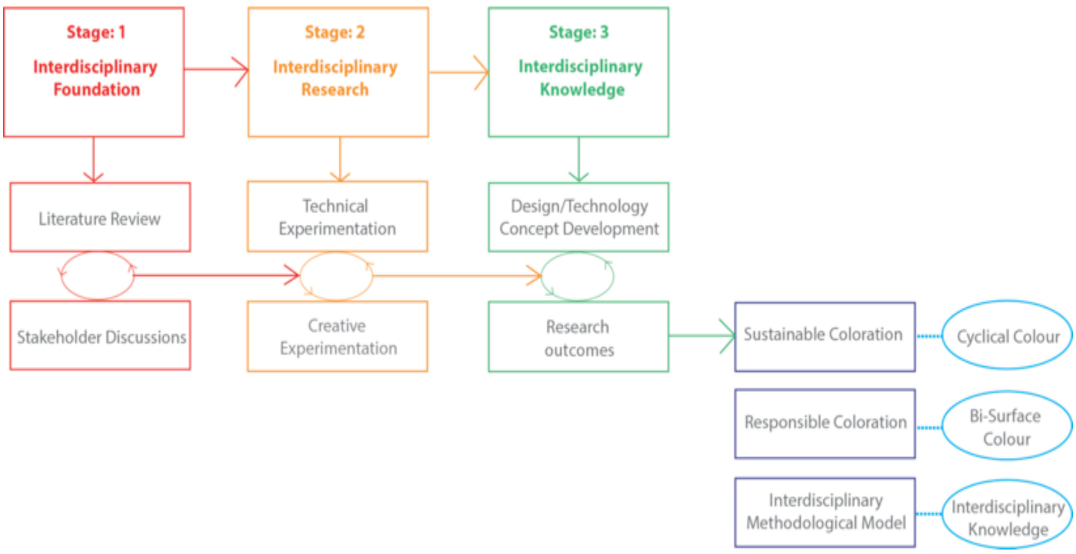


Figure 7. Research Framework for outcomes of sustainable and responsible colour.

Sustainable Colour

The lyocell fibre, in its greige, undyed nature exists within the biological life cycle. At the end of life, though the energy and materials used to produce the textile are arguably wasted, the fibre does biodegrade, and return to the natural cycle, illustrated in figure 8. Introducing colour within this lifecycle interrupts the biological nature of the cycle due to the addition of chemicals to the fibre. There are two broad sources of chemicals: natural and synthetic, which may be used to create colour for textiles: natural and synthetic. It is a common misconception to presume that natural inevitably means good and synthetic bad in terms of its effect on the environment.

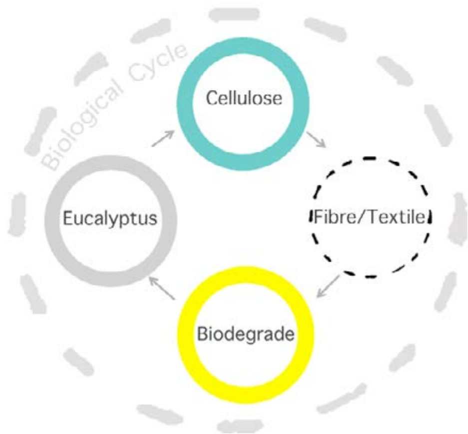


Figure 8. The lyocell biological cycle.

The dyes currently used for the industrial coloration of textiles are almost exclusively synthetic products of the chemical industry, manufactured from finite, non-renewable petrochemical sources (Christie, 2001). Application of these synthetic dyes to textiles generally involves intense use of chemicals, water and energy, with inevitable environmental consequences (Bide, 2007).

While it may be argued that natural dyes offer some environmental benefit compared with synthetic dyes, for example in terms of biodegradability and low toxicity, their use is not free of environmental impact (Glover, 1998). The cultivation of plants specifically for the production of natural dyes would require the use of a significant area of arable land, for which food production is a higher priority. Natural dyeing of textiles commonly requires treatment with a mordanting agent, usually a metal salt, the purpose of which is to fix the dye to fibres for which many natural dyes have little direct affinity, with inevitable environmental consequences (Bechtold & Mussak, 2009). In addition, natural dyes provide a limited range of colours and commonly show inferior fastness properties compared with their synthetic counterparts. The current systems for introducing colour and the lack of systems for recapturing colour at the end of life must be considered as unsustainable over the longer term.

The research applied the interdisciplinary cyclical design approach to designing natural colour, aiming to achieve sustainable colour. Designing coloured fashion and textiles from the fibre stage within the lyocell lifecycle identified opportunities for closed loop coloration by utilizing by-products from the lyocell fibre production to create colour, namely the bark and leaves of the eucalyptus plants that are used for fibre production. The research exploited the closed loop 'lyocell process', as demonstrated in Figure 9, to explore the utilization of by-products that have the potential to provide natural colorant for the coloration of fabrics constructed from lyocell fibres, in particular the grades referred to as Standard Tencel and Tencel A100. Natural colour was extracted from the leaves and bark, which are by-products of the sustainably forested eucalyptus from which the fibres are derived. No harmful chemicals were used at any stage and only water was used in the extraction process. Colour was applied to fabrics by screen-printing using gum tragacanth as a natural thickening agent for the print paste. The printing process was applied to fabrics without bleaching or the use of mordants.

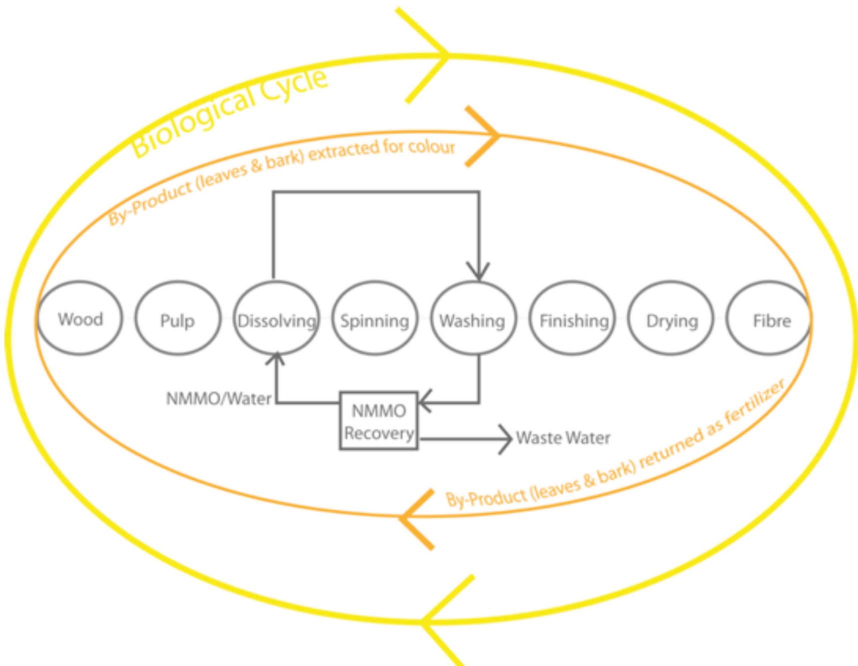


Figure 9. Sustainable Colour within the lyocell life cycle

The dye created within the research was demonstrated to provide a set of technical fastness properties comparable to those of the synthetic dyes that are commonly used to produce a similar colour (Ellams et al, 2014). This outcome, is the first example of colour being produced within a closed loop cycle, with only water required for extraction of the dye, and no mordant used for fixation, yet excellent technical performance were achieved. This result, though limited at this stage to one colour demonstrated in figure 10, has been successfully transferred as a model to other commercial fibre production and is proposed as providing a potential long-term solution for the commercial scale colouring of textiles without the use of synthetic dyes (Ellams, 2016).

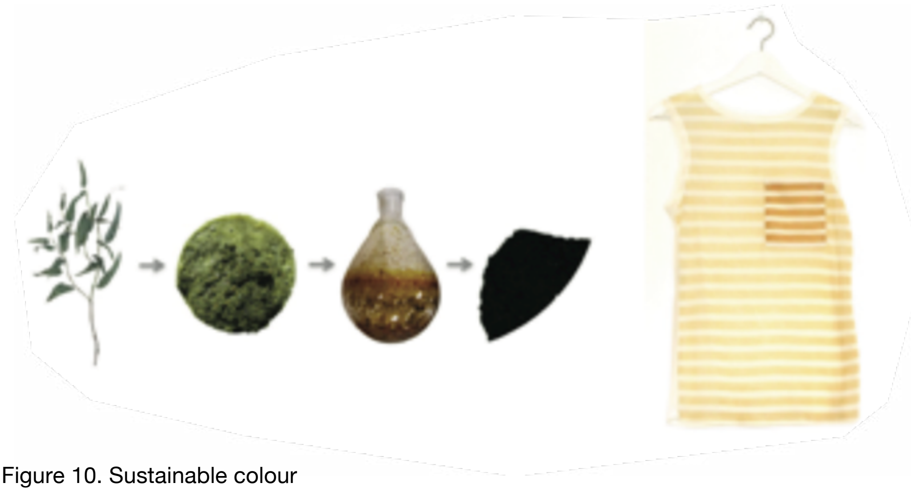


Figure 10. Sustainable colour

Responsible Colour

In contrast to 'sustainable colour', 'responsible colour' aimed to use the interdisciplinary framework to provide a more immediate, short-term approach to reducing the environmental impact of coloured fashion and textiles. The focus of the research was to explore methods for coloration that were as environmentally responsible as possible whilst expanding the colour pallet available to the designer. Synthetic dyes where explored and a range of reactive dyes from the Korean dye company KISCO, with improved fixation rates, the Synocron RD range, was selected for use based on their environmental credentials.

Having established the technically and environmentally most efficient synthetic dyes for application, technical experimentation developed a best practice method for the pre-creative stages of colouration where fabrics are bleached and scoured. The technical results concluded that Tencel does not need to be bleached and a gentle scouring process is adequate in preparing fabrics for printing (Ellams 2016). Design methods and methods of colour application were then explored aiming to further reduce the environmental impact of coloured fashion garments. The design concept of creating a surface that could have more than one face showing colour was inspired by consideration of the bi-functional nature of the reactive dyes. Colour technologists developed the bi-functional dyes to reduce environmental impact through increasing the number of functional groups within the dye molecule. The researcher was inspired by this concept to increase the functionality of fabrics by utilizing both surfaces, front and back, of fabrics. This feature allows garments to change their appearance simply through how the user decides to wear them. Outcomes from this phase of research explored creating bi-surface garments, in which both surfaces of fabrics have colour applied. Screen print and digital print stages were combined, and the processes streamlined, to provide a single fabric with two surfaces. This coloration method could then be used to create a prototype garment that had an extended lifetime through creating two garments within one.

Conclusions and Discussion

The methodological approach developed successfully achieved interdisciplinary knowledge in the researcher demonstrated through the research outputs, an approach categorized within the research as 'cyclical colouration'. The research demonstrated that addressing the environmental impacts of colouration stages through the interdisciplinary exploration of the lifecycle relationship between fibre, colour and garment solutions for sustainable and responsible coloration can be developed. However, the current methods developed are limited in the range of colours available to the designer.

The 'interdisciplinary knowledge' developed during this process is key in developing products that are not only technically informed but have designed waste streams, ultimately aiming to create continuous cycles where waste textiles feed new resources. In developing the technological understanding required to understand the environmental consequences of design decisions made through working within the proposed interdisciplinary framework, the researcher observed that it was through this interaction, between disciplines during the research process, that developed new methods of working and innovative solutions for sustainability, within the 'space in-between'. This stage was fundamental, ultimately the researcher was provided with Interdisciplinary knowledge that enabled the designing of life cycles.

References

Allwood, J.M., Laursen, S.E., Malvido de Rodriguez, C. & Bocken, N.M.P. (2006) *Well dressed? The present and future sustainability of clothing and textiles in the United Kingdom*. Cambridge: University of Cambridge.

Allwood, J.M., Laursen, S.E., Malvido de Rodriguez, C. & Bocken, N.M.P. (2006) *Well dressed? The present and future sustainability of clothing and textiles in the United Kingdom*. Cambridge: University of Cambridge.

Bechtold, T. and Mussak, R. (2009) Natural colorants in textile dyeing, in: T. Bechtold and R. Mussak (eds.). *Handbook of Natural Colorants*. Chichester: John Wiley & Sons.

Bhardwaj, V. & Fairhurst, A. (2010) 'Fast Fashion: response to changes in the fashion industry', *The International Review of Retail, Distribution and Consumer Research,* vol. 20, no. 9.

Bide, M. (2007) Environmentally responsible dye application. In: Christie, R. M. ed. Environmental aspects of textile dyeing. Cambridge: Woodhead Publishing Limited, pp.74-92.

Braungart, M. & Mcdonough, W. (2009) *CradletTo Cradle Re-making the way we make things,* London, Vintage.

Christie, R.M. (2001*) Colour Chemistry*. Cambridge: The Royal Society of Chemistry

Darbellay, F., Moody, Z. (2014) 'Interdisciplinary Research Boosted by Serendipity', *Creative Research Journal* Vol. 26, no 1, pp.1 – 10.

Directive 2009/125/EC. (2009) 'Establishing a framework for the setting of eco-design requirements for energy related products', *Journal of the European Union.*

Ellams, D., Christie, R. M., Robertson, S., 2014 'An Approach to Sustainable Coloration of Lyocell Fabrics by Screen Printing using Extracts of Leaves and Bark from Eucalyptus'. Coloration Technology, Vol.130, issue 1, pages 48-53, February 2014.

Ellams (2016), Environmentally conscious fashion through responsible coloration techniques applied to sustainable fabrics: colouring outside the lines, Heriot-Watt University.

Farrington, D.W. & Oldham, J. (1999) *Colour Technology*, vol. 115, issue 83. Hallet, C. & Johnston, A. (2010) *Fabric for Fashion, A comprehensive guide to natural fibres*, Laurence King Publishing Ltd.

Glover, B. (1998) Doing what comes naturally in the dyes-house. J.S.D.C., January, pp. 4–7.

Graedel, T.E., Allenby, B. R., (1998) Design for environment, Michigan: Prentice Hall.

Mather, R.R. and Wardman, R.H. (2011) *The Chemistry of Textile Fibres*. London: Royal Society of Chemistry.

Sandin, G., Clancy, G., Heimersson, S., Peters, G.M., Svanström, M., 2014. Making the most of LCA in technical inter- organisational R&D projects. J. Clean. Prod. 70, 97–104.

Slater, K. (2003). *Environmental impact of textiles, Production, processes and protection*, Woodhead Publishing Ltd.

Taylor, J.M. (1998) Tencel a unique cellulosic fibre. *J.S.D.C*, July/August, vol.114, pp.191–193.

Thompson Klein, J., & Newell, W. H. (1997). Advancing interdisciplinary studies. In J. G. Gaff, J. L. Ratcliff, & Associates (Eds.), *Handbook of the undergraduate curriculum: A comprehensive guide to purposes, structures, practices, and Change* (pp. 393–415). San Francisco, CA: Jossey-Bass.

Repko, A. (2008). *Interdisciplinary research: Process and theory*. Thousand Oaks, CA: Sage.

Repko, A. F. (2006). Disciplining interdisciplinarity: The case for text-books. *Issues in Integrative Studies*, vol. *24*, pp.112–142.

Wilson, J. (2011), *Handbook of Textile Design*, Wooddhead Publishing

CENTRE for CIRCULAR DESIGN

CIRCULAR TRANSITIONS

23–24 November 2016

The Material Affinity of Design and Science for a Circular Economy

Miriam Ribul (University of the Arts London, UK),
Hanna de la Motte (Research Institutes of Sweden, SE)

Abstract

This paper presents a design and material science collaboration in a science laboratory for regenerated cellulose. The material affinity outlines how both disciplines are connected through a materials practice in communication and production of cellulose films. The outcome presents new transdisciplinary approaches for design and science towards circularity of materials.

Introduction

This paper presents a design science collaboration at RISE Research Institutes of Sweden where a design researcher was a participant observer in a material science laboratory for regenerated cellulose. Design and science are connected through a materials practice, and by collaborations at the raw material stages of the lifecycle, a shared understanding of properties and behaviours may facilitate resourceful material circularity. The brief for the design residency was to explore how design and science can inform each other when working with regeneration of cellulose for a circular economy. To explore these questions, the design researcher was embedded in the laboratory work at RISE, documenting the scientific processes and introducing design tools into the scientific environment. The collaboration has lead to identifying that the exploration of a comparable material process in design and science can develop connected approaches in both disciplines. This was explored through making regenerated cellulose films in the science laboratory and bio-plastic films in a design studio lab. This paper proposes how material processes for design and science can evolve to establish a transdisciplinary practice for a circular economy.

A definition of the material affinity will outline how both disciplines explore materials with their hands. Key approaches to materials experimentation in both disciplines emerged from the lab work and studio practice. The outline of these approaches for each discipline will link to processes and tools for material experiments. The use of different language will demonstrate how this can create barriers and innovation in this context. A final map will field two new areas for design and science in a materials context.

Design and Material Science

The connection of design and technical science in a circular economy is that both develop their work through working with materials with their hands. According to Sawyer, both are connected through experimentation and creativity, and a will to create beautiful outcomes (2002). While scientists explore materials from the molecular level, designers work with the material properties that are perceived through the senses (Karana *et al*., 2014). The Encyclopaedia Britannica (Chisholm, 1911) definition of a chemical affinity is 'the property or relation in virtue of which dissimilar substances are capable of entering into chemical combination with each other.' As analogy, a material affinity defines how design and science can collaborate in a circular economy as they are connected through a materials practice. This was explored during a residency at RISE Research Institutes of Sweden, where the design researcher collaborated with the technical scientist to explore the scientific processes involved in the regeneration of cellulose. This paper maps how both disciplines work with materials, and proposes a model for a material affinity of the disciplines for a circular economy.

In a take-make-dispose linear system for textiles, recycling occurs at the end of the lifecycle and is disconnected from the material selection in the design stage. In Vezzoli's Life Cycle Design approach (2014), design considers the impacts of material selection for a product at the beginning of the lifecycle. In the Ellen MacArthur Foundation definition of a circular economy, materials at the end of their life are reinvested in a new loop (2014). This provides the need for material science and design to collaborate. There are other relevant stages for design-science to interact in a material lifecycle such as retail, distribution and use which connect to services, business models and consumer behaviour, however material science and design are linked through what is described by the Science Community Representing Education (SCOR) as practical work with materials (2008). The technical scientist who develops methods for closed loop material recycling at the end of life and the designer who selects a material at the beginning of the lifecycle are both connected through working with the same material, however with different aims.

This can be related to a question of scale, as described by Oxman (2016), '*The way we view our environment, and interact within it, is ultimately dependent on the lens through which we choose to see it. Choosing is no innocent act. A material scientist will generally explore the physical composition of matter through the lens of properties. A biologist, however, looks at the world not through the lens of properties, but rather through the lens of function. Both live in the same reality, but experience it altogether differently, and therefore act upon it in a singular way. If they could see both views simultaneously, they would link properties and behaviors*.' Ito (2016) argues for *'antidisciplinary'* approaches that '*move beyond "many sciences"–a complex mosaic of so many different disciplines that often we don't recognize when we are looking at the same problem because our language is so different and our microscopes are set so differently*."

According to Ito (2016) and Oxman (2016), design and science are located opposite each other in a coordinate plate. In these, design and science connect through art or engineering. Brown *et al.* (nd) explain how the exploration of a design science practice goes back to Buckminster Fuller's work in 1927 and Cross (2011) argues how efforts to bring design closer to the scientific method were unsuccessful.

Karana *et al.* have listed a range of projects that support collaboration between these disciplines, however designers are still evaluating how to move in the scientific domain (2015). Collaboration is a key word of our time to approach complexity where systemic change is what Rittel and Webber defined a wicked problem (1973). Increased funding pressure, large scale projects and competitiveness require efficient communication between disciplines for an immediate impact on environmental concerns. As both design and material science work with materials, we need to develop a connected practice for both disciplines in what Drazin calls 'material transformations' (2015) at each stage along the material lifecycle.

Material Approaches

Film-making

The residency at RISE Research Institutes of Sweden was split into two parts: one for observation and one for action within the science laboratory. However, the design role in this context varied from observation to action, and no linear separation of stages can be made. According to Reason and Bradbury, the methodology of cooperative inquiry in participatory design outlines that inquiries can be linear, Apollonian, or Dionysian, taking a ‘more imaginal, expressive, spiralling, diffuse, impromptu and tacit approach to the interplay between making sense and action’ (2006). Due to the context of the research where the outcomes were not defined and the approach was open (Muratovski, 2016), a Dionysian approach was chosen. According to Ito (2016), a participatory observer is part of a wider complex system and cannot describe the process in a linear way. The residency provided many potential outcomes for design and science collaboration. However, two main categories crystalised: the first is communication of materials, comprising language and presentation, the second is production or making of materials.

For the development of a practice that considers both design and science, regenerated cellulosic film materials were chosen for the analysis of processes in each discipline for the following reasons: both require similar processes for making in the science lab and design lab, as opposed to regeneration by dissolution and spinning processes that can not be replicated in a design studio due to technical requirements; the science collaborator noted how regenerated cellulose films and bio-plastic films have similar properties and can be achieved in both the design and science lab; the film material does not need a context for a specific product at this stage, and invites an experimental approach in both disciplines. Scientific research in cellulose films has been completed (Sundberg *et al.* 2013, Hameed 2009) and film making is also explored as a material process in design projects (Ribul, 2013; Lee no date; Nijkamp 2012). An initial exploration of cellulose films in the science lab supported a ‘quick prototyping’ approach where the scientist and colleagues were involved in exploring a new ‘recipe’ while the designer introduced design techniques into the laboratory.

The work in the science laboratory evidenced how design and science follow similar approaches of communication and production when working with materials, however at a different scale of materials and with different aims. This connects to Ingold’s two fields of anthropological enquiry of visual and material culture (2013): The former is apprehended through the senses, while the latter through making with materials. Table 1 and 2 compare general approaches of design and science in the practical exploration of cellulose films. The simplified structure is not to be considered in a linear way, as communication and production happen at several stages throughout the cellulose film making process. An equivalent to the scientific method for design does not exist, however the widely accepted design methodology of the double diamond developed by the Design Council can act as a useful framework for the design process (2005).

	Communication	
	Science	**Design**
Documentation	Lab book, excel, pictures, film clips, graphs and spectra, computing softwares	Sketch book, drawing, photography, visualisations, film, material samples, prototypes, descriptions, computing softwares
Communication and presentation	Conference presentations, scientific publications including data and method sharing for replication (retesting by others), internal and external reports	Visual format for presentations, press, web platforms, social media, exhibitions, films, animation, events and publications

Table 1: Communication approaches of design and science with cellulose films

	Production	
	Science	**Design**
Preparations	From observations, questions and problems to hypotheses, predictions and experimental plans	Sketch book, drawing, photography, visualisations, film, material samples, prototypes, descriptions, computing softwares
Techniques	Practical laboratory methods/settings and scientific instruments, computing and calculating methods	Practical design work through planning and making with design tools, textiles-specific techniques or development of new ones
Experimentation	Collection of data using the techniques, replication (iterations and recursions)	Sampling and prototyping using the techniques, iterations
Outcome	Correlations and regressions, conclusions (theories), products (such as different materials)	Process for design, visual outcome and product for use
Analysis and characterization	Data and product analysis, statistical analysis, external reviews	Analysis of experience of information and product by users

Table 2: Production approaches of design and science with cellulose films

The tables demonstrate how both disciplines follow parallel approaches in the development of practical work with materials in communication and production. According to Sawyer, the scientist aims to create outcomes that are clear, well communicated and presented (2002) and the collaboration evidenced how tools and language differ to design. Peralta and Moultrie have analysed how science explores a hypothesis of reality in the properties of materials, while design follows a vision for what could be (2010). To achieve results, both require what the Wikipedia definition of the scientific method outlines as intelligence, imagination and creativity (no date).

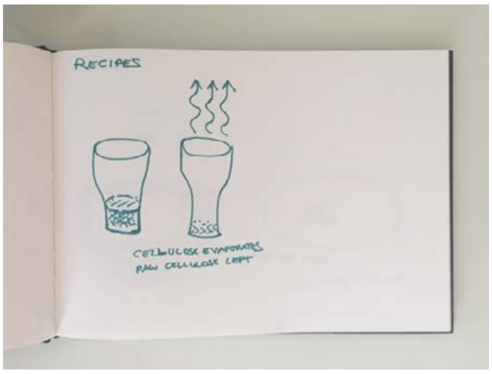
Cellulose films can be produced with shortened cellulosic fibres that are obtained from used cellulosic fibres, therefore link to the circular economy through providing a system for recycling at a later stage in the material lifecycle. Current research by Ma *et al.* (2015) and Östlund *et al.* (2015) into creating high value textiles by regeneration of cellulose fibres are reliant on a production model based on fibres, yarns, textiles and products, and a process where science has to go through engineered yarn technologies to design. This corresponds to Oxman's argument (2016) that science goes to design through engineering. To explore practice-based research that connects design and science without going through engineering, films provided a material process that connects both disciplines. Cross states that design knowledge is acquired through reflective practice, however in order for disciplines to collaborate it is beneficial to find a way to communicate this practice to the scientific method (2001). When working with cellulose films, what we explore is transdisciplinary, or as per Antonelli's definition 'knotty' (2015) as we require knowledge from different disciplines. This implies the complexity of a designer working in a lab and of a scientist exploring design tools.

The residency lead to a low-tech approach to making bio-plastic films in an improvised design lab (Anonymous 2013) that is comparable to processes for making cellulose films in the science laboratory. This ensured making was concerned with a similar material scale.

The inversion of design and science roles

The collaboration between design and science in the science laboratory lead to an inversion of roles. The designer observed processes of regeneration of cellulose in the science laboratory, finally producing a dissolution of regenerated cellulose. The designer introduced design tools into the scientific context of the laboratory: Sketchbooks, work sheets, prototypes and exhibition of samples. The scientist took lead when using the design tools provided for the collaboration. In a cooperative inquiry, where both the designer's and the scientist's questions were explored, the designer does not have the role of the facilitator.

A sketchbook was used to document the collaboration and communicate concepts between the designer and scientist. Both used this to write or draw during conversations. Differences in language can define scientific processes that can also be found in design, however the same words can have a different meaning in each discipline, leading to barriers in communication or innovation: For example, the discussion of an exploration of ‘films’ was introduced by the designer as a tool for communication, while the scientist described it as a material to explore production models. This lead to the collaborative exploration of regenerated cellulose films. For future design-science collaboration, selecting between communication or production can lead to a better understanding of the shared aims for the collaboration.



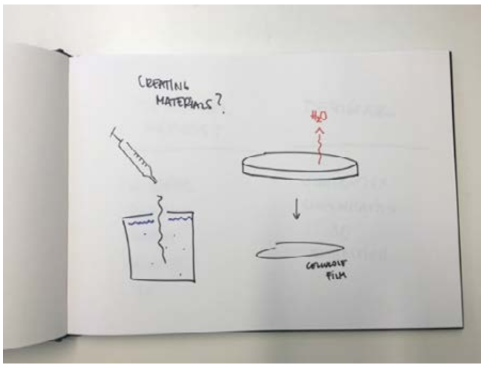


Figure 1 (left): Design sketch for communication of cellulose processes through film.
Figure 2 (right): Scientific sketch for production of cellulose films

Both disciplines encounter barriers to introducing new roles into a daily practice. The introduction of a sketchbook as used to visualise and present possibilities is an exception provided through the collaboration. A designer’s conventional practice is not linked to a science laboratory. Incremental changes to the practice were possible through the collaboration in the adaptation of tools from the other discipline: the scientist increased the use of images in scientific presentation slides, not to communicate results, however to engage a wider audience with a 3D representation of materials; the designer considered the scientific method in the production of material samples in the studio practice. This lead to expanded areas for communication and production for both design and science.

Figure 3 (left): Visual communication of cellulose dissolution in edited scientific microscope picture. Figure 4 (right): Cellulose film experiments in design studio

New Approaches for Design and Science

The residency evolved over a short period of time, and demonstrated initial results for how a collaboration of design and science can impact practical work with materials towards a material affinity. While design and science is often connected to the development of methodologies (Cross 2001, Brown *et al*. nd), according to Karana *et al.* there is no model for how these can inform each other through collaboration (2015). The practice described as 'antidisciplinary' (Ito 2014) or 'transdisciplinarity' (Lawrence and Deprés 2004), is one where individuals move fluently between disciplines such as design and science.

Figure 5 outlines the residency results in how design and science have informed each other's practice to lead to new approaches when working with regenerated cellulose films. While design follows a vision through its practice with the perceived qualities of materials at the macro scale of products in the first quadrant, science develops the scientific method through repeatable and tested processes starting at the material's micro scale in the third quadrant. For a closer connection of design and science in a circular economy, both designers and scientists have developed a transdisciplinary practice at a different scale of materials.

The design researcher has evolved an increased understanding of the scientific processes with regenerated cellulose, particularly through the scientific framework of materials and methods to create valid experiments that are repeatable and shareable. The understanding of the material at the micro scale provides a new input for design in a circular economy context: Design considers the scientific method through the development of valid material experiments in the fourth quadrant that are repeatable and tested to create material samples that can be up scaled and shared for a circular economy (Figure 5).

The scientist increased the understanding of the design processes for visualisation and communication of the material in a 3D format. Adopting a visual format in science will benefit a collaborative process, as it will provide designers with an increased understanding of the processes involved for recycling and end of life in a circular economy. Through images in presentations or through collaborations with designers to produce compelling prototypes, the new third quadrant for visual scientific communication can engage a wider audience (Figure 5).

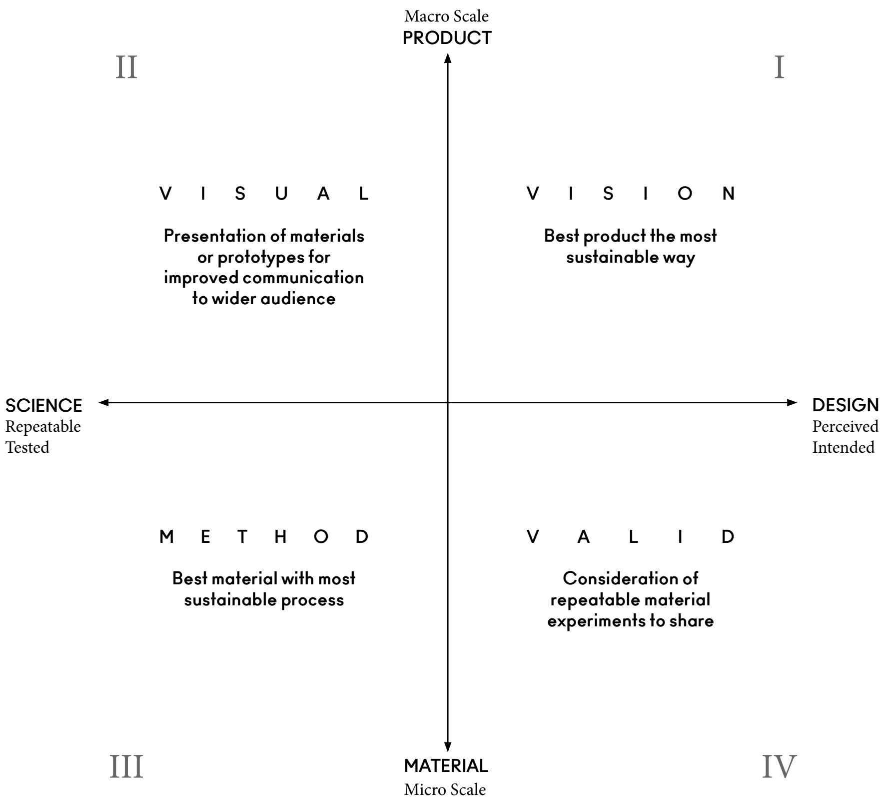


Figure 5: Design – Science Material Affinity diagram. Source: Ribul, 2016

The residency also highlighted a need for better communication informed by language. Both researchers have been working in cross-discipline collaboration before, and this supported the collaboration. Design and science differ in their development of methodology, and questions of explaining the design process for this context have emerged. Like in science, different materials and contexts require different approaches in design. How design and science can work together with materials will be further explored in future residencies, however the starting point is to develop an affinity of practice for a circular economy.

Conclusion

In this paper, we have outlined how design and science can develop new approaches for practical enquiry with materials for a circular economy. The collaboration has led to valid material experiments for the designer and visual approaches for the scientist for practical work with materials. While the designer in this collaboration has a keen interest in working with scientific processes of materials and the scientist is interested in exploring design processes, more work needs to be done to explore how both disciplines can effectively collaborate through the practice of materials to achieve a circular economy. It requires openness towards the development of new skills. Collaboration does not involve eliminating working in separate fields, as professional expertise in practical work in science as well as design are needed to achieve a circular economy. Time efficiency, distances between locations and funding are other barriers for collaboration. The luxury of exploration is to be balanced with results, however the freedom of un-linear approaches to collaboration can bring beneficial outcomes.

References

Antonelli, P. (2015) *Knotty Objects Summit at the MIT Media Lab*. Available at: https://www.media.mit.edu/video/view/knotty-objects-2015-07-16-01 (Accessed: 31 January 2016).

Brown, H., Cook, R. and Gabel, M. (no date) *Environmental Design Science Primer*. Available at: https://bfi.org/sites/default/files/attachments/pages/EnvDesignPrimer-BrownCookGabel.pdf (Accessed: 9 June 2016).

Chisholm, H., (ed.) (1911) 'Affinity, Chemical', in *Encyclopædia Britannica*. 11th edn. Cambridge: Cambridge University Press. Available at: https://en.wikisource.org/wiki/1911_Encyclop%C3%A6dia_Britannica/Affinity,_Chemical (Accessed: 6 July 2016).

Cross, N. (2001) 'Designerly Ways of Knowing: Design Discipline Versus Design Science', *Design Issues*, 17(3), pp. 49–55.

Design Council (2005) *The Double Diamond Design Process Model*. Available at:

http://www.designcouncil.org.uk/sites/default/files/asset/document/ElevenLessons_Design_Council%20(2).pdf (Accessed: 19 July 2016).

Design Council (2007) *Eleven lessons: managing design in eleven global companies*. Available at: http://www.designcouncil.org.uk/sites/default/files/asset/document/ElevenLessons_DeskResearchReport_0.pdf (Accessed: 19 July 2016).

Drazin, A. and Küchler, S. (eds) (2015) *The Social Life of Material: Studies in Materials and Society*." London: Bloomsbury Publishing.

Ellen Macarthur Foundation (2014) *Towards the Circular Economy Vol 3*. Available at: http://www.ellenmacarthurfoundation.org/assets/downloads/publications/Towards-the-circular-economy-volume-3.pdf (Accessed: 10 November 2015).

Ingold, T. (2013) *Making: anthropology, archaeology, art and architecture*. Abingdon, England: Routledge.

Ito, J. (2016) 'Design and Science', *Journal of Design and Science*. Available at: http://jods.mitpress.mit.edu/pub/designandscience (Accessed: 9 June 2016).

Ito, J. (2014) *Antidisciplinary*. Available at: http://joi.ito.com/weblog/2014/10/02/antidisciplinar.html (Accessed: 9 June 2016).

Karana, E., Barati, B., Rognoli, V., and Zeeuw van der Laan, A. (2015) 'Material driven design (MDD): A method to design for material experiences', *International Journal of Design*, 9(2), pp. 35-54.

Karana, E., Pedgley, O. and Rognoli, V. (2014) *Materials experience: fundamentals of materials and design*. Oxford: Elsevier.

Lawrence, R. And Deprés, C. (2004) 'Futures of Transdisciplinarity', *Futures: the journal of policy, planning and futures studies*, 26(4), pp. 397-405. Available at: http://www.sciencedirect.com/science/article/pii/S0016328703001885

Lee, S. (no date) *Biocouture.* Available at: http://www.launch.org/sites/default/files/systems2013_innovator_presentations/Biocouture.pdf (Accessed: 6 June 2016)

Ma, Y., Hummel, M., Määttänen, M. and Sixta, H. (2015) 'Upcycling of Waste Paper and Cardboard to Textiles', *Green Chemistry*, 18(3), pp. 858-866. Available at: https://www.researchgate.net/publication/283181773_Upcycling_of_waste_paper_and_cardboard_to_textiles (Accessed: 18 July 2016).

Muratovski, G. (2016) *Research for designers: a guide to methods and practice*. London: Sage Publications Ltd.

Nijkamp, E. J. S (2012) *Changing the perception of bioplastics*. Available at: http://repository.tudelft.nl/islandora/object/uuid:c49e021e-4986-4e6f-8eeb-991b7ea10eac?collection=education (Accessed: 15 July 2016).

Nishar, H. and Guo, Q. (2010) 'Blend films of natural wool and cellulose prepared from an ionic liquid', *Cellulose*, 17, pp. 803–813.

Östlund, Å., Wedin, H., Bolin, L., Berlin, J., Jönsson, C., Posner, S., Smuk, L., Eriksson, M. and Sandin, G. (2015) *Textilåtervinning: Tekniska möjliheter* *och utmaningar.* Available at: https://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6685-7.pdf?pid=15536 (Accessed: 5 July 2016).

Oxman, N. (2016) 'Age of Entanglement', *Journal of Design and Science*. Available at: http://www.pubpub.org/pub/AgeOfEntanglement (Accessed: 9 June 2016).

Peralta C., and Moultrie J. (2010) 'Collaboration Between Designers and Scientists in the Context of Scientific Research: A Literature Review', (from the Proceedings of the International Design Conference – Design 2010, Dubrovnik, Croatia, 17-20 May 2010). Available at: https://www.designsociety.org/download-publication/29510/collaboration_between_designers_and_scientists_in_the_context_of_scientific_research_a_literature_review (Accessed: 15 April 2016).

Ribul, M. (2013) *Recipes for Material Activism*. Available at: https://issuu.com/miriamribul/docs/miriam_ribul_recipes_for_material_a (Accessed: 7 November 2016).

Reason, P. and Bradbury, H. (eds) (2006) *Handbook of action research*. London: Sage.

Rittel, H. and Webber, M. (1973) 'Dilemmas in General Theory Planning', *Policy Sciences,* 4(2), pp. 155-169. Available at: http://web.a.ebscohost.com.arts.idm.oclc.org/ehost/pdfviewer/pdfviewer?sid=570b10da-cd76-4fa8-8634-807337ec254f%40sessionmgr4004&vid=1&hid=4206

Sawyer, R. K. (2006) *Explaining creativity: the science of human innovation*. Oxford: Oxford University Press.

Science Community Representing Education, SCOR (2008) *Practical Work in Science: A Report and Proposal for a Strategic Framework*. Available at: http://www.score-education.org/media/3668/report.pdf (Accessed: 5 July 2016).

'Scientific Method' (no date) *Wikipedia.* Available at: https://en.wikipedia.org/wiki/Scientific_method (Accessed: 6 July 2016).

Sundberg, J., Toriz, G. and Gatenholm, P. (2013) 'Moisture induced plasticity of amorphous cellulose films from ionic Liquid', *Polymer,* 54, pp. 6555-6560.

Vezzoli, C. (2014) 'The 'Material' Side of Design for Sustainability', in, Karana *et al.* (eds) *Materials experience: fundamentals of materials and design*. Oxford: Elsevier.

Acknowledgements

This PhD research is funded by the London Doctoral Design Centre (LDoc) of the UK Arts and Humanities Research Council. The residency was supported by the University of the Arts London and the Centre for Circular Design where Miriam Ribul is based, by the RISE Research Institutes of

Sweden, where Dr Hanna de la Motte is based, and a cohort of scientists: Dr Emma Östmark (RISE), Dr Sara Olsson (RISE), Dr Helena Wedin (RISE) and Dr Carina Olsson (Swerea IVF).

CIRCULAR TRANSITIONS

23–24 November 2016

RepairAbility Through Repair Thinking

Bridget Harvey (University of the Arts London, UK)

Abstract

Repair Thinking is a framework for extending material and object lifespan within a circular economy model, increasing personal skills through enabling RepairAbility in design and use. The proposed tenets of Repair Thinking are: Openness, Conscious Construction, Visibility, Expanded User, and Social Values.

Introduction

> Clothes are "remarkable instruments from which to build independence, and they can reveal our relationship to power if we take them seriously." (von Busch in Greer, 2014, p77)

This paper proposes that, as clothing is often repairable, through the use of my framework ‘Repair Thinking’, repair could be part of a circular fashion model, and reduce waste streams occurring through breakage.

RepairAbility: Repair-Making as Material and Social Action, started by investigating repair as a material action. Through my own studio practice, curation, and facilitation of repair workshops, I created a lens through which to examine repair as a social action/mechanism too. Observing the network building and dissolving, repetitive and one-off issues and resulting innovations, skills sharing and deployment occurring in act of repair (whether self-done or delegated) I developed Repair Thinking.

Repair Thinking is a series of co-strategies between designer and user for extending garment lifespan and personal skills through enabling RepairAbility. These strategies – openness, conscious construction, visibility, expanded user, and social values – ask both to, in part, think as one another would. Repair Thinking aims to change mindsets, to make RepairAbility a first thought by encouraging not just repair after breakage, but also before. Repair is often a post-break action, however ‘repair before the break’ – during the design process – is a rich area deserving its own acknowledgement and best practices. Seeing repair as prevention as much as cure, and designing for RepairAbility by looking at methods, systems and materials furthers the reach of repair, and extends clothing lifespans, as well as spreading repair responsibility between designer and user. In this paper, I am specifically focusing on clothing, but I am developing Repair Thinking to span disciplines, aiming for product longevity embracing change, circularity and reduced resource use.

Breakage Can Be a Good Thing

Breakage and repair embody many contradictions: a break may cause innovation (Jackson, 2014), make something work better (Burnham, 2011), create and destroy narratives, embrace old and new (Spelman, 2002). User-based maintenance (Salvia et al., 2015) only really works if it has been designed for, and if a reactive system is in place for breakages such as that demonstrated by Patagonia (n.d.).

Contradictions also appear in clothing: being “ephemeral and cyclic, referencing the past but constantly embracing the new; it represents an expression of personal identity and difference, while also demonstrating belonging to a group; it can be both an individual act of ‘performing’ ourselves, and a collective experience“ (Black, 2008, p17). Henry David Thoreau wrote about social contradictions and expression of identity, saying he felt there was “greater anxiety, commonly, to have fashionable, or at least clean and unpatched clothes than to have a sound conscience” (1854, p13). Clothing sometimes embraces aesthetics of breakage and repair; however, this recuperated look is often trend driven and so engages with the linear systems and current economic practices that Repair Thinking endeavors to step away from.

Breakage has potential as an opportunity more than a threat or end (Day Fraser, 2014; Graham and Thrift, 2007; Jackson, 2014), adding loops to the circular clothing systems by lifespan extension, delaying entry to waste streams.

The Circular Fashion website proposes 15 principles for circularity. Principle 13 – “Use, wash and repair with care” – is not to “be further explored as this website is primarily concerned with the producer perspective and those stages of a product’s life cycle on which producers may have direct influence” (n.d.) but as Kate Fletcher points out “repair and reconditioning strategies require more resources [than reuse of goods] and can involve a manufacturing infrastructure to provide parts and labour” (2008, p100). The Ellen McArthur Foundation model (n.d.) implies that to ‘maintain/

prolong' is a user responsibility to contact the 'service provider', yet this loop could include 'parts manufacturer' and 'products manufacturer'. The Royal Society of Arts model could include repair in 'Design for reuse in manufacture', and legislating for repairability (n.d.). Where the EMF and Circular Fashion models are mostly based on material processes, the RSA model, by including potential for legislation acknowledges future needs for a circular economy but does not focus on small actions, instead looking at a larger picture. My Repair Thinking model starts from a local and lo-fi perspective of material repair-making within the larger circular economy.

Terms Used

As Ravetz, Kettle and Felcey write, there is an anthropological assumption that "many of the properties associated with craft … are highly social and open to shared working." Drawing on Tim Ingold's description of 'meshwork', they say "objects, people and institutions are understood to be intimately interconnected" and potentially "co-created" (2013, pp2–3). Here, co-strategy refers to this collaborative and interconnected approach.

Meaning the person, persons or business creating and selling clothing, the 'designer' holds a toolkit of "materials and manufacturing", and crucially, of "idealism, intuition, … aesthetics, and an awareness of the ever-changing social, cultural, economic and political contexts in which products are born and will function (and all the intervening steps)" (Bakker and Schouwenberg, 2013, p376).

Consumers potentially have an "alienated relationship" with possessions, but "when people are approached as users, their humanity remains intact, and the designer can get a grip on the complex relationships people have with their day-to-day context." (Bakker and Schouwenberg, 2013, p380). By approaching consumers as (potential) users, Repair Thinking encourages evolution into "DIY citizens" – "critical makers" who, starting as consumers, become producers (Ratto and Boler, 2014, p5), or, in the case of repair, re-producers. 'User' therefor refers to those who are already users or DIY Citizens, or, optimistically, consumers who may transition to being users. The 'repairer', while potentially a user, designer, or both is here someone who is enacting a repair, whether this is a professional service, voluntary work, or home DIY. The professional clothing designer may be a repair amateur, and vice versa. And although mending is the term more commonly used in textiles, I use 'repair' for its meaning of returning to a working order – whatever that may be.

Repair Thinking

Openness

Open Design is described as “emphasizing innovation, sharing, and design itself” (Van Abel et al., 2011, preface), and as having a deliberate political agenda – “increasing transparency in the production chain, talking about responsibility” (Van Abel et al., 2011, p18). It aims to disrupt “macro-political movements that privatize the commons or control access”, by working on a deeper understanding of what we do when we make things (Van Abel et al., 2011, p19). In Repair Thinking this call for openness becomes acute when proprietary rights prevent repair, under threat of legal action or “bricking” and planned obsolescence (Wiens, 2012). Openness is, in part, a service from designer to user or repairer.

Figure 1: Drop-in clothing repair workshop at Central St. Martins, February 2015

Community repair classes such as those I host (Figure 1) are designed to offer a low risk environment in which learn to mending and increase confidence. Although demonstrating common techniques, these classes can be seen as an actual and metaphorical “dynamic repair” (Sennett, 2009, p238) through skills sharing and openness to different styles of repair needs. The workshops circumnavigate any lack of openness by providing direct access to skills, materials and workspace.

Clothing and clothing repair are already partially ‘open’ – we have access to patterns, tutorials and information. However, user willingness to ‘hack’ clothing – "necessarily post-production, with users working against the intention of the original author" and “respon[ding] to the intense occlusion and uncommunicative nature of the things with which we are now surrounded" (Maxwell, 2012, p23) – in order to repair and accepting the potential altered aesthetic, needs confidence. Stewart Brand argues that maintenance is material learning (1997). The emphasis on innovation, sharing and design might then be social openness – rather than meeting the “fixed target” of the “closed system” (Sennett, 2009, p38) and going no further than replacing broken clothing, Richard Sennett argues that repeated problem solving opens skills[1] (p38).

Openness in Repair Thinking actively encourages conversation between the user and the designer - tinkering, hacking and open source repair information – to shape repair into an action and outcome that works for both.

Conscious Construction

Conscious Construction is designer led and takes into account the “decisional burdens” (Graham and Thrift, 2007, p2) of repair, building on Openness materially. Facilitating repair through ease of deconstruction, universal and replaceable parts, as part of full lifecycle considerations, means that, in a design and use sense, “... repair and maintenance become not just secondary and derivative but pivotal” (Graham and Thrift, 2007, p6). Proprietal fixings are not as common in clothing as in electronic goods, however, bought clothing often does not include spares parts – e.g., buttons, patches of fabric. Repair Thinking asks the designer to consider how might the user access them – this could be a traditional approach (buttons inside shirts) or mail/online order from the retailer (fabric patches, branded parts), or the use of fixings purchasable from a haberdasher.

Where replacing a part like-for like might be considered a “static repair” (Sennett, 2009, p238), this does not make it any less pivotal. However, “dynamic repairs” (Ibid, p238) engage with the issue more deeply – should this zip be replaced with a better zip? –feedback can aid the designer. Then fixings and their replacement become part of the repairers toolkit as well as the designers, where

> “acts of repair are proving ground for all tools. More, the experience of making dynamic repairs establishes a fine but definite line between the fixed and all-purpose tool. The tool

[1] (Sennett, 2009) “When practice is organized as a means to a fixed end, the problems of the closed system reappear; the person win training will meet a fixed target but won't progress further. The open relation between problem solving and problem finding ... builds and expands skills, but this can't be a one-off event. Skill opens up in this way only because the rhythm of solving and opening up occurs again and again.”

> that simply restores is likely to be put mentally in the toolbox of fit-for-purpose-only, whereas the all-purpose tool allows us to explore deeper the act of making a repair" (Ibid, p200).

Working on a wide range of repairs, I see that, in order to facilitate Conscious Construction, encouraging the use of universal fixings, tools, and access to parts is vital. Where the repair is not possible at home (or the user does not want to do it) Repair Thinking encourages service provision.

Visibility

Knitter and textile repairer, tomofholland (van Deijnen, n.d.) is acknowledged as founding the Visible Mending movement, promoting skills, beauty and pride. Although repairing has similarities to a boycott - "a silent choice, made alone, … [which] is a poor way to sustain a sense of injustice and indignation" (Jasper, 1997, p264) - the use of the hashtag #visiblemending where "beautiful darn[s are] worn as a badge of honour"(van Deijnen, n.d.) show solidarity, collectivity and multiple actions. The often solitary and individual action of clothing repair becomes a visible mass movement through public documentation on social media.

Although brokenness can increase the visibility of the broken thing (Harman, 2002), repair also has a deep relationship with invisibility – as a lowly and phased-out task, associated with austerity and poverty (Strasser, 1999, p122). Invisibility can be used as a measure of success (Brand, 1997) – a good repair might be considered one that cannot be seen. Yet, a visible repair could be seen as a re-makers mark, where "marking an object can be a political act, not in the programmatic sense, but in the more fundamental matter of establishing ones presence, objectively" (Sennett, 2009, p144). As such, visibly repaired clothing such as my work Blue Jumper (2012, ongoing) (Figure 2), becomes a "subtle symbol"(Portwood-Stacer, 2013, p55), signifying a choice to repair (also seen in slogan tee-shirts, Figure 3) and to wear repair, establishing ones presence materially, potentially echoing Thoreau's moral statement, and/or a political statement of anti-consumption.

Going beyond visibility of repairs, Visibility as a strategy within Repair Thinking, asks that repairers and services are also visible. Users may not wish to do, watch or understand all (or any) repairing so this visibility builds knowledge, use and connections. According to the Sustainist Design Guide "'local' is becoming a value rather than a geographic marker" (Schwarz and Krabbendam, 2013, p38) about relationships: visibility helps build these. My work with the Hackney Fixers (n.d.) to map repair businesses in Hackney

(Figure 4) increases visibility of repairers, in turn increasing their use and relationships with their communities.

Figure 2: Blue Jumper (Harvey 2012, ongoing) Wool, Tencel, visible darning

Figure 3: Wearing repair slogans;

Figure 4: Mapping repair places in Hackney

Expanded User

User-centered design involves “the end-user, of the design artifact, service or outcome, in the (professionally guided) design process …to some expression of co-design” (Fuad-Luke, 2009, p108) and “aims to interrogate [their] needs, wants and limitations.” (Ibid, p155). Understanding how clothing is used, worn, laundered and why it is disposed of locally and globally may inform new cycles for clothing repair.

To propose repair as part of a sustainable circular economy, user experience and recommended improvements must be considered, but expanding beyond the human-user to being non-anthropocentric: as John Ehrenfeld says ”sustainability is the possibility that humans and other life will flourish on the Earth forever” (2013, p17) (my emphasis). Repair Thinking expands the concept of the user to include the environment within the designer/user dynamic: it therefore becomes an active participant in a flourishing and circular future.

Figure 5: Mend More Jumper at Climate March 2015

Repair Thinking’s environmental stance is obviously activist, against the “sell-by date” of trends where garbage creation exists “prior to any actual or obvious material degradation” (Scanlon, 2005, p37). By repairing, promoting repair, taking a cradle-to-cradle (Braungart and McDonough, 2009) approach, elongating lifespan before continuing back into the production system, but also by actions such as protesting (Figure 5), this expanded view of the user is expressed.

Social Values

John Thackara argues that fashion industries commitment to growth undermines contributions to eco-design and “leaves social and living systems worse off” (2014). In Repair Thinking, reconstruction of social and material tools, and values comes through the Craft-of-Repair and is mostly user and repairer driven. Richard Sennett tells us that “repair is a fundamental category of craftsmanship; today again, an expert is seen as someone who can equally make and repair” (Sennett, 2009, p248). The consequent redefinition of ownership and power by repairing come from the "acts of craft, [with which] we still shape forms of resistance. They are examinations of the seams of our social fabric and acts of disobedience" (von Busch in Greer, 2014, p77).

Repair is direct action. It is interventionist and anarchic, engaging with retrieval of clothing and repair skills from waste streams, customisation, anti-consumption practices, voluntary work (Earley et al., 2016), and sharing to cultivate key elements for well-being. Listed by Martin Seligman (2011, pp24–25) as being positive emotion, engagements, relationships, meaning, and achievement, these elements are subjective and objective, and in order to fulfill them, one must engage positively with others. As a way to “overwrite scarcity with abundance”, Neil Cummings advocates we “keep giving and receiving. This is radical generosity” (in herbst and Malzacher, 2015, p325).

These micro-challenges and actions by individuals and small groups, feed into the larger resistance needed to create macro-changes. Visibility of the Craft-of-Repair move it into an “active dynamic mode” where “in this diachronic role, clothing serves as a communicative device through which social change is contemplated, proposed, initiated, enforced and denied” (McCracken, 1988, p61). These actions together create the Social Values of Repair Thinking, where visibly repairing together or for one another is a form of radical generosity that can overwrite emotional and material scarcity, and create the connections needed for well-being.

Actions I take bring together not just users and repairers, but also multiple approaches. At The Big Fix 2016 (which I co-organised) (Figure 6) taught clothing repair was available, however repair of broken charity donations was an option for those who wished to engage differently.

Figure 6: The Big Fix, Stoke Newington Library, September 2016

Repair Thinking in A Circular Future

Repair Thinking (Figure 7) contributes to a sustainable and resilient repair culture, where maintenance and repair services are visible, accessible, paid or voluntary. Utilising materials, methods, systems, agents and narratives of repair to develop new ways of seeing and understand scales of doing, Repair Thinking is a social learning as well as a material one.

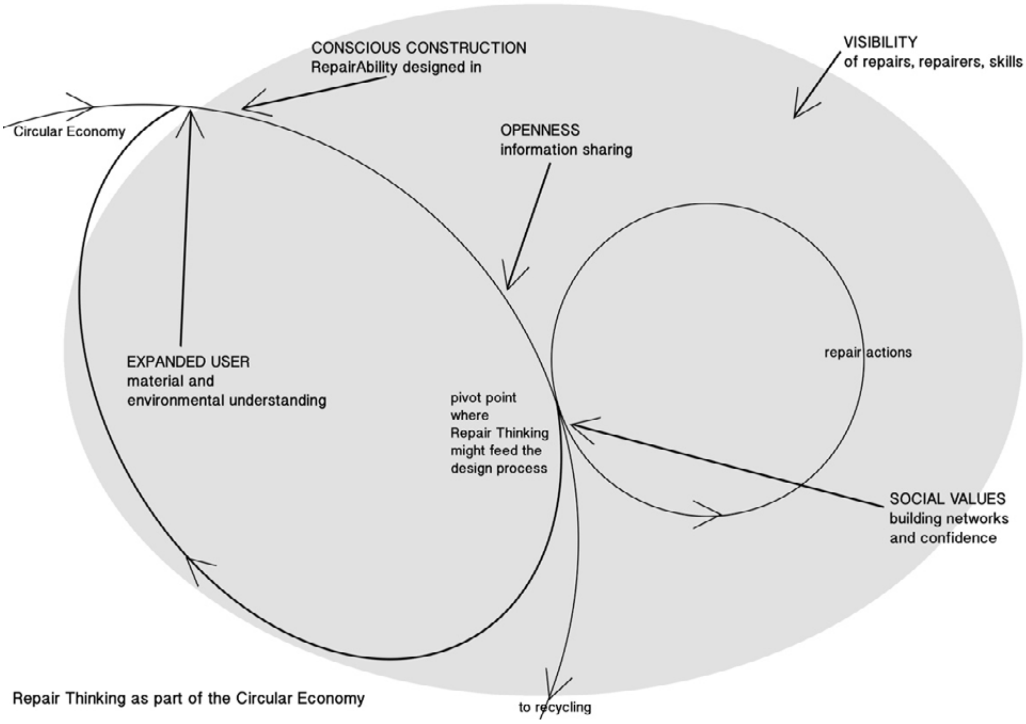


Figure 7: Repair Thinking diagram, (Harvey 2016)

That many people respond to the idea of repair – what they do and do not repair, who they learnt from or who in their family does it - suggests that it is still something that people are conscious of. However, one of its big challenges is the enjoyment that many take from buying new things, replacing the old, the worn and so on. Neoliberal practices do not often promote re-use or maintenance but as scarcity of materials grows, so does the repair dialogue, and its opposition to deskilling, waste and scarcity. In the face of current environmental and economic issues, Repair Thinking includes the local, the lo-fi and the individual as key solutions, and not just as part of the recycling chain. This refocusing towards extra loops on the Circular Economy model engage on multiple levels to bridge divides between designer and not-designer, Expanding the User, and potentially encouraging brand loyalty via Conscious Construction and Openness around parts, information and services.

Communities and businesses built around the Social Values of repair-making show a growing concern for repair. These are small actions in the face of production, consumption and disposal practices but demonstrate a growing grassroots movement, especially as some are replicated internationally, both as not-for-profit franchises and as independent models.

Conclusion

Repair could be considered a necessary skill for resilience, a way of passing time, of exploring and developing new skills, or, simply, just making something you need/want work. Repair Activism comes via application of political statement: it isn't necessarily inherent in the act alone. Repair always stands against replacing broken with new, but may not be contextualised as being an act of activism or resistance. Where a single repaired thing or act may seem insignificant, Visible processes and material manifestations of repair give further agency, moving materials and knowledge back into the use cycle, adding value to human-object relationships and creating communities. Repair then displays personal resistance and resilience in the face of relentless pressure to buy new, and encourages further repair-making.

Through this Repair Thinking acts as a dynamic part of a flourishing, radically generous, circular future.

References

Bakker, G., Schouwenberg, L., (2013). *I am a User, Not a Consumer*, in: Walker, S., Walker, H.L., Giard, J. (Eds.), The Handbook of Design for Sustainability. London / New York: Bloomsbury Academic, pp. 375–388.

Black, S. (2008). *Eco-Chic: The Fashion Paradox*. London: Black Dog Publishing

Brand, S. (1997). *How Buildings Learn - 5 of 6: The Romance of Maintenance.* https://www.youtube.com/watch?v=j_dozoqw4To (accessed 6/8/14)

Braungart, M., McDonough, W., 2009. Cradle to Cradle: Re-Making The Way We Make Things. Vintage, London.

Burnham, S., 2011. Break Things Better, in: Curatorial Cooking: The Design Practice of Platform 21. ArtEZ Press, The Netherlands.

Circular Fashion: Key principles [WWW Document], n.d. URL http://circularfashion.com/key-principles/ (accessed 6.3.16).

Day Fraser, H., 2014. CloTHING(s) as Conversation. Cloth. Cult. 1, pp155–169.

Earley, R., Norris, L., Harvey, B., 2016. Elastic Lives [WWW Document]. URL http://culturesofresilience.org/elastic-lives/ (accessed 6.1.16).

Ehrenfeld, J., Hoffman, A.J., 2013. Flourishing: A frank conversation about sustainability. Stanford University Press, Stanford, California.

Ellen McArthur Foundation, n.d. Circular Economy System Diagram [WWW Document]. Ellen McArthur Found. URL https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram (accessed 6.1.16).

Fletcher, K., 2008. Sustainable Fashion and Textiles: Design journeys. Earthscan, London.

Fuad-Luke, A., 2009. Design Activism: Beautiful strangeness for a sustainable world. Earthscan, London.

Graham, S., Thrift, N., 2007. Out of Order: Understanding Repair and Maintenance. Theory Cult. Soc. 24.

Greer, B. (Ed.), 2014. Craftivism: The Art of Craft and Activism. Arsenal Pulp Press, Vancouver.

Hackney Fixers, n.d. Hackney Fixers Repair Map [WWW Document]. URL http://sustainablehackney.org.uk/map/fixing (accessed 5.14.16).

Harman, G., 2002. Reversal: Broken Tools, in: Tool-Being: Heidegger and the Metaphysics of Objects. Open Court Publishing Company, Illinois, p. pp 44–49.

herbst, steirischer, Malzacher, F., 2015. Truth Is Concrete: A Handbok for Artistic Strategies in Real Politics. Sternberg Press, Berlin.

Jackson, S., 2014. Rethinking Repair.

Jasper, J.M., 1997. National Boycotts and Moral Outrage, in: The Art of Moral Protest: Culture, Biography and Creativity in Social Movements. Unversity of Chicago Press Ltd., Chicago, pp. pp262–266.

Maxwell, P., 2012. Understanding Repair, in: Useless: Critical Writing in Art & Design. Royal College of Art, London, p. pp 13–26.

McCracken, G., 1988. Clothing as Language: An Object Lesson in the Study of the Expressive Properties of Material Culture, in: Culture and Consumption. First Midland Book Edition, USA.

Patagonia, n.d. Patagonia Repair Service [WWW Document]. URL http://www.patagonia.com/eu/enEE/patagonia.go?assetid=5175 (accessed 4.30.15).

Portwood-Stacer, L., 2013. Lifestyle Politics and Radical Activism, Contemporary anarchist studies. Bloomsbury, London.

Ratto, M., Boler, M. (Eds.), 2014. DIY Citizenship: Critical Making and Social Media. MIT Press, Massachusetts.

Ravetz, A., Kettle, A., Felcey, H. (Eds.), 2013. Collaboraton Through Craft. Bloomsbury Academic, London.

RSA, n.d. The Great Recovery.

Salvia, G., Cooper, T., T Fisher, Harmer, L., Barr, C., 2015. What is Broken? Expected lifetime, perception of brokenness and attitude toward maintenance and repair. Presented at the PLATE Conference, Nottingham Trent University.

Scanlon, J., 2005. On Garbage. Reaktion Books, London.

Schwarz, M., Krabbendam, D., 2013. Sustainist Design Guide: How sharing, localism, connectedness and proportionality are creatuing a new agenda for social design. BISPublishers, Amsterdam.

Seligman, M., 2011. Flourish: A New Understanding of Happiness and Well-Being and How to Achieve Them. Nicholas Brealey Publishing, London.

Sennett, R., 2009. The Craftsman. Penguin Books, London.

Spelman, E., 2002. Repair: The impulse to restore in a fragile world. Beacon Press, Boston.

Strasser, S., 1999. Waste and Want: A Social History of Trash. Holt Paperbacks, New York.

Thackara, J., 2014. Keep Your Stuff Alive. Doors Percept.

Thoreau, H.D., 1854. Walden; Or, Life in the Woods. Dover Thrift Editions, Mineola, New York.

Van Abel, B., Evers, L., Klaassen, R., Troxler, P., 2011. Open Design Now: Why Design Cannot Remain Exclusive. BISPublishers, Netherlands.

van Deijnen, T., n.d. Tom of Holland [WWW Document]. URL http://www.tomofholland.com (accessed 1.1.14).

Wiens, K., 2012. The Shady World of Repair Manuals: Copyrighting for Planned Obsolescence. Wired.

CIRCULAR TRANSITIONS

23 – 24 November 2016

Developing Models for Successful Upscaled Upcycling of Fashion

Emmeline Child
(University of the Arts London & University of Northampton, UK)

Abstract

Using research collated from micro pioneers in upcycling, design toolkits have been developed to act as frameworks of design. Disseminating this information to young designers, these have then been tested to see if appropriate techniques can be refined and prototypes developed for upscaling upcycling for commercial re-use.

Introduction

With more than 2 million tonnes of clothing and textiles purchased each year in the UK alone, with only one-eighth of it being recycled (Cassidy and Han, 2013:148), there is a continued problem of usable ‘waste’ in the system, halting the progression of a more circular economy. There are a number of micro pioneers utilizing upcycling on a small scale, but the next stage is to upscale to ‘commercial’ or high street mass production.

By analysing data collected from micro pioneers in the industry and through reflections from an interview with the Salvation Army Trading Company (2016), a model has been developed to support designing within the circular economy. ‘Upcycling…should be considered a new way of ‘thinking about and working with’ a resource abundantly available’ (Torres & Gardetti, 2013:154). This model has then been given to fashion and textile students in order to develop design prototypes, while enabling us to see how successful it is at developing potential designs within the circular economy framework. Some of the prototypes will then be selected and reflected on to understand how effective it has been in upscaling upcycling. Concluding by making suggestions for adaptations and recommendations for potential prototypes of design within the circular economy.

Materials and Experimental Methods

A design toolkit was developed from the findings of the qualitative research carried out through interview techniques. Each student from the 2016 2nd year cohort from the University of Northampton BA (Hons) Fashion and Textile degree was given the design toolkit, to inform and act as a guide while designing his or her item. The students were made aware that they were testing the model, but were given no prior training as to how to work within the circular economy, and only a fortnight to complete the project. They were asked to note their observations throughout the process, which is where reflections have been observed. A micro designer, Emmeline Child has simultaneously followed the model and developed a prototype. This will enable observations to take place and understand if prior knowledge in the field is necessary when designing for upscaling.

When developing models for upcycling, it is important to understand the knowledge that micro pioneers in the field impart when working with upcyclables (materials that have the potential to be upcycled). Interviews have been conducted with pioneers such as Orsola De Castro of *From Somewhere,* and Menusha Gunawarhana from *Brandex.* Observing this can help to understand the successes and the barriers that have had to be overcome in order to create viable business sustainability, in this current niche. Supported further by an interview conducted with the Salvation Army Trading Company, observations have been made to understand the key drivers to success. An auto ethnographic review of Emmeline 4 Re was also undertaken at product level to help draw out the key determinates for success.

Results

Model Development

While working at Emmeline 4 Re it was noted that ‘access to quantities of material required was an on-going issue meaning re-run lead times increased, and therefore sales declined’ (Child, 2016). Considering the availability of upcycleables is key. Another of the drivers for success is the type of material that is suitable for upcycling. Of the initial study, 81% of best sellers were made from ‘luxury’ material types (Child, 2016), therefore due to the high statistics of success, these elements were built in to the diagram. One of the biggest barriers to driving sales and therefore commercial success has been around the sizing of garments made. It was noted that customers are drawn to the natural bespoke elements of upcycling but favour particular exclusivities not necessarily in their size. This is especially prevalent when dealing with printed or patterned materials (Child, 2016). Embedding these principles into the design toolkit will support the streamlining of the process of remanufacture, as the more efficient the garment is to re-make, the more viable it is as a commercially produced item essential in an upscaled environment. Lastly another driver observed for efficiency is the pattern/ cutting process. Using multiple pattern pieces to make use of smaller scale accessible material, or piecing material together beforehand to create 'sheets' of useable lengths is another important element in creating productive upscaling.

The model has been developed from these four 'key' determiners; abundant materials, luxury materials, multiple pattern pieces or pieced material and minimal sizing constraints that define some of the elements essential to successful upcycling. Although there are other considerations when working with the circular economy, from reflections, it is felt that these are the critical implications that determine success and require testing further. Figure 1. showcases the design toolkit in its first incarnation. The ideal upcycled product would cover all four of the elements as shaded by dark green defining the ultimate upscaled garment. Alternatively, three of the elements could be selected to create a garment potentially suitable, but requires further investigation.

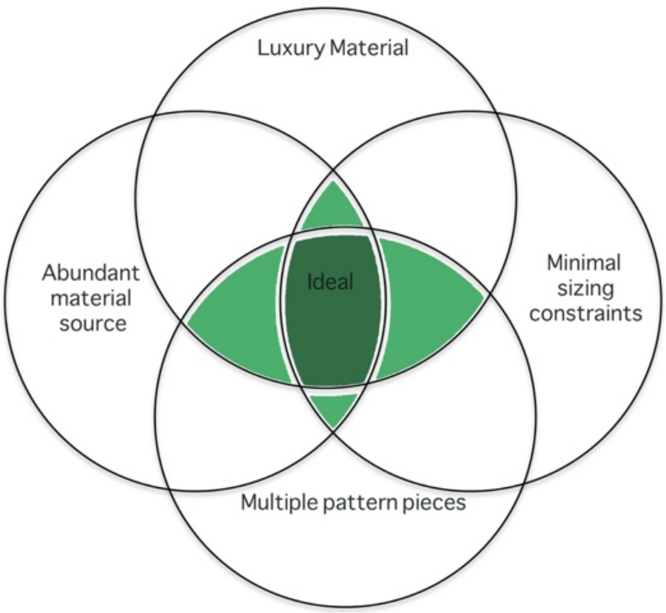


Figure 1: Developed Venn design toolkit defining upscaling upcycling

The participants were given the model along with some basic pointers to help clarify and give examples. They were then given two weeks to develop a prototype without support from experts although they were allowed to work through problems in a collaborative process.

Testing models

Prototype 1: Designed a denim jacket (Figure 2) using three of the four determiners, placing her in the secondary sphere of the diagram. In the students' reflections, it is clear that she was able to follow the chart and identified some of the key considerations. The jacket itself is made from a mix of denim material that she identified as easily accessible, while she utilised the technique of using multiple smaller pattern pieces in order to maximise the usage of the base material.

Figure 2: (left) Prototype produced by Bethany Martin 2nd year Fashion student at the University of Northampton. Figure 3: (right) Prototype produced by Sumaiya Neher 2nd year Textiles for Fashion student at the University of Northampton.

Prototype 2: Designed a jacket utilising both leather and denim (Figure 3) that crossed over three of the four circles. On first observation, it is clear that this student has upcycled successfully, however she has included heavy manipulations which although have a successful design aesthetic, it has the potential to create additional barriers when upscaling. As this student is coming from a textile background, it is clear that she has bought in her own design principles in to the design process itself. This makes it clear that this model is useful for upcycling in 'fashion' but a different model may be needed for 'textile' based designers.

Figure 4: (left) Prototype produced by Sumaiya Neher 2nd year Textiles for Fashion student at the University of Northampton. Figure 5: (right) Prototype produced by Emmeline Child.

Prototype 3: Designed a coat made of both denim and leather. Unlike the other examples developed, this prototype covered all four of the spheres of success on the design toolkit. As a textile based student, she has interpreted the brief by creating and manipulating the material to develop it from its base material. The positives are whatever the 'quality' of the upcycleables given, this design would be able to utilise and maximise on the material. The negatives are in a factory environment, this design could prove difficult to upscale and would not have the commercial appeal that would be needed to drive sales to a large demographic of individuals.

Prototype 4: Designed a denim dress. (Figure 4) This was made from two pattern pieces, using abundant material and focused on minimal sizing constraints. This design covered all four elements within the design toolkit. This prototype was created by patching material together before hand to create 'sheets' of denim that was then used to cut out the minimal pattern pieces. This design would be quick to make in a factory environment and would have commercial appeal. However, it is noted that the method of make would require another stream to the production process to allow for the piecing of the material together prior to cutting. Much like the one developed by Carr and Latham (Cassidy & Han, 2013:155). (Figure 5)

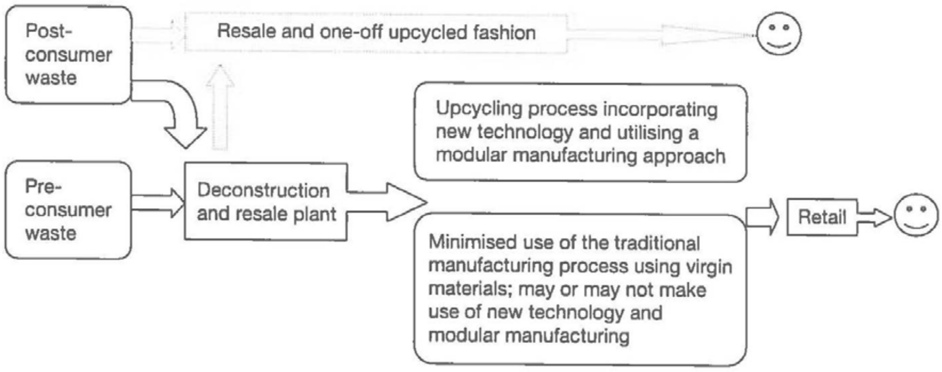


Figure 5: A mass upcycling process suggested for the fashion industry (Torres & Gardetti, 2013)

Table 1 includes a breakdown of each of the garments, showing the key factors the designers considered when developing the garment. This table enables us to see if other factors have been affiliated whilst creating their garment.

Prototype	Luxury material	Abundant material	Minimal sizing	Multiple or pieced together patterns	Other
1. Denim Jacket	Yes -Denim	Yes	No	Yes	Quick to make
2. Jacket	Yes- Denim/Leather	Yes	No	Yes	Manipulations Multiple material types
3. Coat	Yes- Denim/Leather	Yes	Yes	Yes	Manipulations Multiple material types.
4. Dress	Yes- Denim	Yes	Yes	Yes	Quick to make

Table 1: Breakdown of diagram and techniques used

Outcomes

It was interesting to note that all the participants chose to include denim within their design. One student commented that it was due to ‘it never going out of fashion’ (Martin, 2016) therefore having longevity, durability and flexibility in use. ‘It not only exists in every country in the world, but in many of these it has become the single most common form of everyday attire’ (Miller and Woodward, 2007:336). Highlighting how accessible this material is.

Additionally, denim has 'hard wearing qualities' (Cassidy & Han, 2013:157), suggesting why the student's natural response was to utilise this material as a base.

In Table 1 we were able to observe that the 1st and 2nd participants used three of the design principles, while the 3rd and 4th design used all four. This enabled us to see the differentiation between using part or all of the determiners. On reflection, we can see that there are successes in using both the 3 or 4 design principles but it doesn't define the success of upcycling. This highlights that the design toolkit needs further development. As a designer, there is an application of tacit knowledge demonstrated in prototype 4 that needs to be explicit in the design toolkit itself.

Positive aspects to the design toolkit include elements of the descriptors, it was clear that other previous observations of success noted from the interviews and ethnographic review, were embodied into the items that the students made. For example, all the students made items that could transcend seasons (to an extent) and were all outerwear garments, previously observed as a contributing factor to success. (Child, 2016) However two of the students that were textile based, added heavy manipulations that although successful aesthetically, would prove very difficult to develop in an upscaled setting.

Prototype	**How many descriptors have been followed?**	**Is the item aesthetically successful**	**Could it be upscaled?**	**Has the design added value?**
1. Denim Jacket	3 of 4	Yes, although further consideration would be needed with finishing/fastening.	Yes although size range would be required.	Yes, made from 3 original denim items.
2. Jacket	3 of 4	Yes, although more bespoke and less 'commercial'	Difficult to upscale due to the time intensive manipulations.	Yes due to the manipulations, this item has high value.
3. Coat	3 of 4	Yes, although more bespoke and less 'commercial'	Difficult to upscale due to the time intensive manipulations.	Yes due to the manipulations, this item has high value.
4. Dress	4	Yes, commercial appeal that will transcend season and trend.	Yes, easily upscaled for production. Consideration is needed about the additional chain/process in the production cycle.	Yes, made from 4 original denim items.

Table 2: Reflections from tested prototypes.

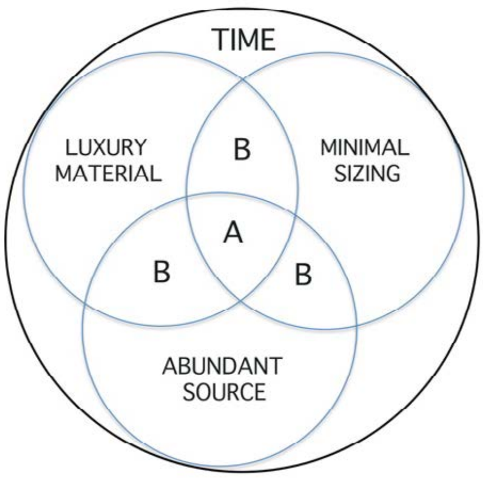
Table 2. Shows reflections for success. From the table, we can see that two of the four products have the potential for success in an upscaled environment. On reflection, it is clear that time to make the item becomes an overarching principle for success, supported by these other factors. With this in mind, using reflections from the ethnographic review and the student observations it was possible to decipher a production time of 1 hour or less (further speeded up by upscaled production) has the potential to be viable for industry cost constraints.

Conclusions

It was noted that some of the students bought their own design skills (especially in textiles) in to the prototypes, resulting in items that would struggle to be upscaled easily. This could be due to the fact that the student is coming from a 'design' perspective and doesn't have the embedded philosophy of sustainability at the centre of the design process. This reinforces the need to embed sustainability in to the teaching and learning of designers while in education 'Start with good intentions at the beginning of the design process' (McDonough, 2013:158), to enable them to make informed decisions suitable to the shift that is now needed with in the industry. This is something that could be evidenced in the commercial environment and therefore adaptations need to be made to make a model that's more explicit.

The next step is to look at models that will upcycle a broader range of material types that isn't so selective on luxury materials. 'It's not always easy to re-design, designers choose [particular] materials as they perform well' (McDonough, 2013:74). This is essential if the model is going to be suitable for upscaling in a commercial environment and not just for micro business use. This is essential if we want to have an impact on the 'approximately 10,000 garments [that] are thrown away every 5 minutes' (Farley Gordon, 2015:24). Despite the micro companies using this technique, it could be argued that larger businesses manufacturing in high quantities may not have to make the same material based decisions due to more effective and streamlined manufacturing processes, while having access to large quantities of other upcycleable materials currently popular in the industry. There is also the potential to address with this model, the issue with both pre- and post-consumer upcycleables 'evidently escalated to such an extent in the fashion industry' (Cassidy & Han, 2013:150). It is worth considering that a number of different design toolkits may be needed in order to define the complexities and the different market levels that the industry/manufacturers deals with.

Despite this design toolkit being successful in defining upcycling, it falls short of the ‘upscaling’ element that is needed to have a wider impact on the industry. It could be argued that the ‘users’ lacked knowledge and experience within the commercial field and therefore were designing from their own experiences to date, however amendments are still needed to the design toolkit to address the issues related to the upscaled environment. From Table 1 we can see the additional success factor that was included in prototype three and four was ‘quick to make’. Due to the cost implications in upscaling, it is imperative that items are efficient to re-manufacture especially as garments need to go through the additional deconstruction process. Therefore ‘time of manufacture’ has been added to the design toolkit (Figure 6), as one hour or less for one person to make an item, which would be further speeded up in a manufacturing environment. Additionally, it was observed that ‘multiple pattern pieces’ was not a descriptor for success and therefore has been omitted. The next stage would be to carry out additional observations with a new sample of students in order to ascertain if the model provides greater clarity and success when demonstrating commercial upscaling of upcycling.



TIME=<1h
A= Ideal for upscaled upcycling (UU)
B= Ideal for micro upcycling (MU)

Figure 6: Design Toolkit 2. Refined model for upscaling upcycling (Child 2016)

From this model we can develop the mathematical equation [1] for success as;

$$T<1+A=UU$$

With the secondary model [2] as;

$$T<1+B=MU$$

Where *UU*= Upscaled Upcycling and *MU*= Micro Upcycling. Proposing that the refined design toolkit is ideal for an upscaled environment, whereas the initial design toolkit developed would be suitable for smaller scale upcycling businesses.

The next stage of this project will be to develop further design toolkits for differencing market levels and then test these out on a larger scale. Ideally these models will be tested in an upscaled manufacturing environment, to greater understand the potential for success. ‘In order to create truly sustainable fashion, it must not be the sole prerogative of the elite. High street shoppers must be addressed, acknowledged and involved.’ (Black, 2008:23).

The potential is to utilise these design toolkits in novel locations such as the Salvation Army Trading Company, as ‘Waste handlers are now becoming ‘Nutrient managers’ and someday upcyclers’ (McDonough, 2013:169), and this could act as a revenue stream for textile recyclers who are finding a market that ‘Is harder today than 10 years ago…It’s a global business, and when things happen globally it has an impact’ (Simpson, 2016). This may be a solution to the location issues in relation to where the post-consumer upcycleables are, to where products are being manufactured on a mass scale. There is a potential for manufacturers to deal with pre-consumer upcycleables with the design toolkits developed, while waste handlers could deal with the post-consumer, paying particular focus to materials such as denim as shown in this study.

References

Black, S. (2008) *Eco-chic: the fashion paradox*. Black Dog Publishing Limited.

Carr, H., Tyler, D.J. (2000) *Carr & Latham's Technology of Clothing Manufacture*. Blackwell Science.

Cassidy, T., Han, S. (2013) Upcycling fashion for mass production in Torres, A, & Gardetti, M (2013), *Sustainability in Fashion and Textiles: Values,* *Design, Production And Consumption*, Sheffield: Greenleaf Publishing, eBook Collection (EBSCOhost), EBSCO*host*, viewed 25 July 2016

Child, E. (2016) *An auto ethnographic review of 48 pieces from the Anonymous collections; Defining barriers and opportunities leading to successful upcycling.* The 90th Textile Institute World Conference. Poznan, Poland 25th-28th April 2016.

Farley Gordon, J., Hill, C. (2015) *Sustainable Fashion Past present and future*. London, New York: Bloomsbury

Martin, B. (2016) *Reflections from using the upcycling model* [email] (personal communication 15th June 2016).

McDonough, W & Braungart, M. (2013) *The Upcycle: Beyond Sustainability-Designing for Abundance.* New York: North Point Press.

Miller, D. and Woodward, S. (2007) *Manifesto for a study of denim.* Social Anthropology, *15*(3), pp.335-351. [online] Available at: https://www.researchgate.net/publication/227624583_A_Manifesto_for_the_Study_of_Denim [Accessed 20th March 2017].

Moreton, N and Simpson, B. (2016) Interview with the Salvation Army. Interviewed by Emmeline Child [recording] 10 March 2016.

Torres, A., Gardetti, M. (2013) *Sustainability In Fashion And Textiles : Values, Design, Production And Consumption*, Sheffield: Greenleaf Publishing, eBook Collection (EBSCOhost), EBSCO*host*, viewed 25 July 2016

Acknowledgements

Special thanks go to Professor Rebecca Earley and Dr Kate Goldsworthy for their continued support, knowledge and passion in the field.

The Creation of Made to Measure Recycled Garments

Andre West & Sanjaykumar Patil
(North Carolina State University, USA)

Abstract

This paper considers the application of three integral technologies to create Made to Measure (MoM) knitted garments from recycled materials using a zero-waste manufacturing process. The focal technologies include: recycling Polyethylene Terephthalate (PET) plastic bottles into yarn, 3D body scanning to generate accurate sizing data to produce MoM knitted garments, and WholeGarment® knitting technology to produce the finished garment.

Introduction

This research focuses on incorporating three converging technologies; recycling of Polyethylene terephthalate (PET) plastic bottles, 3D body scanning to provide personalized accurate sizing measurement data to make fitted knitted garments, and WholeGarment® knitting technology. The objective, to produce a garment that is constructed without the need for sewing and zero waste, manufactured from 100% recycled materials. The final challenge is to complete the circle by recycling the polyester knitted garment rather than simply delaying its journey to the landfill and complete the circle to repurpose it yet again into a similar product.

In 2011, 7.5 million tons of PET was collected for recycling globally, greater than any previous year. Hence, there is a growing infrastructure whereby thermoplastic polyester products could form a closed recycling loop that produces ‘Zero Waste’ in the production process (Ploszajski, 2014). Making textiles from recycled PET is now a feasible option. Recycling of textiles ensures sustainability and environmental protection as it prevents non-biodegradable polymers from spoiling the planet with waste in our landfills. Knitted garment construction produced in a panel or tubular form, can generate up to 1/3 of waste fabric in the construction process. The process of WholeGarment® knitting can eliminate manual construction as well as the waste that is created with cut-and-sew processes. This method also provides garments with more accurate and repeatable construction parameters.

When combined with personalized 3D body scanning, this method affords the opportunity to make a garment personal, fashionable and recycled. 'Made to Order' or 'Made to Measure' production systems allow companies to maintain smaller inventory and manufacture on demand, reducing excess supplies for both raw materials and finished goods. These systems also allow manufacturing units to be smaller and react to seasonal and fashion demands much quicker. New development in the processing of recycled PET makes it possible to return these garments for recycling. Rising consumer awareness regarding sustainability has created a compelling need to adopt environmentally sustainable strategies in product development. Similarly, production and consumption need to be environmentally sustainable (Sustainable Fashion Supply Chain Management, 2015). By forming a closed loop manufacturing process using accessible textile knitting technologies, progress towards these overarching goals is achievable with existing capabilities.

Recycle the Bottles

In the U.S. today, nearly 70 percent of plastic bottles end up in the landfill. Further, demand for polymeric materials in the packaging industry continues to generate (PET) waste (Unifi® Inc. 2015). As characterized by Ploszajski (2014), Polyester, a crude oil derivative, production is considered environmentally unfriendly due to its manufacturing process which is both energy intensive and generates pollution. The release of pollutants into the atmosphere is already a cause for concern in regards to global warming. There is also a concern for the depletion of natural resources, emphasizing the need for environmental conservation to ensure the survival of the ecosystem. The rising pile of rubbish that is crowding the planet's land and oceans poses an increasing threat to the global ecosystem. Waste reduction has become a necessity that is gaining importance due to the rising cost of raw materials and the cost of disposal. In 2003 post-consumer textile products waste in the US amounted to 8.75 billion pounds annually, equal to 35 pounds per person (Steinbring & Rucker, 2003). Recycling contributes to sustainability and environmental protection as it prevents non-biodegradable polymers from spoiling the planet with waste in our landfills.

Production ecology, human ecology, performance ecology and disposal ecology are identified as the four ecologies in textiles (Oeko-Tex Association, 2015). The disposal ecology is concerned with recycling, reuse, and disposal of textiles. The problem with post-consumer waste recycling is that the product being recovered cannot always be returned to the same product it was manufactured into, as most products are constructed with a combination of materials not always compatible with each other. During the plastic bottle life cycle, PET comes in contact with degrading agents such as oxygen, light, high temperatures, shearing, and water (Mancini et al. 2010). Post-consumer bottles can be returned or collected with residues of labels containing inks and dyes, caps, and original food or water contents, as well as other substances that could adhere to the bottles. Therefore, it is virtually impossible to collect a recycled PET product and prevent it from being contaminated in some way. Bottles are discarded in communities where careful waste disposal is not always available, especially when removing glass bottles, which can have a similar label, shape, size, color and even contain the same product. If these impurities are not removed entirely, they will be processed together with the plastic. Thus, the recycled product will be visually, physically and chemically inferior to the original virgin polymer. This can significantly affect the recycler's profit margin, and newly created products might contain contaminants that are hazardous or unhealthy (Mancini et al. 2010).

In the case of plastic food or water vessel or packaging material this is particularly true, using recycled PET is not a feasible option for food packaging as it may affect the flavor of the food due to molecular absorption. Molecular absorption is a process of absorption of the flavor of drinks into the PET polymer (Farhoodi et al. 2011). Recently the introduction of a chemical washing step of ground up PET bottles followed by water rinsing yielded a much cleaner polymer than what would have been obtained with conventional washing in water. However, this is still not clean enough for packaging food products (Mancini et al. 2010). As textiles are not consumed, using recycled PET to make garments and fabric does not cause a direct threat to humans, in fact, it lowers the risk to humanity by providing an alternative to the landfill.

Textile products that can be created from the PET recycling process are 100% filament or spun polyester in a range of yarns such as blended, textured, twisted, covered and dyed yarns. These eco-friendly yarns, fabrics, and garments can be produced with savings in material costs. For this research Unifi's Repreve® brand was used. Repreve® is 100% post-consumer waste (PET water bottles) manufactured into Polyester filament. It takes approximately 7-10 plastic bottles to make a knitted garment. For every 1 lb. of Repreve® polyester yarn, 50,000 British Thermal Units are conserved that are equivalent to 0.4 gallons of gasoline. Since the inception of this program, Unifi has recycled 630 million plastic bottles. The process of crude oil refinery, Naphtha, Benzene, Xylene, Cyclohexane, Paraxylene, Hex Methylene Diamine and Adipic acid, are also eliminated (Unifi® Inc. 2015).

The Repreve® manufacturing process flowchart is illustrated in Figure 1. After the PET waste is sorted by color, it is subjected to pressure baling after crushing. The recycling process begins with washing the material. The fiber waste material is subjected to shredding and sorting to obtain plastic flakes after removal of any labels, caps, etc. combined with filtering to remove any contaminations. The extruded fibers are melted through tiny holes in a spinneret. The size of the spinneret and take-up speed affects the size of the yarn.

Figure 1 The Process Flowchart of Repreve® (Source Unifi®, Inc.)

Evaluation of Polyester Uses in the Current Market

Consumers today are embracing synthetic fibers thanks to improved processing technologies, providing better quality materials, contributing to easier consumer care and maintenance. In addition, many modern fashion trends are relaxed and appeal to a more casual market (Ploszajski, 2014). These recycled fibers are capable of being integrated into desired fabric properties, especially for athleisure and sports clothing that require moisture wicking, permeability, a soft hand, and aesthetic appeal. By using a combination of recycled polyester and other fibers such as recycled Lycra® for swimwear added functionality can be water permeability, breathability, and antibacterial properties. Developments in recycling processing and fiber manufacturing empowers manufacturers to select environmentally friendly raw materials and enables them to use a ‘Go Green’ branding strategy. Furthermore, the processes and products have enhanced the capabilities needed for ‘eco-labeling’ (Patil & Agrawal, 2008).

In a study testing the thermal conductivity of polyester fibers, it was determined that, “the geometric characteristics such as fineness, shape of cross section, and longitudinal profile of fibers significantly affect the transport of heat through the knitted fabrics” (Legerska et al., 2013, p. 1022). The results showed that the sample with 100 percent polyester fibers demonstrated better physiological responses and performance by athletes compared to the other fabric types. This result was related to better moisture management, which was reflected through relative water vapor permeability (68%) and lower thermal conductivity, which support the body’s temperature regulation. Better moisture management increased the athletes’ cardiorespiratory fitness and performance” (Hassan et al., 2012, p. 87). As can be seen from Hassan’s study, polyester is the fiber that is most appropriate for use in sportswear. Not only is it more comfortable from a touch and heat-regulating standpoint, but it also helps by improving the overall comfort of an athlete throughout the period of exercise.

3D Body Scanning for Improved Garment Fit

In Myers-McDevitt’s (2009) technical design guide, a well-fitting garment begins with accurate measurements. Garments need proper ease amounts for size and movement, without wrinkles or gaps, to make the wearer more attractive. Assessing fit also requires previous knowledge of how the garment is supposed to look.

Commercial garments are made to fit average sized customers defined as ‘Pret-a-porter’ or ‘Ready to Wear.’ nearly all knitted garments are made this way. The words Made to Measure (MoM) are associated with a fine men’s suit or a gown destined to be on the Red Carpet. While MoM garments are constructed to fit each customer individually, these do involve some form of standardization in the patterning and manufacturing processes. Of the few knitted garments on the market today that are MoM, the majority are made of expensive fibers and subsequently have a very high price tag, and are usually only available in limited color and design parameters. These involve the use of an experienced tailor or patternmaker. Thus, the majority of knitted garments are unfortunately not made to fit today's wide range of body styles (Helstein, 2003). To measure a human being by hand using a traditional tape measure can be a tedious, time-consuming and impersonal process. The accuracy of the measurement is equated to the experience of the person taking the measurement. This process could easily be streamlined by using an analysis of the printout from a 3D body scanner (Simmons & Istook, 2003).

For this research, a no contact 3D body scanner from Size Stream was used. This body scanner detects over 100 landmark points and takes more than 400 body measurements, including circumferences, heights, lengths, volumes and surface area. The measurement sensor to map the surface of the scan subject is an infrared depth sensor similar to popular video game systems. It takes approximately six seconds for full body coverage. Size Stream software then converts the sensor data to a 3D image of the subject from which measurements can be obtained and displayed (sizestream.com 2016).

The Size Stream scanner comes equipped with a Custom Measurement Scripts program where the user can define custom measurements using coding and algorithms based on their existing 100 landmarks measurements, such as the neck, waist, and hip measurements. The custom measurement program is also more accurate than measuring by hand because it takes the measurements on both sides of the body and averages the total. The custom measurements program associated with the Size Stream scanner was coded to translate the data and make it compatible with Shima Seiki APEX One® design software, specifically Shima's KnitPaint™ program which assists in design and development of knitted garments for Shima Seiki knitting machines.

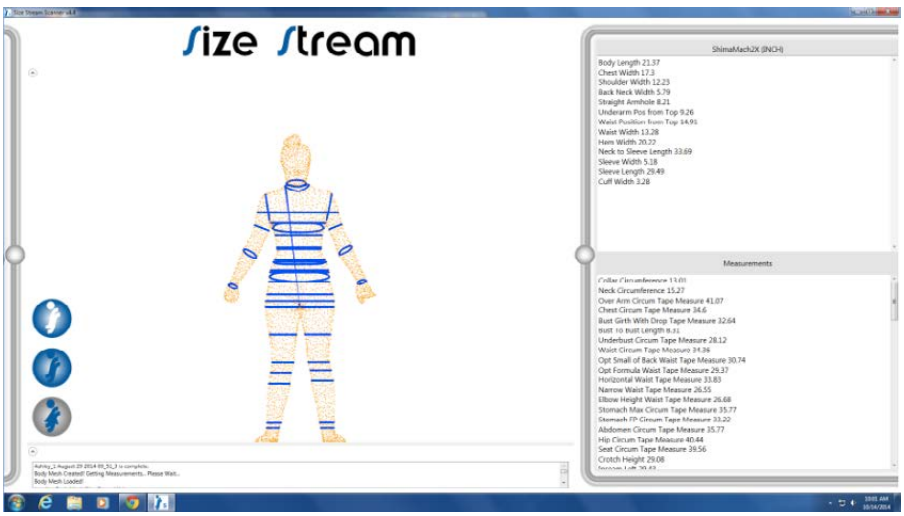


Figure 2. Size Stream Standard Measurement Printout (Source Author)

The KnitPaint™ software requires the input of several key garment measurements as well as knitted wales and courses per inch measurements before the design process begins.

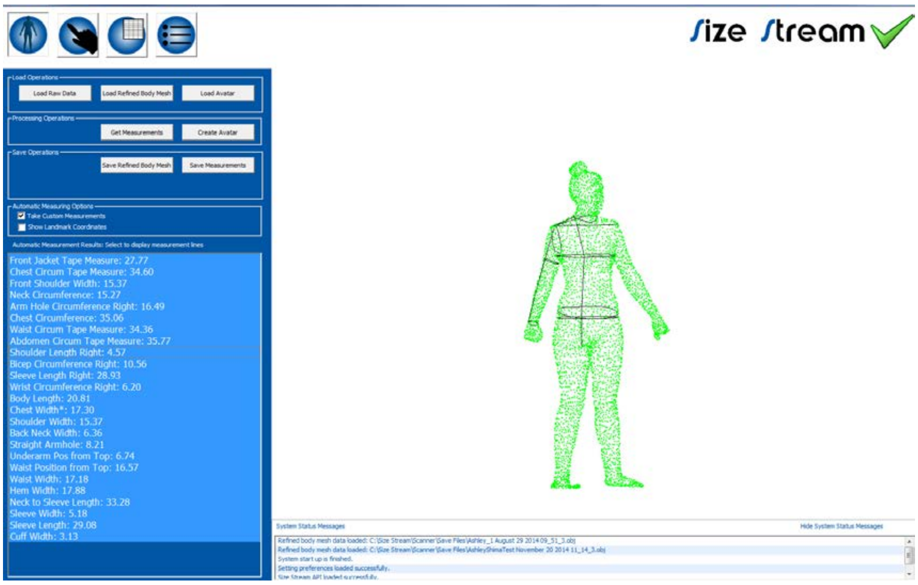


Figure 3. Custom Measurement Program for Shima Seiki KnitPaint™ (Source Author)

Zero Waste Approach to Knit Fashion Design

Eliminating manufacturing waste and selecting eco-friendly raw materials are the fundamental principles in the design process of sustainable apparel products. "Zero-waste design strives to create clothing patterns that leave not so much as a scrap of fabric on the cutting room floor. This is not some wacky avant-garde exercise; it's a way to eliminate millions of tons of garbage per year. Apparel industry professionals say that approximately 15 to 20 percent of the fabric used to produce clothing winds up in the nation's landfills because it's cheaper to dump the scraps than to recycle them" (The New York Times Company, 2015).

There can be different approaches to reduce the waste of fabric. One alternative can be to explore the possibility of designing a garment pattern without any cutting waste. The methods of fabric manufacturing with greater design scope of zero waste along with the freedom to choose the desired garment shape and dimensions would direct a creative designer to think of the possibility of an innovative fabric manufacturing technique combined with new garment design parameters. Knitting machines have flexibility in this area. For many years, weft knit garments were mainly produced in a panel or tubular form. Later a material saving method was developed, fully-fashioned knitting characterized by seaming together knit panels (front, sleeves, back) of the garment to reduce waste, making it possible to create smoother edges on garments (Spencer, 1989). This method did eliminate most of the waste, but the technology limited the designs to simplified traditional patterning and shapes. Today the word “Seamless” and “Seamless garments” are used interchangeably to describe either making garments that are made to exact body widths or full garment knitting which produces a complete garment in a single process without any need of seaming or linking. This terminology has also been used to describe garments that are sewn together, but the seam is almost imperceptible to the consumer.

Some of the manufacturers of seamless garment machines are Santoni (Italy), Shima Seiki (Japan) and Stoll (Germany). The machines not only produce complete 3D shaped garments without seams but also offer continuity of design and a perfect silhouette of the garment. The machines are capable of producing continuous designs and patterns throughout the entire garment: front-to-back; over-the-shoulder; and down the sleeves. Reversible knitwear can be produced without the added weight and bulk due to the absence of seams. The stretch of the garment remains constant as there is no sewing or other thread component. 3D shaping allows the design and silhouette of the garment to be reproduced precisely as the designer intended (Shima Seiki Mfg. Ltd., 2015).

“WholeGarment® knitting,” a terminology trademarked by Shima Seiki (Japan) is the process of knitting a garment without the need to sew (Gover, 2010). This technology has the potential of restoring domestic production and at the same time providing high-quality garments as well as MoM garments. The process of WholeGarment® not only eliminates the garment construction process and its associated waste, but also provides garments with much more accurate and repeatable construction parameters. Yang & Love, (2008). The savings in fabric waste offers great opportunities for reducing the raw material cost. Correspondingly, the labor costs are drastically reduced or eliminated. This process also provides flexibility in the selection of design, silhouette, and shape by the designer, thus enhancing the performance of apparel. The process is capable of producing garments in a shorter lead-time, allowing for mass customization in the Dotcom era. The machines can knit garments sequentially with differing sizes that perfectly match the requirements of diverse shapes and sizes of the human body providing improved stretch, drape, and comfort. The major advantage in garment quality is the comfort due to the absence of seams. This is especially conducive for sports, infant wear, and medical clothing.

There are supplementary benefits with the combination of polyester when knitted using WholeGarment® technology. The combination allows you to design garments that incorporate sweat absorption, ventilation, and compression. Garments can be utilized for functional sportswear with better comfort properties and no seams. As shown in Figure 2, the selection of different types of stitch design in different areas of the fabric can provide advantages. For example, the sweat pattern of the human body could match that of the garment's pattern design, channeling water or dispersing heat.

Figure 4 Garment Made with Transitional Rib Characteristics. (Source Shima Seiki)

The integration of the 3D measurement software in the garment construction research involved creating custom garments manufactured to fit previously scanned body sizes. First, the team tested various knit structures on the Shima Seiki Mach2XS machine to evaluate their impact on garment measurement. In the process, the structure capabilities of the Mach 2XS were also tested. After completing samples of various structures, they were compared to the original measurements programmed into the Shima APEX design system. This determined essential garment knitting factors such as stitch behavior and dimensional change. These factors were then processed into a custom measurement list on the Size Stream body scanner so that the program output would reflect the participant's custom measurements for a Shima Seiki knit top. Subsequently, the garments were knitted and compared to the original measurement setting.

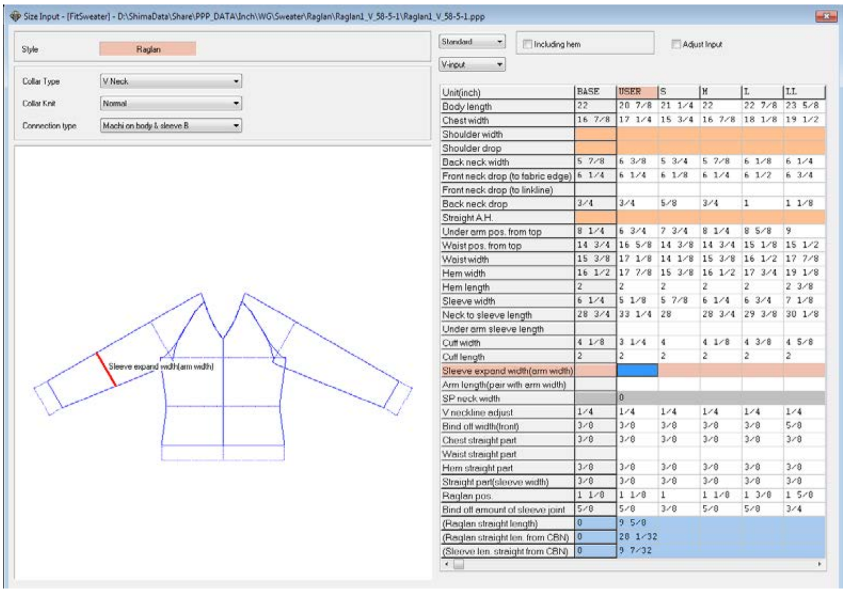


Figure 5. Shima Seiki KnitPaint™ Measurement Input. (Source: Shima Seiki KnitPaint™ Software)

Figure 6. Prototype WholeGarment® garment made from 100% recycled polyester (Source Author)

Conclusion

This research methodology demonstrates that “Closing the Loop” is attainable. Many companies believe that the more environmentally conscious they become, the more it will negatively impact their competitive place in the market due to the added initial costs and lack of immediate benefits (Nidumolu, Prahalad & Rangaswami, 2009). If the waste created by the manufacture of PET bottles and clothes is recycled properly, this can offer a high-quality post-consumer product at a lower financial cost than virgin materials (Unifi® Inc., 2015). The manufacture of recycled polyester staple fibers and filaments create new opportunities for the fabrication of sustainable, fashionable garments. The Shima Seiki Mach2XS machine is capable of utilizing this yarn to produce different knit structures integrated into a WholeGarment®, thus providing greater possibilities in fashion design. Integrating 3D body scanning technologies may resolve the problem of inventory, as it eliminates the need for standardization of measurements. This could lead to mass customization of knitted garments. The use of 3D body scanning will result in greater accuracy in the measurements leading to customer satisfaction particularly with Internet sales. An ideal integration of technologies can achieve product excellence as well as cost reduction through the minimization of process waste. The Zero waste product design approach is demonstrated by utilizing converging process capabilities.
The garments could be returned to the yarn manufacturer for reprocessing along with the plastic bottles if there were customer incentives such as rebates and convenient collection points. This method can create opportunities for sustainable closed loop product development and offer marketing advantages for the products. Further research in the area can also involve an ecological supply chain and new eco fashion brands.

References

Farhoodi, M., Salami, M., Emam-Djomeh, Z., Mousavi, S. M., & Rezaei, K. (2011) *Measurement of Flavor Absorption from Soft Drinks into PET Bottle* by Headspace Solid Phase Microextraction-Gas Chromatography. International Journal of Food Engineering, 7(4).

Gover, A. J. (2010) *Isomorphic Textiles: designing through technology in the medium of WholeGarment knitwear*. Doctoral dissertation, Auckland University of Technology.

Hassan, M., Qashqary, K., Hassan, H., Shady, E., Alansary, M. (2012) *Influence of sportswear fabric properties on the health and performance of athletes.* Fibres & Textiles. 20, 4, 82-88. Instytut Biopolimerów i Włókien Chemicznych

Helstein, M. T. (2003) *That's Who I Want to be The Politics and Production of Desire within Nike Advertising to Women.* Journal of Sport & Social Issues,27(3), 276-292 Sage Publishing

Legerska, J., Lizak, P., Murarova, A., Mojumdar, S. (2013) *Thermal analysis of the polyester profiled fiber.* Journal of Thermal Analysis and Calorimetry. 112, 2, 1019-1023. Springer International

Mancini, S. D., Schwartzman, J. A. S., Nogueira, A. R., Kagohara, D. A., & Zanin, M. (2010) *Additional steps in mechanical recycling of PET.* Journal of Cleaner Production, 18(1), 92-100. Elsevier

Myers-McDevitt, P. (2009) *Complete guide to size specification and technical design.* Fairchild Books; New York, NY.

Nidumolu, R., Prahalad, C. K., & Rangaswami, M. R. (2009) *Why sustainability is now the key driver of innovation.* Harvard business review, 87(9), 56-64. Harvard Business Publishing

Oeko-Tex Association (2015) https://www.oekotex.com/en/manufacturers/textile_ecology/textile_ecology_start.html. <Retrieved on 10/07/2015>

Patil S. A., Agrawal Y. (2008) *Eco Labelled Clothing*. Textile Trends (31). Connect Journals

Ploszajski, A. (2014). *Polyester.* Materials World, 22(11), 60-62. Taylor & Francis <Retrieved on 07/25/2015> http://search.proquest.com/docview/1642539754?accountid=12725

Shima Seiki Mfg. Ltd. (2015). http://www.shimaseiki.com/category/knit.html <Retrieved on 07/28/2015>

Simmons, K., Istook, C. (2003) Body *measurement techniques: comparing 3D body-scanning and anthropometric methods for apparel applications.* Journal of Fashion Marketing and Management: International Journal. 7, 3, 306-332. Emerald

Size Stream, LLC (2016) *FAQs.* Cary, NC. http://www.sizestream.com/faqs/ <Retrieved on 7/20/16>

Spencer, D. (1989) *Knitting technology: a comprehensive handbook and practical guide.* Cambridge: Woodhead Publishing

Steinbring, Y., & Rucker, M. (2003) *Utilization of post-consumer textiles and clothing.* Journal of Family and Consumer Sciences, 95(2), 33. American Association of Family & Consumer Sciences

Volume 1 http://link.springer.com.prox.lib.ncsu.edu/book/10.1007%2F978-3-319-12703-3 <Retrieved on 09/08/2015> Springer

The New York Times Company (2015) *Fashion tries on Zero Waste design*, http://www.nytimes.com/2010/08/15/fashion/15waste.html <Retrieved on 11/05/2015>

Unifi®, Inc. (2015). http://Unifi.com/un_product.aspx. <Retrieved on 07/26/2015>

Yang, M. S., & Love, T. (2008) *Integrated System for Fashion Design using Computerized WholeGarment Knitwear Production.* In Proceedings of ANZSYS'08: 14th International Conference. Australia and New Zealand System Society

Design for Circularity: Material Innovation for Wearable Technology

Anne Prahl (UK)

Abstract

There are significant end-of-life issues with textile-based Wearable Technology, exacerbated by the seamless embedding of electronics and other enabling components. This paper therefore explores alternative, closed-loop design approaches, which investigate what a 'wearable material' could constitute, as well as the design and development of new types of non-integrated form factors.

Introduction

The development of innovative and effective solutions for the end-of-life of textiles and clothing is now firmly placed on the agenda in the fashion industry, as material innovators and designers have been developing unique approaches to utilising pre- and post-consumer material waste. Although this concept of 'designing with waste' is an important first step, the ultimate goal should be to 'design out waste', so that raw material, textile and component waste can be prevented altogether, in line with the goals of a circular economy (Prahl 2016). In order to rise to this challenge, academic and industry stakeholders are now innovating and implementing new concepts, materials, processes and systems, which enable the reuse, remanufacture and recycling of products at end-of-life.

Design for circularity entails the elimination of waste as part of the design process and replaces the idea of a product's 'end-of-life' with 'the end of its period of primary use' (Ellen McArthur Foundation, 2015). This approach builds on the differentiation between consumable product components, which are made of biological ingredients that can be safely returned to the environment, without causing any negative impact, and durable components made of technical ingredients, which can be reused, remanufactured or recycled into new materials and products of the same or higher value in continuous cycles. According to the European Commission's Circular Economy Package (European Commission, 2016), this approach of 'closing the loop of product lifecycles through greater recycling and reuse' will bring significant benefits for both the environment and the economy (ibid.).

Design innovation for the circular economy is gathering pace and recent examples include Adidas' 'Sport Infinity', a collaborative research project that aims to eliminate the need to 'throw away' products such as football boots at the end of their first life (Adidas, 2015), and Levis' collaboration with Evrnu, which utilises a new recycling technology to dissolve used t-shirts into a new, high quality fibre for new jeans (Levis, 2016). However, despite the growing momentum in the textile, clothing and footwear industry, there is a distinct lack of consideration for environmental impact in the specialist category of Wearable Technology, where, in the on-going quest for commercially successful consumer products, innovation is often pushed through at all costs.

Therefore, this paper aims to raise awareness of the end-of-life issues of textile-based Wearable Technology, while highlighting particular design innovation opportunities, which could contribute to advancing design for a circular economy in this field. Furthermore, the paper demonstrates these opportunities through the presentation of wearable sensor concepts, which explore a closed-loop approach to material substrate design, and could offer a starting point for future collaborative developments in the commercial realm.

Challenges

Over the last couple of years there has been an unprecedented rise in the sale of activity trackers and smart watches and in line with this trend, we are seeing the development and launch of more fashion and activewear with integrated sensors and other electronics; indeed, the US market for e-textiles or smart clothing is predicted to reach over US$ 3bn by 2026 (Hayward, 2016). While textile-based Wearable Technology is still considered a niche product, it is poised to reach a more mainstream consumer, as fashion companies like TOPSHOP are exploring the design of stylish and functional Wearable Technology products at more accessible price points (Arthur, 2016).

Despite the positive developments in the textile & clothing industry, stakeholders involved in the design, development, production and sales of Wearable Technology (including hardware and textile-based products) seem reluctant to consider potential negative environmental (i.e. resource depletion and pollution) or human (i.e. potential health hazards to workers and end-users) impacts their products could cause during manufacture, use and end-of-life. With regard to electronic consumer products, it is well documented that the rapid growth of electronic waste (fig. 1a), which is often blamed on shorter lifespans of electronic goods, has had a dramatic impact on developing countries, as these are often left to deal with dumped electronic waste from developed countries due to loopholes in the current Waste Electrical and Electronic Equipment (WEEE) Directives (UNEP, no date). Organisations such as Greenpeace have been publicising associated impacts of e-waste dumping for years, although producer responsibility for electronic products currently not covered under the WEEE Directive (such as electronic textile enabled clothing), appears to be non-existent, thus making the necessity to address the end-of-life impact of any clothing or accessories containing electronic components extremely pressing.

End-of-life issues for textile-based Wearable Technology

In 2008, Andreas Köhler highlighted the potentially devastating consequences of combining electronics with textiles and stated that by integrating electronics into textiles, the industry may be creating a new waste stream, as current textiles recycling facilities and systems are not equipped to deal with this kind of product (Köhler, 2008). In particular, Köhler believes that traditional textile recyclers are unable to collect and process electronically-enabled textiles and that they could become fire hazards during the sorting process due to hidden, integrated batteries; they could contaminate the fibre reclamation processes when accidentally being mixed up with ordinary textile waste and they could cause a range of problems for developing countries, where they are exported to for reuse (Köhler, 2013). Köhler has developed his initial findings further by evaluating particular eco-design principles, which could be adapted and implemented in the innovation process of e-textiles (Köhler, 2013a) and although he has been disseminating his work in the academic realm, there is currently no evidence that anyone involved in the design and manufacture of textile-based Wearable Technology in the commercial domain is taking any steps to integrate design solutions into the innovation process.

Figure 1: (a) Electronic waste, (b) textile waste

Figure 2 (left): Knitted textile-based electrode
Figure 3 (middle): Woven-in technology
Figure 4 (right): Printed sensor

A particular obstacle for the successful recycling of electronic textile products is the manner that electronics and other enabling components are integrated into the textile (Timmins, 2009; Köhler, 2013; Ossevoort, 2013), as seamless integration has become the ultimate goal for textile-based Wearable Technology developments in recent years and permanent and often invisible integration such as knitted (fig. 2), woven (fig. 3), printed (fig. 4), embroidered, laminated and welded technologies, seem to prevail on the innovation agenda (Prahl, 2015). In order to disassemble these types of products at end-of-life to reuse or recycle the various components, designers and material innovators must begin to consider alternative and less permanent forms of integration (Timmins, 2009; Köhler, 2013; Prahl, 2015).

Design Opportunities

Recent PhD research (Prahl, 2015) investigated design opportunities for wearable sensors, which could detect biochemical (from the wearer's skin) and environmental (from the wearer's surroundings) stimuli and data, in order to monitor and improve the user's health and wellbeing. Driven by the end-of-life challenges previously identified by other researchers as outlined above, the practice-based research project explored the creation of new types of wearable sensor substrate materials, which could be designed with closed-loop solutions in mind. Furthermore, and closely linked to the materials exploration, the project investigated new, easy-to-wear form factors for wearable sensors, and supported by the outcomes of an in-depth creative examination of functional aspects through user-centred design, the findings were brought together to inspire the design of an industry-facing collection of conceptual artefacts. This collection aims to bring attention to some of the emerging issues, challenges and opportunities around the design and manufacture of textile-based Wearable Technology in general and wearable sensors in particular, while stimulating debate and ideas for additional collaborative and cross-disciplinary research, design and development of commercial products in the future.

Exploring wearable materials

In order to address the potential end-of-life issues of textile-based Wearable Technology, the author considers it essential to explore what a 'wearable material' (Prahl, 2015) could constitute, as our understanding of textiles continues to evolve. Textiles are generally defined as a type of cloth, which consists of a network of fibres, thread or yarn, created through weave, knit, crochet, lace or nonwoven manufacturing techniques but more recently we have been able to witness groundbreaking innovation in the field of textile and material manufacture. These include a plethora of nonwoven materials and products manufactured through new technologies such as 3-D knitting and printing and spray printing onto templates, such as Tamicare's Cosyflex (fig. 6) and Electroloom's 3-D printed material (fig. 5), or directly on the body, as developed by Fabrican (www.fabricanltd.com). Furthermore, emerging technologies from the field of medical science include flexible and stretchable electronics, such as epidermal and electronic tattoos (fig. 7), as well as paper-based electronics and sensors.

By thinking beyond traditional knitted and woven textiles and utilising new and emerging manufacturing technologies from the fields of fashion and healthcare, the research project demonstrated that it is further possible to engineer these types of textiles so they can be reusable, recyclable or biodegradable at the end of the product’s life, an approach which could contribute significantly to making design for circularity for Wearable Technology a possibility. The project further illustrated that working with a variety of both natural and synthetic nonwoven materials provides the opportunity to investigate wearable sensor lifespan in line with durability, recyclability and biodegradability, proposing disposable as well as reusable wearable sensor concepts.



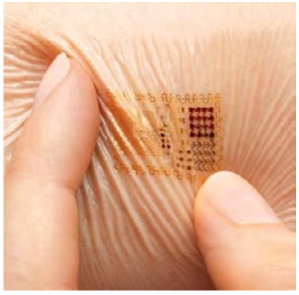


Figure 5 (left): 3-D printed textile
Figure 6 (middle): 3-D print-sprayed textile
Figure 7 (right): Flexible electronics



Figure 8 (left): Biodegradable sensor sample
Figure 9 (middle): Bought sample testing
Figure 10 (right): User workshop

As part of the practice-based material investigation, a diverse selection of material swatches was produced, utilising both natural and synthetic raw materials, such as latex rubber (fig. 8), silicone and paper. Furthermore, an extensive review of commercially available wearable, low-cost, reusable and disposable material substrates used in the beauty and personal hygiene industry (fig. 9) was carried out and a user workshop to generate feedback on material preferences was held (fig. 10). Following the evaluation of the extensive primary and secondary research and sampling activities, the author defined three nonwoven substrate categories; rubber-like materials can provide next-to-skin comfort and functionality, while felt-like materials offer tactility and comfort, an essential feature for successful user interaction and paper-like materials can easily and cost-effectively be printed with the required enabling technologies.

Investigating non-integrated form factors

As mentioned previously, seamless integration of electronics into textiles and clothing can cause significant challenges in regard to reuse and recycling of the various components. Köhler (2013) called for designers and developers to scrutinise and question the concept of seamless integration, especially when designing short-lived products, in order to anticipate and eliminate the issues caused by seamless technology integration at the product's end-of-life. In response to this, the research project demonstrated that investigating the concept of 'non-integrated' wearable sensors (Prahl, 2015) could contribute new options for providing more affordable, accessible and easy to wear on-body monitoring, thus giving a greater number of potential users the opportunity to take active control of their health as part of a preventative lifestyle. In parallel to the material exploration described above, the research investigated the design of non-integrated form factors, inspired by groundbreaking wearable sensor innovation from specialist fields such as elite sports and medicine. Recent examples include adhesive sensing patches developed by John A. Rogers of Illinois and Yonggang Huang of Northwestern University in 2014 (Ahlberg, 2014), the boogio attachable movement and balance sensor (www.boogio.com) and Google's smart contact lens, which is capable of measuring blood glucose levels contained in human tears (King, 2014).

An extensive period of practice-based research included simple wear-testing of several wearable devices, an experience which produced insights into aspects such as comfort, limited wear positions, security and operational issues; a comprehensive visual overview of wearable accessories focusing on specific on-body locations, in which sensing could take place; initial wearable sensor design concepts, which provided the opportunity to test ideas as part of the early design process; and a user workshop, which elicited diverse user responses on form factors to inspire the design of the final conceptual wearable sensor collections. The evaluation of these artefacts and outcomes led to the development of a more evolved classification for three types of non-integrated wearable sensors (fig. 11), comprising skin-worn, body-worn and clothing-attached sensor carrier types (Prahl, 2015).

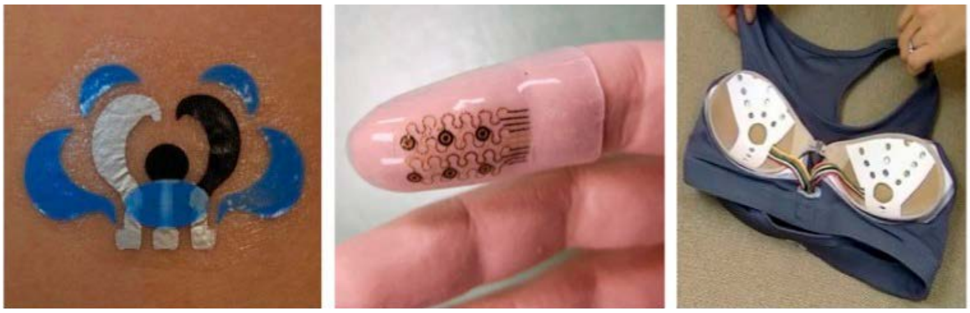


Figure 11: Sensor carrier types overview utilising examples from the medical field; a) tattoo-like sensor, b) fingertip sensor and c) bra-attached sensor (Prahl, 2014)

Developing conceptual proposals

In addition to the exploration of material and form as described above, the research examined functional aspects through user-centred design, most importantly immersion into London's 'Quantified Self' community (http://quantifiedself.com) through a self-tracking experiment featuring various wearable devices, interaction and discussion during monthly community meetings and a user workshop, which generated valuable feedback on users' preferences on the concept of wearable sensors in view to form and function.

In order to formulate a design brief for the creation of wearable sensor concepts, the key outcomes regarding material, form and function were summarised as follows: a) the probing of diverse material aspects highlighted that there were compelling opportunities to explore what a 'wearable material', rather than a conventional textile, could constitute, with a particular view to exploring rubber-like, paper-like and felt-like synthetic or natural nonwoven substrates, which could be recyclable or biodegradable; b) the exploration of form factors determined that new types of easy-to-wear skin-worn, body-worn and clothing-attached wearable sensors could be designed in response to specific stimuli locations and c) the investigation of functional aspects highlighted that users were indeed sympathetic to the concept of wearable sensors based on biochemical and environmental stimuli, but needed these devices to integrate into their lives and routines easily, in order to be effective.

Wearable sensor concepts

In line with the notion of designing out waste as part of the design process, these concepts were created to naturally embed the closed-loop strategies of recyclability and biodegradability, in order to showcase new approaches to anticipating and eliminating the product's potential end-of-life issues during the early stages of the design process (Walker, 2006; Bhamra and Lofthouse, 2007; Sherwin, 2012 and Köhler 2013). Going forward, the aim of the wearable sensor concepts is to inspire the multitude of stakeholders involved in the research, design and manufacture of Wearable Technology to actualise end-of-life considered products utilising these existing concepts as a starting point, or indeed, to create their own design for circularity concepts, before commencing the design and development of products.

Wearable skin: Design for reuse & recycling

Wearable Skin (fig. 12 and 13) combines futuristic approaches and materials by providing wearable sensors that could become a natural extension of the wearer's skin and body. This concept relies on the use of tactile and soft skin-like materials, surfaces and forms, in order to support natural interaction with the devices. Utilising synthetic nonwoven materials, the sensors are designed to be reusable and recyclable and could potentially be disassembled for reuse and recycling through emerging methods such as 'active disassembly' (Chiodo, Billet and Harrison, 1999), 'triggered degradation' (Scott, 2014) or 'end-of-life unzipping' of electronics (Wickham, 2013), which enables recovery levels over 90% of the original structure.

The Make(rs) & fix(ers) concept (fig. 14 and 15) involves the user in the making of personal sensing devices, which are modular, durable and removable, making reusability a key feature. Users can combine traditional crafts like felt making with homemade tech, such as 3-D printing pens and conductive painting and printing. Utilising natural or biosynthetic, nonwoven felt-like materials with rubberised coatings, the sensors can be repaired and upgraded with new tech elements by the users themselves or could be recycled or composted, once the device is beyond repair.

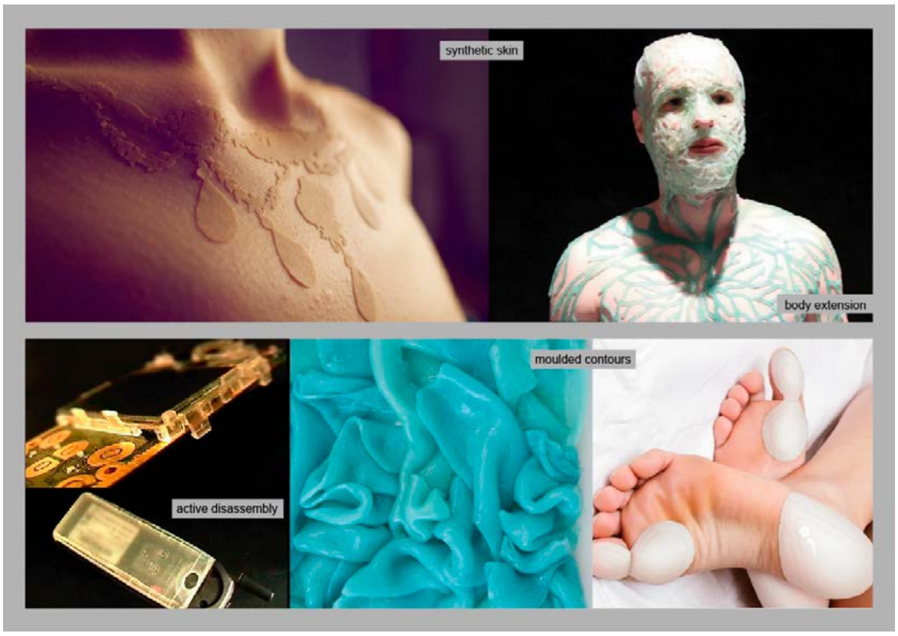


Figure 12: Wearable Skin concept board, utilising inspiration images from the fields of product & conceptual design, science and material innovation (Prahl, 2014)

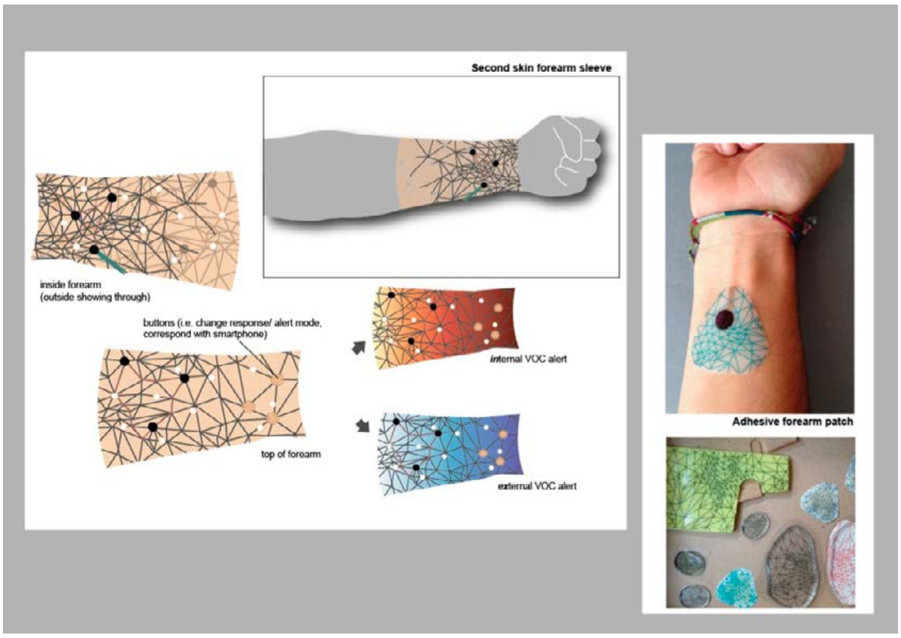


Figure 13: Wearable Skin designs and mock-ups (Prahl, 2014) Make(rs) & fix(ers): Design for repair & upgrade

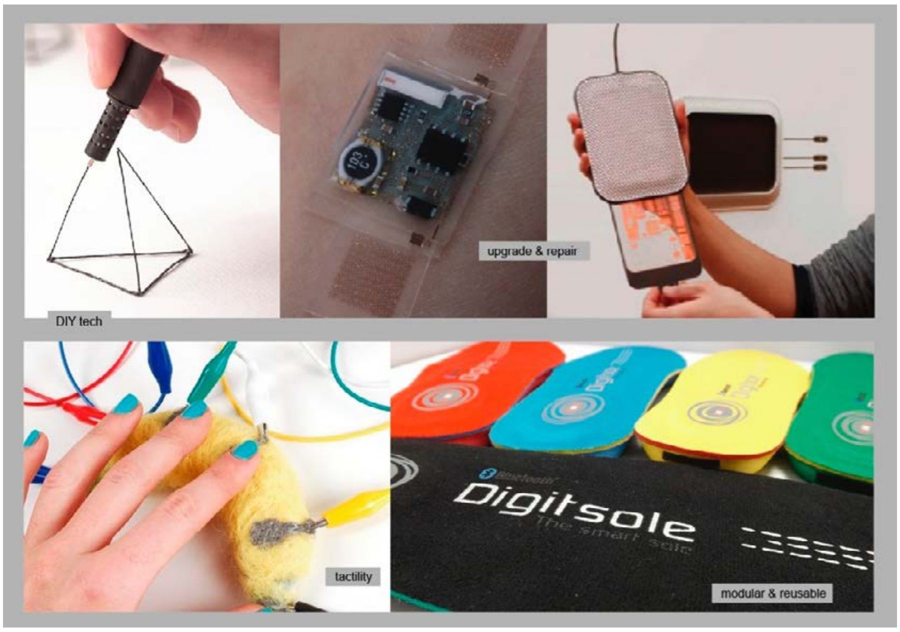


Figure 14: Make(rs) & fix(ers) concept board utilising inspiration images from the fields of product and conceptual design, science and material innovation (Prahl, 2014)

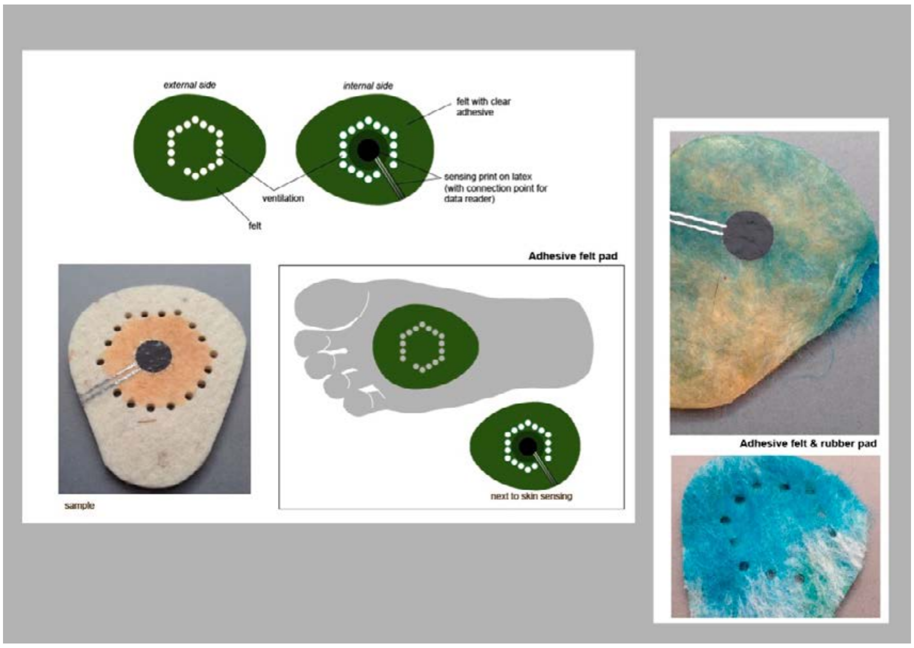


Figure 15: Make(rs) & fix(ers) designs and hand-made samples (Prahl, 2014)

Bio Sense: Design for Biodegradability

The Bio Sense concept (fig. 16 and 17) was designed to appeal to users who crave more simple interaction and low-tech feedback, preferably without the need for complex on-body electronics. Natural or semi-synthetic, paper-like substrates are perforated, lasercut or embossed to provide subtle pattern, which respond through stimuli-responsive colour change. These simple wearable sensors are biodegradable, utilising emerging concepts such as 'transient electronics' (Ahlberg, 2015), which can dissolve at the end of their life, biodegradable batteries made from wood pulp (KTH Royal Institute of Technology and Stanford University, 2015) or biodegradable electronic ink, which can be made from biocompatible materials such as cuttlefish ink (Bourzac, 2013).

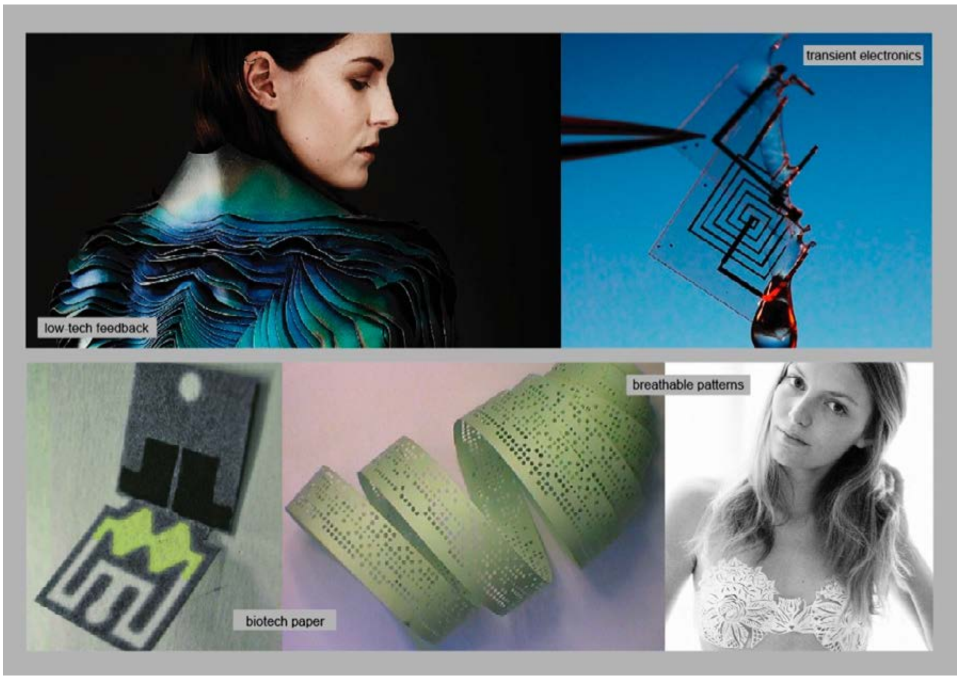


Figure 16: Bio Sense concept board utilising inspiration images from the fields of product and conceptual design, science and material innovation (Prahl, 2014)

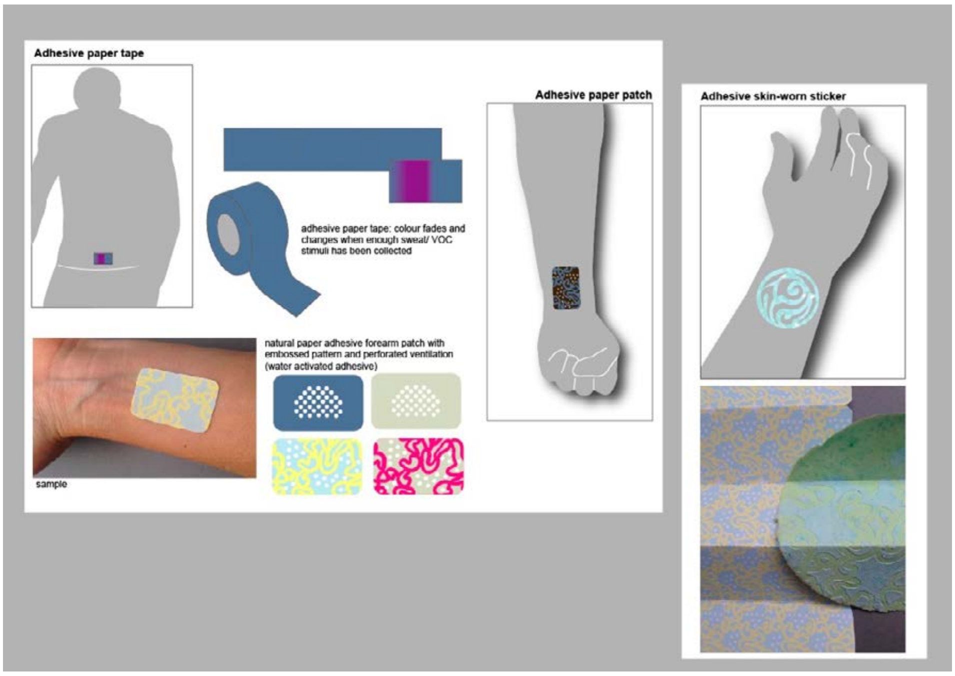


Figure 17: Bio Sense designs and hand-made samples (Prahl 2014)

Conclusions and further work

The design and development of textile-based Wearable Technology is a complex endeavour and requires multi-disciplinary teams consisting of various experts, such as product and textile designers, electronics engineers, scientists and user experience designers, in order to contribute to meaningful innovation. However, the author drew upon her professional background as a textile and clothing designer to explore alternative perspectives she could bring to the design of wearable sensors. As a result, the collections display distinctive concepts for the design of new types of wearable materials and form factors and in particular view to material innovation, the research illustrated prospects for the design and development of biodegradable or recyclable, nonwoven rubber-like, felt-like and paper-like substrates, in order to provide potential end-of-life options in the future. While biodegradable and recyclable electronics are at a relatively early stage of innovation, the concepts illustrate that technologies such as transient electronics and active disassembly could provide tangible inspiration for designing Wearable Technology for a circular economy.

The research displays potential innovation opportunities through conceptual proposals, however, in order to develop these ideas further in a commercial realm, it will be essential to explore effective ways to collaborate with a variety of academic and industrial stakeholders. As many researchers and practitioners engaged in the domain of textile-based Wearable Technology have stated previously (Lee, 2005; Chang, 2005; Seymour, 2010; Dunne, 2010), and highlighted by some of the outcomes and limitations during the author's own research project; unless the design industry develops and supports more appropriate methodologies for cross-disciplinary design research and development, any contributions to knowledge are likely to remain incremental, rather than producing revolutionary innovation. Moreover, in order to make design for a circular economy a reality in a commercial context, stakeholders need to advance and implement persuasive approaches to naturally embed end-of-life thinking into the design process, starting with trend forecasting, the design brief and research and concept stages (Prahl, 2016a). This approach will depend on providing designers with adequate support through inspiring education and skill development, so they can rise to the challenge.

References

adidas (2015) Messi's boots today, recycled into yours tomorrow. [Online] available at:
http://www.adidas-group.com/en/media/news-archive/press-releases/2015/messis-boots-today-recycled-yours-tomorrow/
(Accessed: 26/07/16)

Ahlberg, L. (2014) Off the shelf, on the skin: Stick-on electronic patches for health monitoring. [Online] available at: https://news.illinois.edu/blog/view/6367/233722 (Accessed: 26/07/16)

Ahlberg, L. (2015) Mission possible: This device will self-destruct when heated. [Online] available at:
https://news.illinois.edu/blog/view/6367/232606 (Accessed: 26/07/16)

Arthur, R. (2016) Seeking Start-Ups: Topshop Launches Innovation Program Geared To Wearable Tech. [Online] available at: http://www.forbes.com/sites/rachelarthur/2016/04/27/seeking-start-ups-topshop-launches-innovation-programme-geared-to-wearable-tech/#77270c1470c9 (Accessed: 26/07/16)

Bhamra T. and Lofthouse, V. (2007) Design for Sustainability. Hampshire: Gower Publishing Limited.

Bourzac, K. (2013) Biodegradable Batteries to Power Smart Medical Devices. [Online] available at:
https://www.technologyreview.com/s/522581/biodegradable-batteries-to-power-smart-medical-devices/ (Accessed: 26/07/16)

Chang, A. (2005) Engineers are from Mars, Fashion designers are from Venus: Bridging the gap between two opposing industries. Wearable Futures Conference University of Wales, Newport, 2005 [online]. Available at:

http://www.docstoc.com/docs/164623458/Engineers-Are-from-Mars_-Fashion-Designers-Are-from-Venus. (Accessed 04/03/12)

Chiodo, J. D., Billet, E. H., Harrison, D. J. (1999) Active disassembly using shape memory polymers for the mobile phone industry. Proceeding of the 1999 IEEE International Symposium on Electronics and the Environment, pp. 151–156 [online]. Available at: http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=765867 (Accessed 18/11/11)

Dunne, L. (2010) Smart Clothing in Practice: Key Design Barriers to Commercialization. Fashion Practice: The Journal of Design, Creative Process & the Fashion Industry, 2 (1), pp. 41-66(26).

Ellen Mcarthur Foundation (2015) Towards the Circular Economy Vol. 1: an economic and business rationale for an accelerated transition. [Online] available at: https://www.ellenmacarthurfoundation.org/publications/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an-accelerated-transition (Accessed: 26/06/16)

European Commission (2016) Closing the loop - An EU action plan for the Circular Economy. [Online] available at: http://ec.europa.eu/environment/circular-economy/index_en.htm (Accessed: 26/07/16)

Hayward, J. (2016) E-Textiles 2016-2026: Technologies, Markets, Players. [Online] available at: http://www.idtechex.com/research/reports/e-textiles-2016-2026-technologies-markets-players-000459.asp (Accessed: 26/07/16)

King, L. (2014) Google Smart Contact Lens Focuses on Healthcare Billions. [Online] available at: http://www.forbes.com/sites/leoking/2014/07/15/google-smart-contact-lens-focuses-on-healthcare-billions/#17651dad1dfa (Accessed: 26/09/14)

Köhler, A. (2008) End-of-life implications of electronic textiles. Assessment of a converging technology. Master of Science thesis. Lund University, Sweden [online]. Available at: http://lup.lub.lu.se/student-papers/record/1480555/file/1480556.pdf (Accessed: 10/10/11)

Köhler, A. (2013) Anticipatory Eco-Design Strategies for Smart Textiles Perspectives on environmental risk prevention in the development of an emerging technology. PhD thesis. Delft University of Technology [online]. Available at: https://www.researchgate.net/publication/256472264_Anticipatory_EcoDesign_Strategies_for_Smart_Textiles_Perspectives_on_environmental_risk_prevention_in_the_development_of_an_emerging_technology (Accessed: 26/5/15)

Köhler, A. (2013a) Challenges for eco-design of emerging technologies: The case of electronic textiles. Materials and Design, 51, pp. 51-60 [online]. Available at: https://www.researchgate.net/publication/236584328_Challenges_for_eco-design_of_emerging_technologies_The_case_of_electronic_textiles (Accessed: 10/04/14)

KTH Royal Institute of Technology and Stanford University (2015) Trees are source for high-capacity, soft batteries. [Online] available at: https://www.kth.se/en/aktuellt/nyheter/de-har-uppfunnit-mjuk-elektronik-1.569410 (Accessed: 26/07/16)

Lee, S. (2005) Fashioning the Future: Tomorrow's Wardrobe. UK: Thames & Hudson.

Levis (2016) Levi Strauss & Co. + EvrNu Create First Pair of Jeans From Post-Consumer Cotton Waste. [Online] available at: http://www.levistrauss.com/unzipped-blog/2016/05/levi-strauss-co-evrnu-create-first-pair-of-jeans-from-post-consumer-cotton-waste/ (Accessed: 26/07/16)

Ossevoort, S. H. W. (2013) Improving the sustainability of smart textiles. In: Multidisciplinary know-how for smart-textiles developers, Kirstein, T. (ed.), Cambridge: Woodhead Publishing Limited, chapter 14, pp. 399-419.

Prahl, A. (2015) Designing wearable sensors for Preventative Health: An exploration of material, form and function. PhD thesis, University of the Arts London [online]. Available: http://ualresearchonline.arts.ac.uk/9077/ (Accessed: 23/05/16)

Prahl, A. (2016) Designing with/ designing out waste. Trend presentation at Performance Days Fabric Fair, April 2016 [online]. Available at:
https://www.performancedays.com/fair/presentations/details/designing-with-designing-out-waste.html (Accessed: 23/05/16)

Prahl, A. (2016a) Responsible innovation for Wearable Technology: Exploring design strategies and future concepts. Webinar presentation on behalf of the European Outdoor Group / Sustainable Apparel Coalition, September 2016 [online]. Available at: https://vimeo.com/184590624. (Accessed: 10/10/16)

Scott, J. L. (2014) Skeleton-Material for Triggered Disassembly and Organs-Recovery of High Value Materials, CLEVER Symposium, London, 20 May.

Sherwin, C. (2012) Embedding sustainability in all design. [Online]. Available at: http://www.guardian.co.uk/sustainable-business/blog/embedding-sustainability-designfuture?INTCMP=ILCNETTXT3487 (Accessed 30/11/12)

Timmins, M. (2009) Environmental and waste issues concerning the production of smart clothes and wearable technology. In: McCann, J. and Bryson, D. (eds) Smart clothes and wearable technology. Oxford: Woodhead Publishing Limited, chapter 16, pp. 319-331.

UNEP, (no date) E-Waste Management. [Online] available at:
http://www.unep.org/gpwm/FocalAreas/E-WasteManagement/tabid/56458/Default.aspx (Assessed: 12/1/13)

Walker, S. (2006) Sustainable by Design: Explorations in Theory & Practice. London: Earthscan.

Wickham, M. (2013) Reuse of electronic products. [Online] available at:
www.npl.co.uk/upload/pdf/20130516_reuse_elec_prods.pdf (Accessed: 26/07/16)

Acknowledgements

The PhD research *'Designing wearable sensors for Preventative Health: An exploration of materials, form & function'* on which this paper is based, was supported by an EPSRC Creative Industries Knowledge Transfer Network Studentship under the Industrial CASE award scheme, funded by the Engineering and Physical Science Research Council (EPSRC).

Figures and Sources

All links checked on 28 July 2016

Figure 1: (a) Electronic waste (Greenpeace) http://www.greenpeace.org/international/en/campaigns/detox/electronics/

(b) Textile waste in Syria http://wastebiorefining.blogspot.co.uk/2011/04/collecting-system-for-textile-wastes.html

Figure 2: Knitted textile-based electrode (Textronic Inc.) http://www.talk2myshirt.com/blog/archives/423

Figure 3: Woven-in technology (Project Jacquard, Google & Levi's) http://www.themanufacturer.com/articles/google-debuts-new-electronic-smart-fabrics

Figure 4: Printed sensor (University of California, San Diego) http://jacobsschool.ucsd.edu/pulse/fall2010/research7.shtml

Figure 5: 3-D printed fabric prototype (Electroloom) https://medium.com/electroloom-blog/thanks-and-farewell-b0c128c3043f#.xw27gq5cn

Figure 6: Cosyflex 3-D printed fabric (Tamicare) http://www.israel21c.org/3d-printed-cosyflex-panties-to-debut-in-israel/

Figure 7: Flexible electronics (MC10) http://www.dezeen.com/2013/03/28/biostamp-temporary-tattoo-wearable-electronic-circuits-john-rogers-mc10/

Figure 8: Biodegradable sensor sample (Author's sample and image)

Figure 9: Sample testing (Author's image)

Figure 10: User workshop (Author's image)

Figure 11: Sensor carrier types (a) Skin-worn tattoo-like sensor (J. Wang, University of California San Diego)

http://www.rsc.org/chemistryworld/2012/06/electronic-skin-health-and-security-checks

(b) Body-worn fingertip sensor (J. Rogers, University of Illinois at Urbama-Champaign)

https://www.newscientist.com/article/dn22162-fingertip-tingle-enhances-a-surgeons-sense-of-touch/

(c) Bra-attached sensor (Cyrcadia Health, formerly First Warning System) http://newyork.cbslocal.com/2013/02/13/seen-at-11-cancer-detecting-bra-may-be-game-changer-for-women/

Figure 12: Wearable Skin concept board:

(a) Skin jewellery (Raluca Grada-Emandi) http://ralucagrada.net/Finely-Grafted-Jewellery

(b) Algae inspired future body (D. MacKenzie & M. Le Page) http://www.huffingtonpost.com/news/body-modification/

(c) Footstickers (Frieke Severs for Nike) http://www.wired.com/2010/12/foot-stickers-the-most-minimal-sneakers-around/

(d) Silicone rubber (M. van Arkel) http://www.artaffairs.net/?Tnext=image&Titem=P01ace%20W01c3a

(e) 'Active disassembly' prototype (Nokia Research Center with Helsinki University of Technology, the Finnish School of Watchmaking and the University of Art and Design Helsinki)
http://www.treehugger.com/gadgets/gadgets-that-self-destruct-active-disassembly.html

Figure 13: Wearable Skin designs and mock-ups (Author's designs and image)

Figure 14: Make(rs) & fix(ers) concept board:

(a) 3-D printing pen (Lix) http://www.designboom.com/technology/lix-3d-printing-pen-05-01-2014/

(b) Epidermal sensor plaster (J. Rogers, University of Illinois at Urbama-Champaign)
https://news.illinois.edu/blog/view/6367/233722

(c) O.System updateable speaker (Krige, du Preez and Hams)
http://www.creativeapplications.net/objects/o-system-the-future-of-personal-electronics-by-peter-krige-rca-ide

(d) Digitsole http://www.gizmag.com/digitsole-warms-feet-counts-calories/34047/pictures?thumb=true#picture4

(e) Needle-felted touch sensor (Adafruit)
https://blog.adafruit.com/2012/12/24/adafruit-holiday-gift-guide-2012-makey-makey/

Figure 15: Make(rs) & fix(ers) designs and hand-made samples (Author's designs and image)

Figure 16: Bio Sense concept board:

(a) Stimuli responsive clothes (The Unseen) http://seetheunseen.co.uk/collection-archive/air/

(b) Biodegradable integrated circuit during dissolution in water (Beckman Institute, University of Illinois and Tufts University) https://news.illinois.edu/blog/view/6367/204978#image-7

(c) Paper bra (B. J. Kleipool) http://www.thisisjanewayne.com/news/2011/04/07/wahre-scheren-kunst-der-bh-aus-papier/paper-bra-2/

(d) Perforated paper tape for data storage (IBM)
http://www.nic.funet.fi/index/FUNET/history/mbase/en/reika.html

(e) Wax printed sensor (H. Liu et al. University of Texas at Austin and the University of Illinois at Urbana-Champaign)
http://www.laboratory-journal.com/news/scientific-news/origami-styled-sensor-technology-rapid-diagnostics

Figure 17: Bio Sense designs and hand-made samples (Author's designs and image)

CIRCULAR TRANSITIONS

23 – 24 November 2016

Where Does Wearable Technology Fit in the Circular Economy?

Marie O'Mahony (Visiting Professor, Royal College of Art),
Alison Gwilt (Sheffield Hallam University)

Abstract

Wearable electronics has emerged from a niche industry to one expected to rise to US$70 billion by 2025 (Harrop, 2015). While starting to recognise environmental concerns they have yet to become an industry driver. In this paper, we explore options to better position wearable technology in the Circular Economy.

Introduction

Environmental concerns have become a core focus in today's fashion and textile industry. Sustainability underlies all aspects of the industry from sourcing raw materials through design, manufacturing, consumer use and end-of-life disposal. Wearable electronics has emerged from a niche industry to one with an estimated market value of US$20billion in 2015 and expected to rise to US$70 billion by 2025 (Harrop, 2015). Although still a relatively immature industry, it is starting to recognise environmental concerns but thus far it has not become an industry driver. In this paper, we first look at the current state of sustainability within wearable technology. In the second section we identify key drivers and issues then propose ways in which wearable technology can more fully embrace the Circular Economy. In the concluding section we look at future technologies and their likely environmental impact.

As wearable technology has now started to mature all aspects of sustainability need to be addressed. We will look at lessons that can be taken and applied from the textile and fashion industry such as the sourcing, use, reuse and disposal of material. We will also examine issues unique to wearable technology for example the need for a power supply and the problem of technological obsolescence within the garment. From a design perspective we examine the ways in which wearable technology is applied within fashion and how this could more closely relate to the activity of garment use. From this position we then question whether it is possible for wearable technology to contribute to garment longevity by examining issues and concepts related to fashionability, durability, and repair. In the concluding portion of the paper we consider the introduction of future technologies and disruptive manufacturing processes that have the potential to provide challenges that demand design and manufacturing solutions that are both sustainable and innovative.

Wearable technology

Wearable Technology refers to the incorporation of technology into clothing to provide for a dynamic clothing system that senses and responds to stimulus. It is also referred to as Smart Clothing, Interactive Clothing, Intelligent Clothing and Wearable Computers. The discipline emerges from the fields of Military, Medical, Space, Sportswear (O'Mahony, 2002) and Computers. Early iterations can be traced back to the 1960's, however, it was in the 1990's that developments began in earnest with partnerships forged between industry and academia notably in America with universities such as Massachusetts Institute of Technology (MIT), Georgia Tech and Carnegie Mellon University. The early iterations were driven by a desire to create wearable computers (Suh, et al 2010). The prototypes that emerged through the 1990s can most accurately be described as 'portable' rather than 'wearable'. There were many reasons for this. Energy was key as many waited to see whether the much-anticipated lithium battery would materialise and be affordable, bringing with it a smaller, lighter and more efficient power source. Wearable Technology has excited technologists and fashion designers alike causing it to be seen both as the "future of fashion" and the "future of computing" (Dunne, 2010). It is only relatively recently that technology has become 'cool' and the computer industry has begun to reach out to fashion acknowledging its value to their products.

The end of the Cold War saw a reduction in military spending on research and development and as a result there was a shift towards consumer applications for wearable technology. While the soldier had little choice about what they wore, the consumer clearly expected any garments and devices to be fully functional, reliable, lightweight, comfortable, and stylish. Early adopters include Hussein Chalayan with spectacular clothes that appeared on the catwalk as early as 2002. While fashion embraced the concept and aesthetic of wearable technology, cost and development meant that it is sportswear that has taken the lead on commercialisation and getting products into the shops. In particular, biometric clothing that monitors the wearer's vital signs during activity is being produced by brands such as adidas, OMSignal and Hexoskin with products that are being well received by Early Adopters. The challenges they and others entering the market face include increasing user engagement, greater aesthetic and comfort, ease of use and customisation. Environmental issues are starting to emerge, as the industry is realising that they are part of the apparel industry and the concerns there need to be addressed by wearable technology also.

Clothing and the circular economy

Clothing products are developed for a wide range of markets, and they have to meet the specific requirements, needs, and values of an identified consumer. It is because of this variety that garment characteristics differ in their aesthetic qualities, fabrications and construction methods, most of which will have been determined to suit a predetermined price point, purpose, and function. High street fashion garments, for example, are typically developed for their aesthetic appeal and are constructed from inexpensive materials that keep the items affordable and (easily) replaceable. Meanwhile many workwear and uniform garments typically place a greater value on functionality and durability during use, connected to performance during wearing and maintenance requirements.

Post-purchase, during the use phase, a garment goes through a series of activities including wearing, washing, storing, repairing (adaption and alteration), and disposal (Bras-Klapwijk and Knot 2001). Each person will have an individual pattern of use that may be different to the practice employed by others. Consequently, this means that whilst the characteristics of a garment may be the same the practices adopted by two people may be starkly different (Gwilt, 2015). Laundering may be poorly or carefully executed, for example, or a garment may be discarded early or it may be repaired or altered and kept for longer. Significantly when and where a garment is discarded will depend on the philosophical viewpoint of the wearer. In a study conducted by WRAP (2012) more than half the adults interviewed believed that discarded garments had no value and so placed items in a waste bin.

These points show that there is a direct relationship between design and production of garments, the practices applied during use and the generation of textile waste. Working towards a circular economy in the clothing industry can, then, pose a variety of challenges. While it is apparent there is a need for specific and specialized solutions that take into account the individual characteristics of a garment type, there is also a necessity to be aware of the individual practices adopted by wearers during use. The question is whether the picture will be further complicated if garments are embedded with wearable technology.

Reflecting on the strengths and weaknesses of wearable technology in the circular economy

Wearable Technology is in a unique position aligned both to the clothing and technology industries. Dunne describes the current model of developing smart clothing as "…a grafting of two existing approaches (an electronic device grafted onto a garment), when what is necessary is a redevelopment of both." (2010, p56). From an environmental point of view this allows it to transcend some of the issues that the fashion and sportswear industries in particular are currently struggling with such as fast fashion. That said, it also creates another set of problems. There are three areas in particular that have to be addressed: energy in production and use; technology integration; design aesthetics and garment care.

Energy

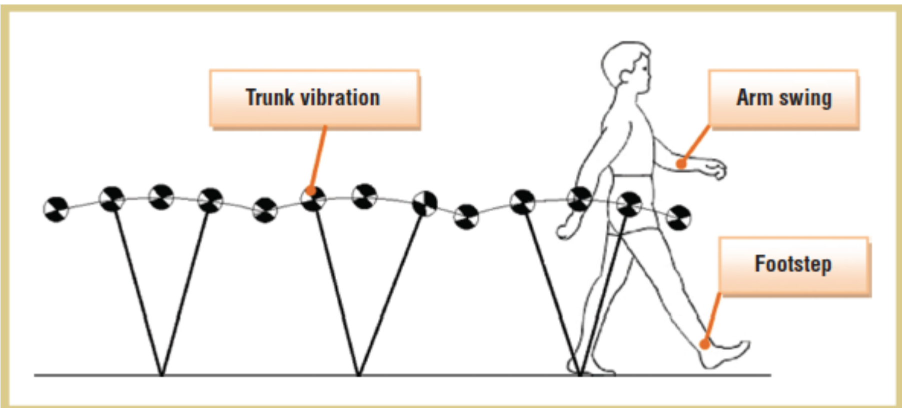


Figure 1: Human movement while walking showing the hip and trunk motion up and down measuring 4-7cm as the body is propelled forward from one leg to another. Illustration: Xie and Cie

Energy is an issue in material selection, garment production, distribution, and use as with all garments. However, Wearable Technology brings with it additional challenges of the energy needed to provide power to the devices incorporated into the garment. While Steve Mann was transporting his energy supply in a Pentium II housed in his backpack, one of his fellow researchers at MIT Thad Starner, was investigating the potential of the wearer to supply their own energy needs through movement (Starner, 1996). Starner points to two issues here. The first is that of energy that he defines as being "the capacity to do work", and the second is that of power being "the time rate of doing work". As his research looks at the potential of breath, body heat and movement (leg and footfall in particular) to provide energy, ultimately he concluded that it was not feasible beyond certain military applications because of the consumer demand for fast Central Processing Unit (CPU) speeds and high broadband. More recent research in the field looks at foot and human trunk motion to provide power identifying the need for further development in reducing weight and bulk in such devices before they become acceptable to the consumer (Xie and Cie, 2014). An energy approach that is receiving greater commercial success is the use of Photovoltaic (PV) Cells. More commonly used in architecture to harness the sun's rays and convert it to electricity, the technology has developed sufficiently that is can be scaled down and produced in a flexible form that can be incorporated into garments.

Figure 2: Garments designed to maximise the positioning of the PV cells, Yuxi Wang Digital Futures Graduate collection, OCAD University. Photo: Yuxi Wang.

Technology

The integration of technology into clothing in Wearable Technology has technical, comfort and aesthetic criteria that need to be addressed. Hussein Chalayan's Ballerina dress (S/S, 2002) used forty-five meters of shape memory alloy and was powered off-stage at Sadler's Wells by a car battery. While acceptable for a catwalk show this is not something that could be sold commercially in that form.

New developments in yarns, conductive inks and fabric technologies are making it easier to design more discrete garments. There remain challenges of how to protect the technologies against wear, laundry and human perspiration while ensuring that they are correctly positioned to be effective at all times while in use. The ideal material in terms of recycling is a monomaterial that ensures a material can be broken down at the same temperature and process (O'Mahony, 2011). In wearable technology materials are by necessity hybrids, usually comprised of a textile and non-textile component presenting the challenge where "the existing Design for Recycling (DfR) principles for textiles or electronics do not match with the properties of the combined products." (Kohler, 2013).

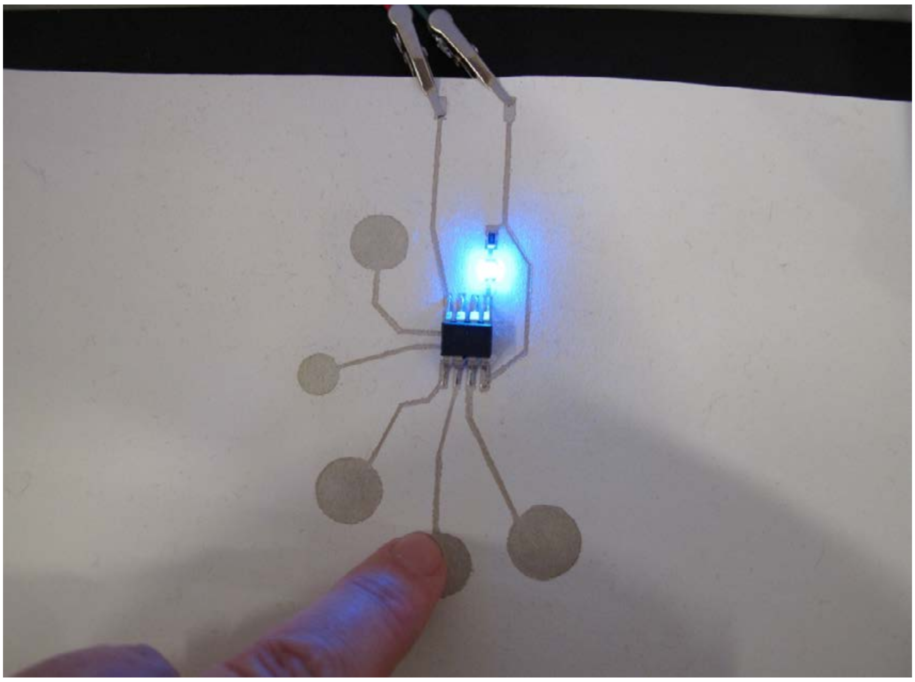


Figure 3: Advances in textile and coating technologies that are making it possible for designers to incorporate conductivity and sensors more discretely into garments. Photo: Marie O'Mahony

Design

In a commercial context wearable technology has become an increasingly important attribute in the development of performance sports and outdoor wear clothing. Garments designed for these sectors usually place an importance on functionality, and the aesthetic look of the garment will be developed in a way so they can be worn for a number of seasons or years. In the fashion industry there is a great emphasis on producing garments with a built-in obsolescence. As Welters (2008) argues, the availability of inexpensive, poor quality clothing has created a demand for 'instant fashion', products that are designed to stimulate the cost-conscious fashion consumer's desire for consumption. For the fashion industry the promotion of the disposal of one garment in pursuit of another is a model of production / consumption that provides economic benefits. However, this emphasis of a 'designed obsolescence' in fashion items may be highly problematic in the context of wearable technology. Since the fashion garment typically has a different lifecycle to that of technology components, Seymour suggests that, "…making a workable integration between the two is a challenging preposition" (2009, p25). Garments may still be discarded after one season although they incorporate technology developed to last for many years.

Amongst the existing literature a common perception is that the future for wearable technology "…lies in applications such as medical, workwear and other technical applications rather than fashion." (Berglin 2013, p24) Whether this is a correct assessment or not these items of clothing, just like fashion garments, will still require some care and maintenance during use, which may include laundering. Typically care labeling is provided in clothing at the point of purchase to assist users at home (Cox, et al 2013). However, whether there are benefits in providing labeling is contentious. Many people, it seems, do not execute the advice given on care labeling even though it is known that the life of a garment may be extended if care instructions are followed (van der Merwe, et al 2014). Routinely people will draw on existing knowledge that is either self-taught or passed on by family members (Shove 2003). Whilst the disparate practices in themselves may not be poor for conventional garment types, for those with embedded electronics laundering practices may be complex or problematic especially if the circuit boards and components are not encased in a detachable compartment (Dunne 2010). Further, as garments age specific areas may break down requiring repair, however in general people are not routinely involved in the practice of repairing worn or damaged clothing (Fisher et al., 2008; Gwilt, 2015). While this in general is problematic in a circular economy, if users lack basic repair skills then any attempt to replace or reattach rigid electronic components maybe difficult especially if, as Dunne (2010) notes, stitching through wires can damage the electronic circuitry.

Where next for wearable technology?

The enthusiasm for Wearable Technology is reflected in the fact that one in ten Americans own such a device (Lee, et al 2016). Unfortunately, the same research shows that one third of these consumers stopped using their product within six months. The illustration (Figure 4) highlights the importance of social impact, meaningful design purpose and public interest as key tenets. This is starting to take shape at a research level from the medical and wellness sector. In his PhD, Martijn ten Bhomer raises the important question of how Wearable Technologies can offer services that are more meaningful to people's lives (ten Bhomer, 2016). In his garment titled 'Vigour' for instance, the intention is to explore the potential for healthcare applications to become a means of communication between Alzheimer patients and their therapists encouraging greater interaction. The knitted, long-sleeved shirt uses a combination of stretch sensors and conductive yarn to gather patient data over the course of the day, which is communicated to the care-giver and the patient through sound or vibration. However, there are other ways in which Wearable Technology can positively contribute to life whilst being mindful of a need to work within the Circular Economy.

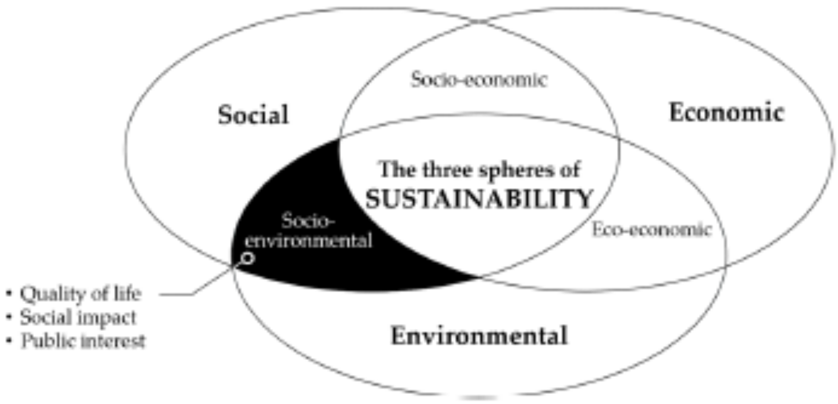


Figure 4: Three spheres of sustainability. Illustration: Lee, Kim, Ryoo and Shin.

Durability

Products based around technology can be open to accusations of creating 'planned obsolescence' that reduce their longevity (van Hinte, 1997). However we are starting to see a number of distinct routes emerge towards creating a greater durability in Wearable Technology. As technology becomes more energy efficient and components flexible and discrete, the aesthetic can be exploited to enhance the wearing experience. Through the use of illumination garments can be developed to change their design, effectively allowing the wearer to constantly alter the appearance of their garment throughout the day. The London-based Cute Circuit is an example of this, creating garments such as the Galaxy Dress (2009) with 24,000 Light-Emitting Diodes (LEDs) and the Twitter Dress (2012). Looking to the future Cute Circuit's Ryan Genz imagines social media moving technology to provide a wider environmental benefit enabling greater efficiencies in public transport systems for instance (Black, 2016).

Beyond embedded lighting, designers such as Ying Gao are also creating more dynamic garments that change shape in response to sound and light. Behnaz Farahi is developing garments that respond to gaze using a discrete camera and face-tracking algorithm to detect the onlooker's gender, age and viewing direction. Further, if as Dunne (2010) suggests there is a greater focus on "…interdisciplinary collaborations or multidisciplinary training..." between the technology industry and clothing producers it may be possible to better match the lifecycle of garment and technology thereby improving the durability of wearable technology.

Figure 5: Cute Circuit's Twitter Dress (2012). Photo: Cute Circuit

Repair and recycling

Developing wearable technology that enables the wearer to be "more creatively engaged in the transformation process…" (Earley and Goldsworthy, 2015 p5) may open up the opportunity to extend the life of existing wearable technology products. However as existing literature has shown (Fisher et al., 2008; Gwilt, 2015), support is needed to assist wearers with no or little repair experience.

Wearable Technology has a strong association with the Maker Movement with making, and by extension repair cafés and studio spaces appearing in larger cities. Much of the development is coming from small start-ups who by necessity have to develop not only the concept, but bridge the gap between the working prototype and scaled up manufacturing. This is one of the most challenging aspects of the field but it does bring with it an intricate knowledge of all aspects of the garment so that design for repair and disassembly can be factored at a very early stage in the process. Environmental and ethical concerns are becoming part of the ethos with brands such as Berlin-based Moon promoting their garments as offering "Intelligent Sustainability" with "top-quality products of long durability and devote our efforts to providing innovative, resource-saving production processes on fair terms" (Moon, 2016).

Emotional engagement

Consumer engagement on an emotional level is challenging for designers when working with man-made materials and with technology. But Wearable Technology has the potential to provide a wearer with a garment that can, as Earley and Goldsworthy suggest, meet three key requirements of “durability, adaptability and personal connection…” (2015, p5). A key challenge in designing for Wearable Technology is creating a bond with the consumer that goes beyond performance and aesthetics. The Digital Futures students at OCAD University were tasked with developing a concept for a biometric shirt and creating a working prototype. Consumer engagement was key and students began the process by creating their own avatar based on the principles outlined by Dunne and Watkins (2015). This was reinforced in asking the students to design for a friend, so the body was very real and fittings involved movement and real-time feedback on comfort and ergonomics. Molly Sayers' Hug Me shirt was conceived and designed to engage with its owner, tracking their body expression and helping to correct negative ones while encouraging positive interactions with other people (Figure 6).

Textiles themselves have a great capacity for emotional engagement and this is likely to increase now that natural fibres are starting to be used in conductive materials. In considering the nature of fabrics in this respect, Diamond argues that "Biological and psychological approaches may contribute to the ontology of textile memory, as textiles are perceptual and cultural" (2015, p.368). She goes on to lament the persistent search by textile and fashion manufacturers to find ways of eliminating stains, wrinkles, odours and other forms of human trace left naturally on clothing. In effect, striving to eliminate the contemporary garment's memory.

Figure 6: Hug Me biometric shirt concept and prototype design by Molly Sayers, Ontario College of Art and Design (OCAD) University (2015). Conductive fabric sponsored by Noble Biomaterials. Photo: Molly Sayers

Conclusions

Wearable Technology while a relatively immature industry comes with the benefit of a rich provenance from the apparel and computer industries. Although there are barriers to commerciality in fields such as fashion design, there are aspects of the clothing industry that have been making great strides towards an improved integration of technology in garments. Many of the environmental initiatives being adopted (recycling, emotional engagement etc.) have been tried and tested in other related fields. However, because of the hybrid nature and complexity of producing and using wearable technology, there are unique challenges to be faced in creating wearable technology products in a circular economy. Some can be met with design-led solutions, while others require new technological developments or new forms of supply chain. It is apparent that collaboration is proving key whether in academia or in industry.

References

Berglin, L. (2013) Smart Textiles and Wearable Technology – A Study of Smart Textiles in Fashion and Clothing. Swedish School of Textiles, University of Boras, Sweden.

Black, S. (2016) Reconciling Electronics and Fashion: Cute Circuit's Francesca Rosella and Ryan Genz in Conversation with Sandy Black, Fashion Practice, Berg, 2:1, (2016) :117

Bras-Klapwijk, R.M. And Knot, J.M.C. (2001) Strategic environmental assessment for sustainable households in 2050: illustrated for clothing, Journal of Sustainable Development, 9 -2 (2001): 109-118. Canadian Center of Science and Education

Diamond, S. (2015) The Fabric of Memory: Towards the Ontology of Contemporary Textiles, The Handbook of Textile Culture, London: Bloomsbury, 367-385

Dunne, L. (2010) Smart Clothing in Practice: Key Design Barriers to Commercialization, Fashion Practice, 2-1: 41-65 Taylor and Francis

Earley, R. and Goldsworthy, K. (2015) Designing for Fast and Slow Circular Fashion Systems: Exploring Strategies for Multiple and Extended Product Cycles, PLATE Conference, Nottingham Trent University

Fisher, T., Cooper, T., Woodward, S., Hiller, A. and Gorowek. H. (2008) Public Understanding Of Sustainable Clothing: A Report for the Department for Environment, Food and Rural Affairs. DEFRA, London.

Gwilt, A. (2015) Fashion Design for Living. Routledge, London

Kohler, A.R. (2013) Challenges for eco-design of emerging technologies: the case of electronic textiles, Journal of Materials and Design, Volume 51, Elsevier: 51-60.

Moon, http://www.moonberlin.com; accessed 31st July 2016

O'Mahony, M (2002) Cyborg – the Man-Machine' (2002). Thames and Hudson, London

O'Mahony, M (2011) Sustainability – Nature or Nurture book chapter for Shaping Sustainable Fashion ed. Alison Gwilt and Timo Rissanen, pub. Earthscan.

Seymour, S. (2009) Fashionable Technology: The Intersection of Design, Fashion, Science and Technology. Springer Wein, New York.

Starner, T. (1996) Human-powered Wearable Computing, IBM Systems Journal, Volume 6, Nos 3+4. IBM

Suh, M., Carroll, K., Cassill, N., (2010) Critical Review on Smart Clothing Product Development. Journal of Textile and Apparel Technology and Management. Volume 6, Issue 4, (Fall 2010): 3. NC State College of Textiles

Shin, J, Kim, D., Ryoo, H-Y, Shin, B-S, (2016) Sustainable Wearables: Wearable Technology for Enhancing the Quality of Human Life, licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC-BY) license (http://creativecommons.org/licenses/by/4.0/).(2016): 2

Shove, E. (2003) Comfort, Cleanliness and Convenience. Oxford: Berg.

Ten Bhomer, M. (2010) Designing Embodied Smart Textile Services: the role of prototype for projects, community and stakeholders, PhD, TU Eindhoven

Van Der Merwe, D., Bosman, M., Ellis, S., Van Der Colff, N., & Warnock, M. (2014) Consumers' Knowledge of Textile Label Information: An exploratory investigation. International Journal of Consumer Studies, 38, (2014): 18-24. Wiley

Van Hinte, E. (1997) Eternally Yours: visions on product endurance, 010 publishers, Rotterdam: 60.

Watkins, S.M., Dunne, L.E. (2015) Functional Clothing Design, from Sportswear to Spacesuits. New York: Bloomsbury.

Welters, L. (2008) The Fashion Of Sustainability. In: Hethorn, J. & Ulasewicz, C. (eds.) Sustainable Fashion: Why Now? A Conversation About Issues, Practices, And Possibilities. New York: Fairchild Books.

Xie, L., Cia, M. (2014) Human Motion: Sustainable Power for Wearable Electronics, Pervasive Computing, IEEE CS, October – December.

Digital Denim by Design

Dawn Ellams (University of the Arts London, UK),
Nick Morley (Faering Ltd)

Abstract

Life cycle assessment research has shown that denim is a disproportionately polluting part of the textile manufacturing sector. The linear industry structure is reliant on cotton with its well-known land use, water and pesticide issues. The traditional manufacturing of denim fabric uses environmentally and socially detrimental processes in the dyeing and finishing stages. The distressing of denim compounds these impacts whilst reducing technical performance and longevity. At the end of life, the materials, chemical and embedded energy from initial production stages are also lost when garments are disposed of.

As a way of increasing material circularity, there has been increased interest in re-spinning denim and incorporating it into new products. Re-spun content is typically limited to around 20%, so most denim is today largely recycled into low grade industrial products such as insulation. The paper explores a more radical approach which combines lower whole life cycle impacts whilst enabling new materially circular business models. Digital inkjet printing was explored as an alternative coloration method for denim. Denim dyeing and distressing are combined in a single, low impact design-led process. Material circularity involving re-distressing and reprinting to enhance and rejuvenate denim products are then possible.

Introduction

The initial interdisciplinary research presented was conducted at the design/technology interface in collaboration with fibre manufacturer, Lenzing as part of a larger extensive programme of doctoral study and is being used to inform future stages of research.

Five billion pairs of jeans are manufactured globally every year using 35% of world Cotton production (Musante, 2013). The production of denim fabric is well known to be intensive of water, dyes and chemicals from initial fibre cultivation through to manufacturing processes causing significant environmental impact. This has been confirmed by cradle-to-grave life cycle assessment of denim garments, the fabric production phase, including dyeing and finishing, is identified as having a large environmental impact across several impact categories (Roos et al, 2015). The environmental impact is then often further increased, and the technical performance of fabric reduced, by selective destruction of the fibre properties to create distressing 'worn' effects on fabrics, using lasers, water jets or enzymes or alternatively the more traditional techniques of sand blasting, washing with abrasive media, or holding the fabric against a grinding wheel.

There are many eco-efficiency strategies to reduce environmental impacts and increase resource efficiency of denim fabric and garment production, for example those reviewed by Hasanbeigi and Price (2015). The main strategy to the material circularity of denim garments, and thereby improve environmental impacts by displacing virgin fabric production has been to increase recycling. Mechanical recycling has been achieved firstly with post-industrial cuttings, and latterly with the use of post-consumer garments, for example from the I:Co / H&M collaboration. In this arrangement, denim garments are separated from the clothes collected in H&M stores, are shredded and pulled back to fibre, and then re-spun with virgin fibre. The major limitation of this approach is the shortening of the fibre caused by the pulling process, and hence reduction in mechanical strength. This means that the current maximum incorporation of recycled content is around 20%.

Another more radical recycling strategy is to pulp or otherwise separate the fibres of the denim cotton, dissolve and re-extrude them in order to produce a regenerated cotton material. This strategy is being explored by researchers such as Saxion University, VTT and Chalmers University and by start-up companies such as RenewCell and Evrnu. A review of recycling technologies, including for denim cotton, has been presented (WRAP, 2016), such a recycling approach fits within the conventional business models of retailers and brands, albeit with the additional reverse logistics challenge of sending recycled garments or fibre from the developed world to the developing world where most of the fabric and garment supply chains for retailers such as H&M exist.

An alternative approach to reducing environmental impact of denim production, presented within this paper is to link design stages with production processes through digitally printing a denim effect onto greige twill fabric i.e. undyed denim. By printing individual pattern pieces rather than a roll of fabric, bespoke distressing effects can be produced. The ability of digital printing to rapidly and easily change designs has been harnessed to create a range of base denim pieces and distressing patterns, using reactive dyes as ink media. Through careful use of design software, the irregular features of denim fabric have been mimicked. Additional features such as stitching effects have been added.

Such a “made in white” approach is similar to that seen in industries such as automotive, where a base model is made which can then be customised at the end of the production process. The production process is therefore altered to one that is able to exist much closer to the consumer’s home market, without compromising existing large volume fabric producers. This in turn enables new more materially circular business models to be created. For example, the customisation and personalisation of jeans design should increase the first-user lifetime; elimination of processes to degrade the fibres should increase the technical lifetime; there is the potential to re-print or re-distress garments part-way through their life with new distressing patterns, so increasing first-user life, or in order to increase the attractiveness of garments for second users.

Identifying Life cycle ‘Hotpots’

The primary objective of this research was to reduce the environmental impact of producing a pair of denim jeans, and so the research presented adopted an ecodesign approach. Ecodesign is a sustainable design approach for processes and products that incorporates life cycle thinking into the design process, the designer is consciously aware of the ecological impact of products they are designing for production throughout their whole lifecycle from manufacture to consumption (Chick & Micklethwaite, 2011). Considering the whole life cycle identifies key stages of environmental impact caused by the production and consumption of design outcomes and highlights areas for interception designers can focus on to reduce environmental impact of final products. Environmental considerations are integrated into design decisions, material and process choices are made that balance aesthetic and environmental value without sacrificing one for the other.

The interdisciplinary research combined colouration technology with design, literature and life cycle assessment data, which measures the use of chemicals, water and energy were used to identify key areas within the life cycle of denim jeans that cause environmental impact. Once identified these life cycle areas were classified as ‘hotspots’ as illustrated in figure 1. The identified hotspots within the production stages of denim then became the focus for this research. Hotspots were incorporated and addressed within the design process to provide an outcome that re-designs denim. Traditional materials and process choices were replaced and alternative options explored were design decisions are linked to environmental performance for fibre choice and coloration and finishing processes.

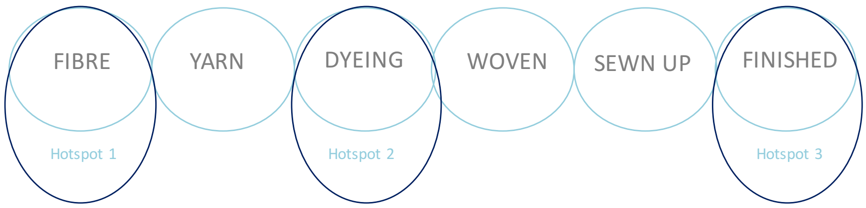


Figure 1. Life Cycle 'Hotspots' of Denim Jeans

Incorporating production stages through Digital design and Print

Printing Digital Denim

Traditionally denim was produced by dying using natural indigo derived from a plant source, most denim produced today is dyed using synthetic indigo. The blue hue of Indigo is synonymous with denim, indigo as a dye is unique in the depth of blue colour it provides but as a dye has little affinity to cotton, resulting in a permanent unfixed state of dye molecules to fibres. These non-binding properties enable the worn, distressed appearance of denim to be created either gradually over time through wearing and washing or speeded up by finishing processes that knock unfixed molecules off specific areas of the cotton fabric. During the dyeing process chemicals are used to pre-treat the cotton so that the dye engages with it. Chemicals including caustic soda and hydrosulphite are used to reduce both natural and synthetic Indigo, resulting in the presence of these chemicals in the dye effluent, which are not beneficial to the environment (Thiry, 2009).

Digital inkjet printing provides opportunity to explore an alternative coloration method for denim. Printing with reactive dyes allows colour to be applied in a localized design or pattern to a textile material. Digital inkjet printing refers to the creation of individual drops of ink deposited in a precisely controlled manner onto a substrate in doing so creating an image (Fralix, 2001). Within the research two separate finishing processes of traditional denim production are combined to reduce energy, chemical and water usage. These being, the initial coloration stages of indigo dyeing and finishing stages such as stone washing, bleaching, treatment with enzymes, laser treatment or sulphuric acid. The comparison of processes for inkjet printed denim with traditionally produced dyed denim is shown in Figure 2.

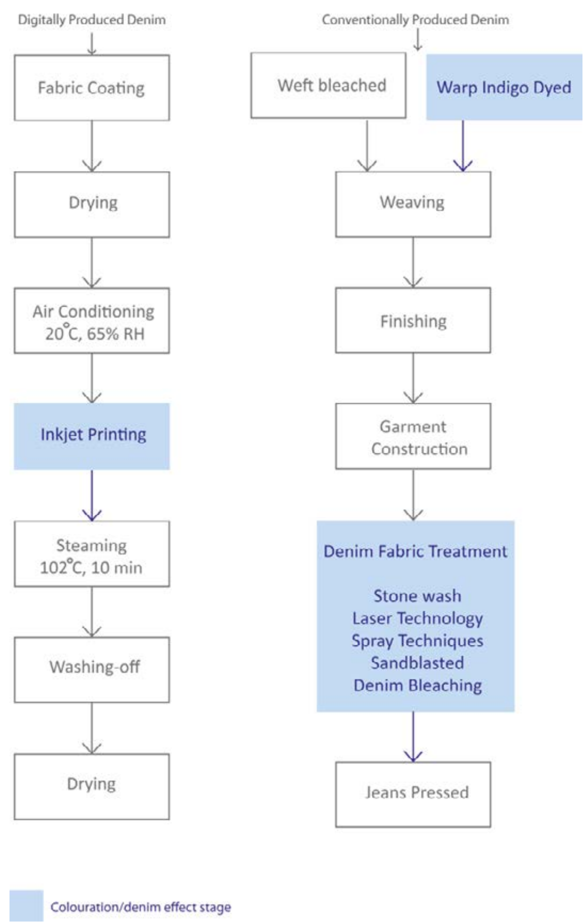


Figure 2. A comparison of the methods for denim production

Digital inkjet printing for textiles was first exhibited by stork in 1991 though the model exhibited, the TruColour TCP2500 was designed as a sampling machine and could only print rectangular fabric swatches. At ITMA (an international trade show and conference for manufacturers and suppliers of textile) in 1995 Stork introduced the 'fashion jet', a model of printer capable of continuously printing rolls of fabric, (Moser, 2003). Since the initial introductory interest in digital print, improvements in technology and capabilities of both computers and computer-aided design soft-wear programs have continued to grow. Digital inkjet printing offers a method for creating denim effects that are reproducible and controllable, through the hand of the designer, technology and computer aided design.

The research needed firstly established whether denim fabric could be simulated using digital printing. 'Irregular Twill' fabric was specifically woven from Tencel A100 for the purpose of the research. The change from cotton, used in traditional denim, to Tencel avoids the negative environmental features of cotton, and takes advantage of the positive environmental features of Tencel. Lyocell, marketed as Tencel by the manufacturers, Lenzing AG (Austria), is a regenerated cellulosic fibre strong environmental credentials (Taylor, 1998; Mather & Wardman, 2011). The manufacturing process uses wood pulp derived from eucalyptus species, particularly Eucalyptus Grandis, Urophylla, Nitens and Dunnii, all of which are hybrids. The eucalyptus is farmed marginal land, i.e., unable to sustain agricultural crops, are fast growing without additional water irrigation or pesticide use. The manufacture of lyocell involves dissolving the pulp in N-methylmorpholine-N-oxide (NMMO) containing a small amount of water. The fibres are formed by a dry-jet wet spinning process in which the viscous, concentrated solution of cellulose is extruded through a spinneret into a water bath. The organic solvent, which is claimed to be essentially non-toxic and biodegradable, is recovered at a rate of 99.5% (Mather & Wardman, 2011). Unlike other regenerated cellulosic fibres, such as viscose, there is no chemical conversion involved and the cellulose content of the pulp used to feed the lyocell process remains chemically unchanged in the final product.

The Tencel fabric was prepared for digital print by impregnating with a solution of sodium bicarbonate, Metaxil p-AL and urea in water. Fabric must be pre-prepared in this way to allow reactive dye molecules to penetrate into the fibre during inkjet printing, and to cause them to be fixed to the fibre by chemical reaction after printing using steam.

Designing Digital Denim

To create the denim imagery for printing, a selection of denim swatches were scanned into Photoshop using a high-resolution setting (300 dpi). The digital imagery was required to replicate both the structural twill effect of denim as a result of the traditional construction method which interweaves blue and white yarns, and the unique ‘blue’ colour achievable on dyeing with indigo. Four traditional denim fabric swatches varying in colour, shade, and depth were selected for further design development. Trials were carried out in which the digital images from each of these swatches, placed in a repeat pattern, were printed on to the pre-treated Tencel. Figure 3 shows the initial inkjet printed samples of the four denim swatches used as tiles to create the denim fabric. It was decided, based on visual inspection of the printed fabric, that samples B and D provided the most realistic denim appearance.

Figure 3. Initial digital denim imagery developed.

The digital denim swatches shown in Figure 2 were then imported into Lectra (Kaledo Style) software, and developed into a repeat image. The main challenge faced with digitally printing denim is creating a fading effect (worn look) in the desired area of the jeans. To attempt to achieve more precision in placing the worn effects a pattern for jeans was drafted to a sample size 10 sizing specification. A traditional paper pattern was made to ensure the pattern pieces fitted accurately then the pattern was digitally drawn into Lectra (Modaris CAD software program for patternmaking, grading and 3D digital prototyping). The benefit of developing a digital pattern is that it allows the designer to work with accurate scale pattern pieces digitally on the computer screen which is vital in manipulating imagery to create faded denim areas. This method allowed the desired denim effect to be directly placed onto each pattern piece whilst importantly retaining the scale. The designer can work into the plain denim pattern pieces to create unique worn effects on focused areas of the pattern piece.

At this stage, the combined imagery and pattern pieces were tested by digitally printing a selection of colours and fading effects. Four leg pieces were printed as test samples. Sample were printed both without and with an additional fading effect. This allowed initial investigation into incorporating both coloration processes with the finishing process. The results of the trials are demonstrated in Figure 4.

Figure 4. Developing digital denim imagery into a garment shape and adding a 'worn, aged, effect' at the inkjet printing stage.

Once printed, a standard steam finish process (100°C for 20 minutes) was used in order to fix the reactive dye to the fabric. Imagery and processes used to produce sample B presented in figure 4 were then developed into a full jean pattern and printed (illustrated in figure 5). The jeans were then constructed, as a standard pair of jeans would be to allow visual comparisons with traditional produced denim illustrated in Figure 6.

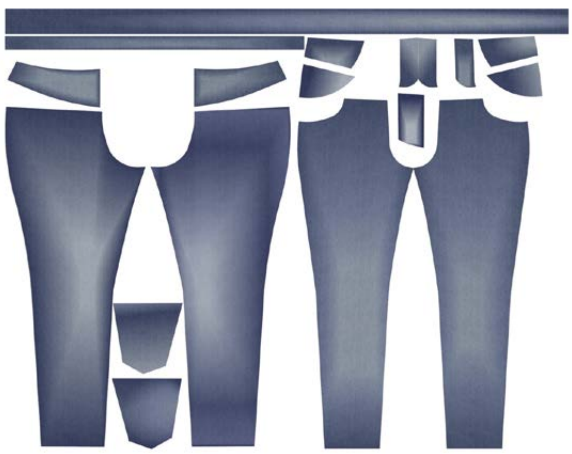


Figure 5. Digital trouser pattern digitally printed with developed denim imagery

Figure 6. Digital Denim initial sample trouser

Visual assessment of the initial sample jeans produced informed the research development stages. A larger colour palette for denim was developed in Adobe Photoshop by using the curve tool, a tool designed to increase and decrease colour tone. The varying shades of denim produced using this method are shown in the inkjet printed samples shown in Figure 7, along with the curve input and output numbers used to create the new swatches.

Figure 7. Developing a digital colour palette by exploring the effect of manipulating colour depth.

The denim pattern was developed into a simpler four-piece pattern with the designer developing seam and pocket imagery to reduce the component parts required on the constructed garments. This was to make end of life simpler as the garment would now be mono material and also to increase accuracy of effects added to the pattern during the design stage. The second sample produced using the refined methods is presented in figure 8.

Figure 8. Digital Denim developed sample trouser

Conclusions and Discussion

The challenges of this approach include creating garments by digital print that are realistically denim-like and aesthetically pleasing; locating market segments where the different production narrative presented to consumers does not clash with brand image; and using print techniques that have low environmental impact but give good performance, in particular print longevity. Of course, printed denim may wear in a different way to conventional denim and produce its own particular aesthetic, which could be pleasing.

The process presents improvement in material circularity by allowing garments to be over printed once the first use phase is completed which is an ongoing interest of the research presented. Next stages of the research explore the customisation and personalisation of jeans and explore whole garment printing technology to utilize and recirculation of both pre-and post-consumer garment waste. For commercial viability though this is dependent upon new business models and new types of supply chains that allow this production technique to become possible. In terms of like-for-like replacement of traditional indigo dyed fabric with printed fabric using reactive dyes, the innovation of design and production will be fundamental to the success of products produced.

References

Chick, A. and Micklethwaite, P. (2011) *Design for Sustainable Change*, London: AVA.

Fralix, M, T. (2001) 'From mass Production to Mass Customization', *Journal of Textile and Apparel, Technology and Management*, (Winter 2001), Volume 1, Issue 2.

Hasanbeigi, A.,Price, L. (2015) 'A Technical Review of Emerging Technologies for Energy and Water Efficiency and Pollution Reduction in the Textile Industry', *Journal of Cleaner Production,* Volume 95, pp. 30-34.

Mather, R.R. and Wardman, R.H. (2011) *The Chemistry of Textile Fibres*. London: Royal Society of Chemistry.

Moser, L.S. Itma (2003) review: textile printing, The journal of textile and apparel, technology and management, Vol. 3, Issue, 3.

Musante, G.B. (2013) 'Denims Sustainability Curve', *AATCC Review,* November/December, pp. 32-36.

Roos, S., Sandin. G., Zamani, B., Peters, G. (2015) 'Environmental assessment of swedish fashion consumption. Five garmebts – sustainable future', Mistra Furute Fashion. http://mistrafuturefashion.com/wp-content/uploads/2015/06/Environmental-assessment-of-Swedish-fashion-consumption-LCA.pdf (Accessed, 01.08.16).

Taylor, J.M. (1998) Tencel a unique cellulosic fibre. *J.S.D.C*, July/August, vol.114, pp.191–193.

Thiry, M.C. (2009) 'Eco-Denim: Can jeans save the Earth?', *AATCC Review*, 9th September, pp. 25-31.

WRAP (2016) 'A review of commercial textile finre recycling technologies'.

http://www.wrapcymru.org.uk/sustainable-textiles/scap/re-use-and-recycling/reports/textile-fibre-recycling-technologies (Accessed, 01.08.16).

CENTRE for CIRCULAR DESIGN

CIRCULAR TRANSITIONS

23 – 24 November 2016

The Designing of a Speciality Hand Knitting Yarn using Appropriate Technology

Manju Sugathan (Nottingham Trent University, UK)

Abstract

An insight into the developing a speciality hand knitting yarn using silk remnants collected from sari weaving handlooms in Vellanchery village, South India. The paper looks at engaging the unpaid labour, who are women in the hand weaving sector in the manufacture of speciality yarn using appropriate technology acceptable for the community.

Introduction

Schumacher (1973) developed the idea of intermediate technology, which is more productive than indigenous technology that is low in price compared to sophisticated technology used in modern industry. Intermediate technology is considered useful when work places are created where people live, reducing migration to urban areas. These work places can be created in large numbers without huge capital, and production methods can be simple – mainly using local materials. The term intermediate technology is criticised for implying a technological fix for development problems separate from the political and the social factors involved (Hollick, 1982). However, the term "appropriate technology" (or AT) is suggested as a substitute, which includes the social and the cultural dimensions of innovation (Pellegrini, 1979). Appropriate technology is characterised into two ideas: resource localisation and soft approach. Resource localisation means the appropriateness of using AT is decided by the designer according to the use of available resources in the targeted community. The soft approach is related to the sensitivity towards local conditions in development of technology. Both the characteristics discussed are based on considering the local conditions for the choice of technology (Sianipar *et al.*, 2013).

In the above context observation method was used to generate knowledge about specific issues in the village and identify an appropriate method for the manufacture of speciality yarn. It was employed at the primary stages of the research project to explore an area which could be studied further by utilising other methods (Sapsford and Jupp, 1996; Robson, 2011). According to Sapsford and Jupp (1996) there are two types of observation: structured observation and participant observation. Structured observation methods require systematic observation of behaviour, but without directly questioning the people who are observed. Participant observation involves asking questions that arise naturally during observation. At the initial stage of the research, the researcher followed participant observation where she approached observation with a relatively open mind, in order to minimise the influence of the observer's preconceptions and to avoid imposing existing preconceived categories.

The observation was carried out in Vellanchery village where the main occupation of male members in the family is handloom silk sari weaving. The weavers' work in a government authorised worker cooperative, who provides them with handlooms and silk yarns for weaving saris. The looms are installed in the weaver's house where the family is involved in the weaving process. The worker cooperative in the village provides membership for the male members who are skilled in handloom waving in the family. However, women in the household are involved in silk reeling and setting up the loom (fig. 1). They are not involved in the sari weaving process due to socio cultural reasons.

Figure 1: Hand Reeling of Silk Yarn

Work undertaken by women in this sector is unpaid labour and this research is about developing a technique for the manufacture of a specialised hand knitting yarn using the silk remnants collected from the handloom after weaving saris. The purpose is to involve women in the manufacturing of yarn, which could provide employment and income. For women, it will be a source of supplementary income, which also has implications for increased bargaining power, and socio economic status. The researcher carried an initial observation process in the village to identify a manufacturing process for the yarn. It was observed that these women are skilled in silk reeling and they can easily adapt to hand spinning technique to produce the speciality yarn. Silk reeling is a similar process as hand spinning using a spinning wheel.

In the second set of observation the researcher has the capability to communicate with the community in their language and provided a visual representation of the process involved in the manufacture of yarn. The process was discussed with the women in the village and they could relate the hand spinning technique with their existing skill of silk reeling. In order to design the technology appropriate for yarn manufacture, observation of the geographical location and resource availability were necessary aspects. Moreover, communicating with the community had created an opportunity for the researcher to directly contribute to the understanding of the literature related with technology choice and identify the gap via participatory learning (McIntyre, 2008).

At present, the most common practice of AT is to take western technology and modify it primarily by removing features to reduce cost with little regard for indigenous perspectives and skills (World Health Organisation, 2013). However, this research is designed to answer the question of developing a speciality yarn using silk remnants collected from the handloom, identifying an appropriate technology that is acceptable for the village community. The paper is structured in following sections:

- Section 2 - contains the literature relating appropriate technology to produce speciality hand knitting yarn
- Section 3- methodology
- Section 4-development process for speciality yarn

What Is Appropriate Technology (AT)?

Appropriate technology is considered useful when work places are created where people live, reducing migration to urban areas. These work places can be created in large numbers without huge capital, and production methods can be simple – mainly using local materials. According to Long (1980) in the selection of technology that accounts for regional social values plays an important role. For example, the appropriateness of technologies should not be decided purely on economic and factor endowment grounds. Long (1980) states that AT is a technology that is appropriate to the particular situation faced by a given group of people, where consideration is given to value priorities along with the economic circumstances and the available resources. Accordingly, Lissenden *et al.,* (2015) refers to AT as simple, labour-intensive and local-manufactured, technology solutions that aim to improve the lives and livelihood of people in resource constrained environment. AT is applied differently to each venture and there is no single framework through which AT ventures should be undertaken. In order to make the technology used successful within a particular locality, it has to be firmly related to the: technical, economic and social conditions in existence (Francis and Mansell, 1988; Lissenden *et al.,* 2015).

Hazeltine *et al.*, (1998) state the reason why AT relates well to the cultures because it adapts to the local needs and is controlled by those using it. The characteristics of AT like low cash requirements, being repairable and controlled by users matches the situation of women in the developing countries. If cultural factors are not taken into consideration while introducing a new technology, then it is likely that the aim of the new technologies may not be met – perhaps because of unexpected contingencies or resistance by those involved. AT tends to put participants in control so that it can be adapted to local conditions, it does not require major changes in people's lives, and it is a promising way to improve living conditions without cultural damage (Sianipar *et al.*, 2013; Pearce *et al*., 2012). According to Sianipar *et al.,* (2013) researchers believe that AT as a phenomena emerge together from specific conditions from a local area that needs a technology which is appropriate with local people's needs and wants. The literature review reveal that, AT for a small-scale manufacture of speciality yarn can create employment through optimising the use of existing skills and resources and raise the productive capacity of the community. Thus, literature review helped the researcher to identify a technique for manufacture of speciality yarn that is: simple, cost effective and socially appropriate for the women in the weavers' community in the Vellanchery village.

Why Appropriate Technology is suitable for small-scale application?

The benefits AT outlined by Francis and Mansell (1988) Schumacher (1973) and Mc Robbie (1981) for small-scale application are summarised as follows:

- Employment can be created in the place where the unemployed live and that can restrict migration of unemployed people to urban areas
- Through reducing the needs for imports, and creating an export market, savings from wages and profits generated can be used for investment in further capital development
- There is a greater opportunity to use renewable resources (solar, wind, hydro, wood and biogas)
- Small-scale industries using AT can reduce pollution and ecological imbalances prevalent in most concentrated large-scale industry. Furthermore, ecological problems can be remedied at much less cost
- Growth of the industry can occur in small steps, as required by demand and made possible through new capital, which includes changes in the products through innovation.

Accordingly, Sawhney et al., (2002), Buitenhuis et al., (2010) defines AT as a technology that fits local condition and are easily and economically utilised from readily available resources in local communities to meet their needs.

Methodology

As the research was conducted in a real-world setting, there was a need to participate with participants to engage in a collaborative process aimed at improving and understanding their world in order to change the system. Participatory Action Research (PAR) is a philosophy more than a methodology and was chosen for the study. The aim of the research is achieved through a cyclical process including exploration, knowledge construction and implementation at different stages through the research process (McTaggart, 1997). PAR is a recursive process that involves a spiral of adaptable steps in four stages:

- Question the issue of recycling the silk remnants collected from handlooms to produce a value added speciality hand knitting yarn
- Reflect and investigate the issue using observation method in order to achieve clarity
- Develop a manufacturing process for speciality hand knitting yarn
- Finally review the manufacturing method with the women in wearers' community in Vellanchery village

The manufacturing process of speciality hand knitting yarn

Sari weaving is a domestic process carried out on handlooms using a warp of approximately twenty-one metres; from which, three six metre sari lengths are produced. This leaves close to three metres of remnant silk yarns on the warp beam. Past efforts to make use of these remnant yarns have been aimed at the production of fashion accessories, including items such as: bangles and necklaces, which crucially are of low value and only sold in the local market. As such, the production of these items from remnant yarns provides minimal economic empowerment of the women in the village, which is very much needed. However, development of speciality hand spun knitting yarn using 30% of these silk remnants collected from handlooms blended with 70% scoured lamb's wool; alluring and unique yarn colours that are non-repeatable, and have excellent handle and knit-ability can be produced. Notably, non-repeatable yarn colours make this product unsuitable for the mainstream fashion market, however bespoke designs are extremely desirable for craft hand knitters. As Savithri, a weaver's wife from the Vellanchery village stated "If there is continues demand for speciality yarn in the market then we are ready to engage in the manufacturing process of the yarn." The connection between craft, eco-friendly manufacturing process involving women in the village community to provide employment and income is a good branding and marketing strategy. It will keep the consumers informed about the story behind the manufacture of speciality yarn, so the consumers will be aware about the cause before they decide to purchase the yarn.

Speciality yarn design stages

The first task is to ask questions about opening the silk fibres in order to mix it with lamb's wool. This step brings challenges about desizing the silk remnants, the length of the silk remnants converted to staple silk fibres, the percentage of silk content to mix with the lamb's wool. Fig 2 shows the different stages of product development. The silk filament sari remnants are highly coloured and the colours vary across the warp depending on the design of the sari. When the filaments are cut into short lengths and mixed with the undyed lamb's wool, unique and non-repeatable tones, tints and shades are obtained.

Mulberry silk is used for weaving a silk sari. A unique feature of the sari is its strength, which is achieved by twisted yarn, and the yarns are dyed in a variety of colours. The dyed yarns are dipped in rice water (sizing) and sun dried. This is done in order to protect yarns from damage while weaving.

It is necessary to desize the silk yarns by removing the sizing agent (rice starch) to open the silk before carding.

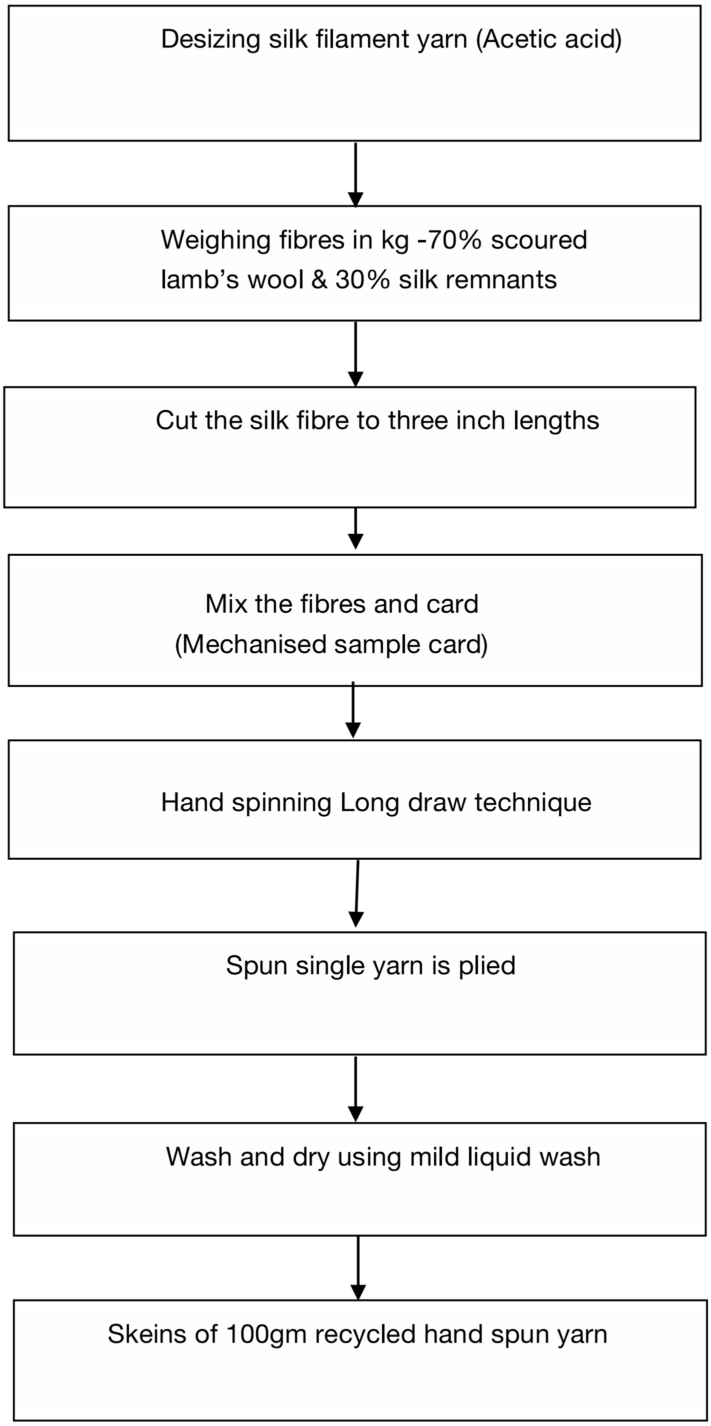


Figure 2: Stages of Product Development

The next stage after desizing is to weigh the silk remnants in proportion to scoured lamb's wool. Two options were considered 50% of each or 30% of silk remnants and 70% of lamb's wool. There was minimal difference noticed in the form of colour or texture in the yarn spun using 30% silk and 50% silk content. Thus, it was decided to keep the silk content as 30% and scoured lamb's wool 70% for cost reasons. The desizing methods were carried out and the results of which are given in table 1.

The tests suggested that Acetic acid steeping is best for desizing silk yarn in a liquor ratio 1:200 (1g of fibre mixed in 200g of water) with 0.2% of acetic acid in grams added. The desized yarn is then dried at the room temperature and conditioned for 24 hrs before carding. The portion of acetic acid used for desizing is very minimal and effluent disposal would not be an ecological problem.

	Chemical	Dwell time	Temperature (°c)	Yarn weight difference
Rod steeping	Distilled water	10min	98	0.88%
Acid steeping	H_2SO_4 (Sulphuric acid)	7-12h	25	0.72%
Acid steeping	CH_3COOH (Acetic acid)	7-12h	25	0.71%

Table 1: Desizing Experiments

Figure 3: Sample Carding Machine used for Carding Silk Remnants and Scoured Lamb's Wool

Carding method used for speciality hand spun yarn

The carding machine (fig 3) was small scale and consisted of a series of pinned rollers between which the fibres are shared, pressed and finally raised to form a web. Carding is the process by which fibre clumps or tufts are opened and mixed to produce a coherent fibrous web assembly which can then be drafted (made long and thin) and twisted using a hand spinning wheel to produce a yarn of the desired count (fineness) and twist content. The silk yarn remnants were cut to three-inch length after desizing. Desized silk yarns were carded twice in the carding machine, in order to open the yarn twist and changed to fibre stage. The scoured lamb's wool was carded separately and then mixed with the silk fibres.

To mix the fibres in the carding machine the web was collected at the output end of the machine and cross fed back into the carder. This method of cross feeding the material from scribbler to carder gave an additional blending to the fibres and assisted in levelling the density across the width of the carded web to produce regular sliver.

Hand spinning and plying

The carded fibres were spun on a hand spinning wheel using a long draw technique (fig 4). The singles are spun in 'Z' twist and plied in 'S' twist. Plying was done using a lazy kate (spool rack). Two filled bobbins of hand-spun singles are removed from the spinning wheel and put on the spool rack or lazy kate. The two single yarns were guided to the bobbin through the orifice and then the wheel was turned in an anticlock wise direction to give 'S' twist to the plied yarn.

Figure 4: Hand Spinning and Plying

Washing the plied yarn

The yarns were washed in sensitive detergent used for washing baby clothes in hot water at 42 to 43 °c and allowed to cool. This process helped to bleed the excess dye content in the silk. It was then rinsed in cold water to remove the detergent. The rinsed yarn was put in the spin cycle of a washing machine with no added water to remove the moisture, and hung to dry in skeins (fig. 5, fig. 6, fig. 7 and fig. 8).

Figure 5 (top left): Drying of Hand Spun Yarn. Figure 6 (top right): Speciality hand spun knitting yarn. Figure 7 (bottom left): Speciality hand spun knitting yarn in skeins. Figure 8 (bottom right): Hand knitted garment using speciality hand spun yarn.

Findings

Appropriate technology is designed with special consideration to natural environment, socio cultural and economic environment of the society. The technology identified to produce speciality yarn is environmentally friendly, low cost and easy to understand for women in the village. The paper provides a holistic analysis in two ways; first to understand the cultural context of the weavers' community in Vellanchery village. Second, based on recycling a waste material available in the village and identifying a method that is acceptable for the community is used as a platform to develop a technology that is suitable for women in the village.

References

Buitenhuis, A., Zalenika, I., Pearce, J, M. (2010) *Open Design- Based Strategies to Enhance Appropriate Technology Development,* Proceeding of the 14th Annual National Congress. NCIIA [online], Available from: http://nciia.org/sites/default/files/pearce.pdf

Francis, A. J., Mansell, D.S. (1988) *Appropriate Engineering Technology for Developing Countries*, Australia: Research Publications Limited.

Hazeltine, B., Wanhammar, L., Bull, C. (1998) *Appropriate Technology: Tools, Choices and Implications,* UK: Academic Press.

Hollick, M. (1982) *The Appropriate Technology Movement and Its Literature: A Retrospective*, Technology in Society, 4: 3(1982), 213-229, Technology in Society, Elsevier.

Lissenden, J., Maley, S., Metha, K. (2015) *An Era of Appropriate Technology: Evolutions, Oversights and Opportunities, Journal of Humanitarian Engineering*, 3:3, 24-35. [Online], Available from: https://www.ewb.org.au/jhe/index.php/jhe/article/download/34/42

Long, F. A. (1980) *Appropriate Technology and Social Values: A Critical Appraisal,* American Academy of Arts and Sciences, 33:4, 4-14, JStor.

Mc Intyre, A. (2008) *Participatory Action Research: Qualitative Research Methods*, LA: Sage Publications.

Mc Robie, G. (1981) *Small Is Possible*. London: Jonathan Cape.

Mc Taggart, R. (1997) *Participatory Action Research: International Context and Consequences*, Albany: State University of New York Press.

Pearce, J., Albritton. S., Grant, G., Steed, G., Zelenika, I. (2012) *A New Model for Enabling Innovation in Appropriate Technology for Sustainable Development,* in Sustainability: Science, Practice and Policy, 8:2 (2012) 42-52, Taylor & Francis.

Pellegrini, U. (1979) *The Problem of Appropriate Technology*, in: De Giorgio, A. and Roveda, C. (Eds.), *Criteria for Selecting Appropriate Technologies Under Different Cultural, Technical and Social Conditions*, New York: Pergamon Press.

Robson, C. (2011) *Real World Research*, 3 Ed Ed., Oxford: Blackwell.

Sapford, R., Jupp. V. (1996) *Data Collection and Analysis*, London: Sage Publications.

Schumacher, E. F. (1973) *Small Is Beautiful: A Study of Economics as if People Mattered*, UK: Blond and Briggs.

Sianipar, C, P, M., Yudoko, G., Adhintama, A., Dowaki, K. (2013) *Community Empowerment Through Appropriate Technology: Sustaining The Sustainable Development,* The Third International Conference On Sustainable Future For Human Security, Sustain, 1007-1015.

Swahney, N., Prestero, T., Griffith, S., Maguire, Y. (2002) *Think Cycle: Supporting Open Collaboration and Sustainable Engineering Design in Education,* Development by Design, Second International Conference on Open Collaborative Design for Sustainable Innovation, Bangalore, India.

World Health Organisation (2013) *Emerging Economies Drive Frugal Innovation,* Bulletin of the World Health Organisation, 91:1

CIRCULAR
TRANSITIONS

23 – 24 November 2016

A Sustainability Textile Design Course as a Transformative Process

Yuval Etzioni, Ziv Neeman (Shenkar College of Engineering, Tel Aviv, Israel)

Abstract

This paper discusses the change of outlook following the practical introduction of textile sustainability principles within an academic setting. Retrospective interviews and selected projects' analysis trace transformations in students' perceptions, highlighting how engagement with sustainability generated issues such as gender, identity and tradition, and their significance in ecological textile culture.

Introduction

Written from the perspective of an instructor of a sustainability-informed textile design course in a design school, this paper describes the course's progression and visual products as a transformative process that promotes a change of perception among its sophomore students, during the course and beyond. Of special significance for my discussion is the manner that engagement with sustainable design (SD) issues prompted students to consider in their projects critical progressive issues such as cultural and gender identity.

Sustainability Education

The textile/fashion industries rank high among the global factors adversely affecting the environment, from cultivation and production stages, through consumption and use, to aspects pertaining to employment, society, and culture (Fletcher, 2008). From a SD, educational perspective, there is a need for courses integrating practice-base methodology with theoretical education concerning SD principles.

The past decades have witnessed a global dynamic in which much of the Global North's textile industries have been outsourced or moved to the Global South (Politowicz, 2009). Until quite recently, textile design education was usually framed by two approaches: either preparing students for work in the textile industry, or cultivating artistic or artisanal textile practices, as in the designer-maker model. Simultaneously, rising global ecological crises have prompted a call for a sustainable textile industry. Both developments have led to demands for a re-orientation of textile education and design education in general: one emphasizing that SD principles should become the basis of all aspects of design education in order to prepare students to find their avocation within their career (Orr, 1992). Designers have a critical impact in their creative process and decisions on the environmental life cycle of textile's materials and final products (Earley, Goldsworthy, Vuletich, 2010). Therefore, the need to adapt textile design curriculum to the environmental and social challenges is inevitable (Politowicz, 2009). Education for sustainability covers textile/fashion product's entire life-cycle including: design, production, consumption, use and recycling. It also focuses on many kinds of practices: technological solutions, social conventions, cultural practices, and ethical considerations that are basic elements in textile sustainability as a whole, with the ultimate goal of a circular economy (McDonough & Braungart, 2002). Furthermore, as Schon has claimed, Environmental ecology is a natural platform for discourses in design studies (1983).

The Course

The Course is a practice-based introduction to sustainable textile design. At the outset, students were introduced to TED's Ten Sustainability Principles (Earley, & Politowicz, 2010). Several practical exercises in sustainable textile and fashion were given using only found materials. Through these, students, got a practical taste of traditional textile technics—knitting, plaiting, embroidery, and stitching—informed by SD principles, focusing on redesigning, recycling and upcycling a textile item, material or procedure (Aus, 2011; Fletcher, 2008). Based on both theoretical and practice-based sustainable principles, students worked on final project of their own choosing.

The Study

The study relies on an analysis of interviews held with nine students from the course's two graduating classes and review of selected final projects. Four interviews were selected for discussion based on the interest of students' final project and the insights revealed in their interviews; nonetheless, it should be emphasised that the topics in the selected interviews represent general themes appearing in all the interviews. As a qualitative research tool, the act of retroactive interviewing' which emphasizes the self-as-storyteller of both interviewer and interviewee, allows both to gain new understandings and even address future avenues of action; thus, becoming a further step in the pedagogical process (Bruner quoted in Shkedi, 2003). Discourse analysis of the interviews (Gill, 2000) followed an approach, inspired by Donald Schon (1983), where the course instructor acts as a practitioner holding a reflective discourse with students, that provides an opportunity to reconstruct students' learning processes retrospectively. The analysis of the final projects is written from a visual literacy perspective (Avgerinou & Pettersson, 2011).

Common Central Themes in the Interviews

Students consistently noted the importance of the course in converting vague knowledge about the environmental harm of the textile industry into concrete information:" I had pretty elementary background knowledge about sustainability [and] the environment […] I wasn't well acquainted with figures […] of how polluting the textile industry is […]. I [also] grew more aware of the link between issues of environmental ethics and social ethics". (Interview 3)

Another common thread running through the interviews and final projects was the wish to design a new textile object or item from existing materials, despite the option of making theoretical proposals for technological projects or energy/water saving solutions. Overall, all interviews addressed social and ethical aspects of fair employment, as well as aspects of surplus consumerism, an acute problem in this field (Fletcher, 2008). All students noted that the course's contents resonated in other courses that did not concern sustainability: "the course really made me think, changing my entire outlook, it really grabbed me…I used it in further projects as well" (Interview 8). However, each interview articulated a unique individual response to the course.

Project 1: Technology, Textile Image and Practice

Figure 1: Reouth Erez, "Kayma"- Sustainable Home Print Kit, 2016, Photographs: Yuval Etzioni.

This project offers a proposal for a children clothing design kit. It provides transfer print paper of different patterns that can be ironed onto clothing items before each use, which can be washed away during laundry, and reprinted with a different image. The student also addressed the need of a future development of ecologically friendly printing dyes.

Reprinting attempts to reduce the “need to consume” through technical means and consumer participation in co-designing without resorting to new purchases. From a SD perspective, the project has various drawbacks that require further attention to its critical ecological implications (Fletcher, Goggin, 2001). However, its engagement with issues of consumption, consumer's behavior and use phase within the lifecycle of textiles deserve attention.

Another issue was concern about the continuing value of textile in an increasingly industrially mass-produced context. Hence, the print images are graphically iconic textile images: weaving, embroidery and knitting that the student considered as representing textile’s often overlooked presence in mass industry and consumption. In the interview, she stressed her interest in digital technologies as means for sustainable mass-production and textile-printing without compromising textile tradition: “It’s not my intention to use technology to override tradition and textile […] I’m suggesting here a solution for mass production […] that’s not necessarily going to cut down many jobs” (Interview 3). Significantly, she perceives her technological solution not merely as a technical innovation but in a social and ecological context: as a tool that facilitates sustainability and as a social practice that preserves textile tradition.

Project 2: Disassembling as a Sustainability Learning Strategy

Figure 2: Neria Saf, Man's Wallet Taken Apart, 2015, Photographs: Ahikam ben Yosef.

This exercise—disassembling an object in order to learns how it is made, used a man's wallet as a raw material: "sustainability was introduced here with the idea of really using available materials, as available as they get […] an old wallet, taken apart, because that's what I feel like doing in this kind of operative moment" (Interview 8). The item proved surprisingly complex: "there's so much you can learn out of something that's out-of-use […] and has 20 parts […] the unravelling made me realise there were more and more strata to… this object" (Ibid). Disassembling sheds light on materials, design and construction, attesting to the object's complexity—one of the challenges facing SD textile practices. Binding, as a reference to historical textile practices was selected for this act of redesign. The student generated a creative and meaningful SD textile object by presenting the wallet in pieces, visually intensifying its complex materiality; revealing, thereby, how a variety of materials in a single item impedes mono-materiality sustainable principle (Earley & Politowicz, 2010).

In this project redesign as an educational process constitutes a visual research process, rather than a new design:

> "I took it a step forward… it acquires a whole new meaning… so I reckon this is in away the essence of the project, it's also the essence of the course. […] A creative artist could come along and change the essence of the cube […] perhaps that's… the meaning of sustainability […] it's [changing] a way of life, it changes your [whole] outlook" (Ibid).

Project 3: Identity, Body and Gender

Figure 3: Layla Klinger "Zombie" Jacket, 2015, Photographs: Layla Klinger.

This student's final project asserts the "feminine" in a context where the "masculine" unravels, choosing an upcycling modification that promotes critical body and gender discourses. The project features a tattered male biking jacket by a well-known brand, found in the street. The student explained that the act of re-designing constitutes a stage in the jacket's life-cycle, bringing it back to life: "It's [about] reincarnation, first with the man who bought it, then a second time, when dumped and found, and then for the third time, which is now, when it's a bit like a zombie, or actually, post-zombie" (Interview 5). This comparison, between the object and the "zombie," locates the clothing item as a representation of the body in an emergency situation (Ram, 2014). In the next reincarnation, the student targets the gender-coded field: "It's a women-oriented field […] dominated by femininity, and I think that a failure to engage with this means erring to the issue… erring to textile as well […] overlooking the seamstresses, women embroiderers, women wearers, consumers, designers, fashion writers" (Ibid). The redesign was first conceived as a "feminine vs. masculine" struggle, but later on, rather than take them, as pre-assumed categories, she explored body and gender identity as a process of transformation.

> "It's not necessarily the case that now, when I paint it all pink, it's going to change from all-masculine to all-feminine. We're talking bodies that are gender-deviating, sexually-deviating, deviating in every sense from conventions of how a body should be […] I'm going to give it gender fluidity, which is also a constant [process of] transition" (Ibid).

This re-design inhabits body and gender as a state of constant reincarnation, without dichotomous definitions. Alongside circular principles of sustainability, fluid gender circularity is highlighted, rather than the stereotypical feminine-coded pink colour. The technics selected for reusing the textile portray a state of continuous conversion: the more advanced the object’s wear-and-tear, the further advanced the embroidery. Arguably, embroidery is considered by the student as a feminine pursuit that increases the object’s value, by dint of being Sisyphean: “It turns it into something far more expensive than it originally was […] something that’s feminine, painfully marked, and made in a very Sisyphean way […] which is very much a marker of femininity” (Ibid). As the interview draws to an end, it transpires that the SD setting allowed her to imagine and express a new approach to sustainable textile design: “I felt that for the first time, I really managed to express the way I want to do textile […] it’s got to be very encompassing, a sweeping movement of female designers and makers, declaring, […] ‘I’m pledging ethical and sustainable production”. (Ibid).

Project 4: Materials, Objects, And Hybrid Cultural Identity

Figure 4: Mariana Obmetkin Matalon, Homage to Grandma, 2015, Photographs: Ahikam Ben Yosef.

Sarat Maharaj (2001) notes that textile can inhabit two significations simultaneously: as a domestic commodity and as conceptual narrative device. This student was born in Ukraine and immigrated to Israel as a young girl. She had no previous experience of textile sustainability, yet professes to re-using materials: “I had some material-related knowledge, material reuse, but I didn’t explore it in depth until this course (Interview 2). The student refers to textiles as a raw material that allow change as a transformative means for new thinking: “when I finished my first object, [the] order was in fact a new order, not something I had planned. All of a sudden new things turned up” (Ibid).

Ahead of the final project, the student introduced a cushion she had created, featuring a traditional Ukrainian image, overlaid with embroidery work: “it was an artistic tradition referred to as Chochloma […] I took the emblem and transferred it […] then I embroidered the whole of it on a textile and sewed a pillow for grandma” (Ibid). Here the student pursues her engagement with her cultural-familial heritage, while alluding to the sustainability principle of reusing and renewal:

> “It’s been around for many years […] they used to make it even without elaborate technology […] I actually used […] my grandma’s textiles from the Ukraine, and just unpicked them. I made some long ribbons from them, weaving them together. It also relates in a way to my family’s history, because my grandma actually used to make baskets and rugs” (Ibid).

Referring to the new object she created, the student points to the materiality as a reference to her country of origin: “Yes, it is the colour and it is … this stiff feeling, so it refers to […] grandma, family, and… childhood” (Ibid). The new object is described as a vessel with a frame, meaning there is visual reference to the square cushion and to a basket. The redesign involves cutting and unpicking textiles, referencing a cultural tradition severed by immigration. The use of weaving, transformed it into a 3D object. As an instructor, I was troubled by the potential symbolic severing of family tradition, through the literal cutting of her grandmother’s textiles. But the student explained: “The traditions are still traditions, the weaving is still the same […] the thread is the same thread, even if we change it somehow […] it doesn’t go away. It’s the other way around, you can intensify these things […] the material has a language of its own” (Ibid).

Implicitly, this is an example of textile activities and materials in themselves constituting a representation of tradition. The student specifies how the floral print textiles become an abstract representation of memory that allows new growth: “the textile itself was black, with floral prints on it, and when I unpicked it […] it’s like […] this little, pixelated garden… so I reckon memory is still there but it has changed shape a bit… it’s not disappeared completely” (Ibid).

Unravelling and re-weaving allow a deeper resolution and a transition from the specific floral image to the option of facilitating a new, abstract “garden.” The textiles from the culture of origin represent family heritage cultural memory and identity, thereby affirming it, so that circular sustainability redesign becomes an activity that maintains representations of familial and cultural traditions, while facilitating a creative practice by the designer. Immigration entails transitions in identity; hence, her material-related practice constitutes a vessel expressing her hybrid identity. As the interview ends, the struggles of acclimation, as well as a new sense of empowerment emerge from her embrace of a hybrid cultural identity: “Culturally, for instance, [after moving to Israel I felt] I had to hide my identity… and… where I came from at times… now … I’m not hiding it; on the contrary, I let it show as much as I can” (Ibid).

The course activities emerge as an empowering process on the designer’s part. The act of changing traditional images and materials constitutes a circular process of referencing her heritage and new identity-formation within the context of immigration. This project’s educational value lies in its sustainable redesign, which constitutes upcycling—a circularity that grants the object and activity an added value, through hybrid identity formation and the possibility of expressing oneself in a multicultural society.

Conclusion

The examples discussed here represent a spectrum of ideas and proposals for textile sustainability within an educational framework. The opportunity to experience a research-and-learning process promotes a comprehensive conceptual progression by the students, so that the act of sustainable design is perceived not only as the conversion of material into product, but as an essentially transformative process that grants it new meaning. This process marks sustainable design education as a critical link in the life cycle of the textile product and textile culture (Orr, 1992). The course facilitated the insight that practice-based methodology situates the textile object and textile practices under continuous conditions of conversion. Students consistently incorporated textile’s social, cultural and historical significance into their sustainable practices. This is consonant with the principles of ethical production and the preservation of textile traditions that are among the precepts of sustainability (Earley & Politowicz, 2010). The context of sustainability raised issues of body and gender identity from a feminist perspective, as change-driving forces in the textile object’s life-cycle. Offering the power to unite women and undermine economic and patriarchal hegemonies (Parker, 2010). That such issues of textile culture were incorporated within principles of sustainability demonstrates how the challenges of sustainability include new social and cultural formations as much environmental ones. The combination of such issues as hybrid migratory identity or fluid gender identity with upcycling principles, contributed to the involvement, identification, and empathy of the students' projects. This introduced an affective dimension to the reuse phase of up-cycled textile object (Earley, Goldsworthy, Vuletich,2010; Fletcher, 2016). The students clearly perceived the link between textile design and sustainability principles as drawing on human actions, pertaining to their own social contexts as individuals in society, as can be seen from their work and interviews. Participants emerged as critical learners, highly aware of the challenges ahead and stressed their commitment to SD in their future work and career as designers. Hence, sustainability education constitutes a critical phase in the turn towards a circular economy and culture.

References

Avgerinou, M.D., Pettersson, R. (2011) Toward a Cohesive Theory of Visual Literacy. Journal of Visual Literacy, 30(2), pp 1-19.

Aus, R. (2011) Trash to Trend: Using Upcycling in Fashion Design. Doctoral Thesis: Estonian Academy of Arts. [online] Available at: https://issuu.com/runnel/docs/reet-aus (Accessed July 25 2016).

Earley, R., Politowicz, K. (2010) The TEN Strategies. [online] Available at: http://www.tedresearch.net/teds-ten-aims/ (Accessed July 25 2016).

Earley, R., Goldsworthy, K., Vuletich, C. (2010) Textiles Environment Design (TED): Making Theory into Textiles through Sustainable Design Strategies, Pedagogy and Collaboration. In: R. Brink, M. Ulrich (Eds) *Future Textile Environments*. [online] Available at: http://www.tedresearch.net/online-resources/key-publications/ (Accessed 12 June 2016).

Fletcher, K. (2008) Sustainable Fashion and Textiles: Design Journeys. London: Earthscan

Fletcher, K. (2016) Craft of Use Post Growth Fashion. London: Routledge.

Fletcher, K., Goggin, P.A. (2001) The Dominant Stances: A Critique. Design Issues [online] 17(3), pp 15-25. Available at: http://www.mitpressjournals.org/doi/abs/10.1162/074793601750357150 (Accessed 25 July 2016)

Interview 2, Obmetkin, M. M. (12 July 2016)

Interview 3, Erez, R. (14 July 2016)

Interview 5, Novak, I. (14 July 2016)

Interview 8, Saf, N. (20 July 2016)

Gill, R. (2000) Discourse analysis. In: M. W. Bauer, & G. Gaskell, Qualitative researching with text, image and sound: a practical handbook for social research. 1st ed. London: Sage, pp 172-190.

McDonough, W. & Braungart, M. (2002) Cradle to Cradle: Remaking the Way We Make Things. New York: North Point Press

Maharaj, S. (2001) Textile Art-Who Are You? In: J. Jefferies, ed., Reinventing Textiles: Gender and Identity, 1st ed. Winchester: Telos Art Publishing, pp. 7-10.

Orr, D.W. (1992) Ecological literacy: Education and the transition to a postmodern world. Albany: SUNY Press

Parker, R. (2010) The Subversive Stitch: Embroidery and the Making of the Feminine. 2nd ed. London: I. B. Tauris.

Politowicz, K. (2009) Textiles: The Sustainability of Research. Futurescan: Mapping the Territory, Conference Proceedings Association of Fashion & Textile Courses, [online] (FTC) Available at: http://www.tedresearch.net/online-resources/key-publications/ (Accessed 14 July 2016).

Ram, M. (2014) The Political Necrography of the Living Dead: Theory, Criticism, and Zombies. Theory and Criticism, [online] 43, (In Hebrew), Available at: http://theory-and-criticism.vanleer.org.il/%D7%92%D7%99%D7%9C%D7%99%D7%95%D7%9F-43-%D7%A1%D7%AA%D7%99%D7%95-2014/ (Accessed 14 July 2016).

Schoen, D. (1983) The Reflective Practitioner: How Professionals Think In Action. New York: Basic Books

Shkedi, A. (2003) Words of Meaning: Qualitative Research Theory and Practice. (In Hebrew) Tel-Aviv: Ramot.

Acknowledgments

We warmly thank all the students taking the course for their enthusiastic and creative participation during the course and for their willingness to be interviewed. We thank Dr. Katya Oicherman, Chair of the textile design department at Shenkar College for promoting sustainable contents—including this course—in the Textile Design department curriculum.

CENTRE for CIRCULAR DESIGN

CIRCULAR TRANSITIONS

23 – 24 November 2016

Whole Systems Thinking for Circular Economy Design Practice

Sara Li-Chou Han, Nick Hall, Phoebe Apeagyei, David Tyler (Manchester Metropolitan University, UK)

Abstract

To develop the role of designers in the context of the circular economy, this paper aims to investigate the significance of the concept of Whole Systems Thinking (WST) for design practice. Designers' practices were examined not just from the product orientated perspective, but by taking a more holistic systems thinking approach. This addressed a combination of the market, consumers and communication, plus design and production processes, supply chain and end-of-life considerations. The methodology employed a review of literature relating to circular systems approaches to WST, and combined this with primary data from semi-structured interviews. Interview data from ethical fashion brands and designers identified barriers to the wider adoption of circular economy fashion strategies. The paper concludes that the designers taking a systems based approach are more congruent with the circular economy model and the wider skills and attributes that enable such approaches, such as research skills and entrepreneurial methods.

Introduction

The concept of the Circular Economy requires the re-appraisal of how we value products, components and materials; thereby introducing sustainable patterns of consumption through responsible production and sustainable re-industrialisation that builds resilient infrastructure (United Nations, 2016). Current development in the fashion and textile industry focus on incremental improvements to existing designs for the purposes of added-value consumption, and are dictated by the limits of existing production systems and the need for profitability through cheap, high turnover goods. Designing for the Circular Economy must go beyond material throughput towards a switching process where the objectives of products and services are evaluated for efficiency, functionality and longevity; a systemic change geared toward greater social and environmental responsibility transitioning away from a finite materials economy. (Ellen MacArthur Foundation, 2015b).

Rethinking design, means dealing with far more complex, system-wide relationships, introducing innovation in functionality, use-phase and life-cycles of created objects (Charnley et al., 2011). To do this requires consideration of the methods that are used; to re-learn how to design is to innovate in the context of the Circular Economy. Designers need to apply tools that can help them deal with re-engineering complex systems and the products and services therein, changing what they do from the inside out. One such approach, strongly connected to the Circular Economy is Whole System Thinking (WST) (Charnley et al., 2011). Understanding the interconnectedness of the many different components, how they interact and the problems embedded within these connections enable designers to optimise each of these processes into a single solution.

By using WST methods, designers innovate not just in sustainable design, but in the processes, research, business models and life-cycle interventions needed to make a product or service less negatively impactful by design. The focus is shifted away from retro fitted 'greening' and towards preconceived, objective sustainability, designed in from the very beginning. To enable this requires collaborative approaches to understanding systems and their drivers, and accessing the most appropriate expertise and capabilities to further the learning process. What WST provides are guiding processes, principles and methods that can enhance designers thinking on a systems based scale and introduce them to a broader set of problems that need to be considered in the context of establishing more circular methods of designing (Blizzard and Klotz, 2012).

Though there is a trend toward upcycling, little is currently done with low-grade textiles or textile based items with multiple components and how these are recycled into feedstock for textile manufacturing. A WST approach to developing a response to this idea would include developing a team of experts or a network that collaborate to evaluate low-grade textile waste from a variety of perspectives, thereby discovering new ways of addressing the problems of certain textile waste streams that have the potential for innovation, such as end-of-life mattresses and how these could be re-designed for disassembly, enabling easier deconstruction and reuse of components. Creating networks provides access to capabilities and processes needed to develop WST. This is linked to the principles of developing a WST approach, briefly summarised in the following points:

Focus on Outcomes

WST is a method that is applied to a situation. Thus, generating a series of operational principles and applying these to the project in hand is of utmost importance. The result of the project must meet the specific requirements of Circular Economy design, such as closed loop production and recyclability. The alignment of interests between actors in a network then establishes roles and responsibilities to take the project forward, prioritising design elements which are most purposeful and contribute to the greater whole. (Blizzard and Klotz, 2012).

Open Innovation Networks

Open Innovation is the paradigm of seeking and collaborating with a range external organisations and find opportunities for innovation through new partnerships; forming networks that share knowledge and research as well as market risks and rewards. The advantages are reduced costs of research and development, improved productivity, broader access to user needs, increased capabilities and wider market potential (Powell and Grodal, 2005). Matching specific information with appropriate expertise is key to creating synergies between actors. In this way a network can generate the perspectives and knowledge required for WST more rapidly, resulting in faster identification of problems, opportunities and solutions. (Chesbrough, 2003).

Find New Solutions

Existing design solutions include the preconceptions, processes and systems that limit innovative thinking. WST requires that designers start with a ‘clean sheet’ and build ideas over time without returning to previous assumptions before generating new concepts. (Blizzard and Klotz, 2012). Circular Economy alternatives of regenerating, virtualising or exchanging should be considered (Sempels, 2013). Analysis of the interrelatedness of problems identified should lead designers to seek alternative solutions, such as materials that can be replaced to form technical or biological nutrients. This process should create a product story that is both transparent and traceable. (Braungart and McDonough, 2002).

Close the Loop

Adding value to waste and repurposing discarded textiles provides a key opportunity for innovative thinking towards the Circular Economy. Whilst upcycling is one solution for higher grade waste, the need to evaluate how products are designed for the environment through pre-development techniques that mitigate or eliminate waste issues and impacts is more broadly effective to reducing the environmental and social impacts of the fashion industry. The need for more robust forms of value analysis, cleaner production techniques and the elevation of sustainable value is required (Catarino et al., 2011).

Establish Standards and Share Knowledge

Finally, cooperation and establishment of knowledge networks is the key to developing guidance, training and policy around WST approaches to circular design. Sharing information in this way serves to formalise more independently governed ways of increasing the levels of truly sustainable products that meet the requirements of the Circular Economy value circle. Preserving and enhancing natural capital through control of natural stocks and establishing renewable resource flows is key to the survival of the global fashion system, an industry that is currently underpinned by issues such as perceived obsolescence and unsustainable material supply, amongst many other factors. (Ellen MacArthur Foundation, 2015b).

Methodology

In order to assess the relevance of the WST approach for designers in the context of the circular economy, semi-structured interviews were carried out with eight fashion brands with experience of designing, producing or retailing upcycled or ethical fashion. Questions centred on key points in the circular fashion system; from consumers and communication, to design and production, plus wider considerations of the fashion industry and sustainability, and how to create meaningful change. Determining where gaps in knowledge lay and where barriers existed to the wider adoption of circular economy and closed-loop strategies enabled recommendations on the integration of a systems based approach in fashion design.

Selection of Participants

Using purposive sampling eight ethical fashion brands were selected to represent the range of market levels present in the fashion industry. Designers and brand owners were contacted to be interviewed as part of this study. An outline of key interview informant brands is given in Table 1.

Semi-Structured Interviews:

Semi-structured interviews were carried out with key informants on design and production, communication, consumers and gaps in knowledge. In flexible semi-structured interviewing style, questions varied between respondents to reflect what data could most appropriately be collected from each specific informant and how interviewees were directing the flow and emphasis of the data gathering. (Jankowicz, 1995; Lindlof and Taylor, 2011; Bryman, 2012). In analysing the interview data, a descriptive framework was employed to categorise topics according to emerging themes. Cross-case synthesis was then used to comparatively tabulate the data, allowing for similarities and contrasts to emerge. (Yin, 2014)

Table 1: Key Interview Informant Brands

Brand	Key Interview Informant Brands
Brand 1	A well-established Berlin based business that showcased and retailed upcycled fashion and jewellery from all over Europe, and provided a network hub for the local sustainable design community.
Brand 2	A micro sized ethical cycle wear enterprise based in London. The owner and director of this brand had previously held roles designing collections for two different London based upcycled fashion brands.
Brand 3	An upcycled fashion label of a UK based charity raising money for vulnerable children in Romania. Both the head designer and creative director were interviewed.
Brand 4	A well-established organic clothing line from London, produced under ethical conditions in China and printed in the UK. The brand specialised in printed organic cotton and hemp t-shirts.
Brand 5	A high profile upcycled fashion brand based in Spain and the UK, with production in Bulgaria. The brand also functions as a consultant and facilitator for outsourced ethical and upcycled production in Bulgaria.
Brand 6	A collaborative studio shop in London that was used to design, showcase and sell sustainable and ethical fashion and accessories, focusing on high quality handmade craftsmanship, fair trade, and transparency of production.
Brand 7	A well-established micro-enterprise upcycling brand based in Bristol, with a background in academic research informing sourcing decisions. This brand manufactured and produced through a network of local UK makers and artisans.
Brand 8	A high-profile upcycling brand, known for campaigning and public engagement, and pioneering collaborations between educational institutions and upcycling innovators. Based in London with production in Italy.

Results and Analysis

Using the principles of WST outlined in the review of literature, the results of the key informant interviews were analysed using cross-case synthesis in Tables 2 and 3, outlining how each brand's strategy aligned with WST. Table 4 outlines the main barriers to adoption of WST, as identified by the key informants.

Table 2. Whole Systems Thinking – cross case analysis

Brand	Focus on Outcomes	Open Innovation Networks	Find New Solutions
Brand 1	Reuse waste and operate a shop space which functions as a hub for the local sustainable fashion network.	Consultancy with larger brands, advising on supply chain issues. Collaborations with research and academia.	Flexible design formula. Local sourcing and production.
Brand 2	Create low carbon, non-toxic and recyclable waterproof clothing.	Participation in academic research.	Emphasis on style and design. UK and Europe based production.
Brand 3	Transform donations of clothing and textiles through upcycling, to be sold for charity.	Designer-makers given the opportunity to develop skills. Participation in academic research.	Flexible design formula. Local sourcing and production.
Brand 4	Produce ethical, eco-friendly and politically conscious street wear created from sustainable and fair trade materials.	Collaborations with artists and activists. Participation in academic research.	Focus on t-shirts and street wear combining design and politics.
Brand 5	Use reclaimed materials wherever possible, and combine these with sustainable and recycled fabrics to create high-end, fashion-forward collections.	Collaborations with mainstream clothing brands. Participation in academic research.	Emphasis on style and design. UK and Europe based production.
Brand 6	Connect customers to the process of production, including the materials, skills and time required to create unique products by hand.	Collaborations with makers and artisans. Participation in academic research.	Focus on artisans. Fair trade producers in Kathmandu.
Brand 7	Combine fashion forward shapes with reclaimed materials and heritage craft, through sustainable and ethical design.	Collaborations with makers and artisans. Collaboration and participation with research and academia. Feedback from retail buyers.	Slow fashion emphasis. Local sourcing and production.
Brand 8	Use upcycling as a design solution to the environmental problem of textile waste.	Collaborations with mainstream clothing brands. Participation in academic research.	Flexible design formula. Ethical production in Italy.

Table 3. Whole Systems Thinking – cross case analysis continued

Brand	Close the Loop	Establish Standards and Share Information
Brand 1	Reuse waste and operate a space which functions as a hub for the local sustainable fashion network.	Create upcycled fashion designs using fair trade and transparent production methods. An overall ethos to inform, inspire and educate consumers about upcycled fashion, and the consequences of over production and fast-paced consumption. Social media content also shares brands point of view.
Brand 2	Use of low carbon recyclable, waterproof, breathable membrane fabric, produced in Europe.	Materials and certification information available on company website. Social media content also shares brands point of view.
Brand 3	Upcycled clothing designed, made and sold as part of a charity.	Open plan workshop enabled customers to see makers and production. Social media content also shares brands point of view.
Brand 4	Hemp, carbon-neutral organic cotton, and recycled salvage plastic fibres used in clothing, printed with designs created by artists with a political message.	Information on awards and accreditation available on company website, as well as materials used. Social media content also shares brands point of view.
Brand 5	Design informed by recycled fabrics and upcycled textiles.	Participation in sustainable fashion education events. Social media content shares brands point of view.
Brand 6	Shop space provided a platform from which to inform customers on the production and materials used in the showcased items.	In store dialogue, website and social media content enabled the brand to share information on their materials and production.
Brand 7	Slow fashion collections created using upcycled, sustainable and local materials.	An ethos of contributing to the knowledge and understanding around sustainable fashion design through consultancy, education, research, curation and community projects. Social media content also shares brands point of view.
Brand 8	Sourcing policy to reuse the textile waste from high end garment factories in Italy.	The brand also endeavoured to do as much as possible concerning education and advocacy in ethical fashion, speaking at and working with educational institutions, and becoming leading campaigners in the Fashion Revolution organisation.

Table 4. System Barriers

Consumer Barriers
Lack of consumer awareness of the impact of consumption behaviours.
A lack of information provided to consumers on responsible alternatives to high street fashion.
Consumer resistance to behaviour change.
Ethics a low priority for the majority of consumers.
Consumers regard ethical credential of products as a bonus feature at best.
Social stigma of second hand clothes / textiles for consumers.
Risk of upcycled and sustainable products being disposed of irresponsibly by consumers.
Risk that feelings of guilt and judgement are off putting for consumers.

Communication Barriers
A lack of mainstream media coverage.
Identifying how to successfully communicate the wider benefits of sustainable production to consumers.
More consumer knowledge needed regarding:

- Communication preferences
- Price expectations
- Style and design requirements
- Lifestyle preferences
- Importance of quality, longevity and ethics to consumers
- Receptiveness to environmental and ethical messages
- Motivations to follow through on expressed good intentions
- Motivations to cease continued irresponsible consumption

Design and Production Barriers
Designers are required to spend significant amounts of time researching sourcing options.
Uncertain supply through reliance on only one sourcing stream (e.g. post-consumer textiles).
Lack sustainable options presented to designers and product developers in larger organisations.
Lack of skills, knowledge and agency for designers and product developers to make sustainability decisions.

Retail Barriers
Identifying the most effective retail strategy for sustainable fashion.
Limited understanding from UK retail buyers regarding stock variability and product quality.
Retail buyers prejudge upcycled stock to be inconsistent in supply, quality and consistency.
Unwillingness of retail buyers to place orders leads to a lack of wider acceptance.
Extra time on sourcing and smaller production runs lead to higher prices for consumers.

Industry barriers
A lack of integration of sustainable fashion into the mainstream – sustainable fashion shown as a novelty.
Lack of fashion industry acceptance of sustainable brands and practices.
Lack of wide spread fashion industry transparency.

Focus on Outcomes

It could be argued that the desired outcome of sustainable fashion is for consumers to buy less, and to buy better quality, longer lasting items and for their behaviour to be informed by Circular Economy concepts. Informants were of the opinion that consumers were often unaware of how their consumption behaviour had contributed to wider problems in the fashion industry, and those that were aware were unwilling to change their behaviour. It was felt that the most important factors for consumers were price and design. Ethics were not a key consideration for consumers and would only be viewed as a bonus feature at best. The nature of remanufactured and upcycled garments created exclusivity for consumers through limited editions and unique styles, however the social stigma many consumers attached to second hand clothing presented a problem to designers using post-consumer textiles as a source material in designs. For consumers to make more considered purchases, a paradox is created for those attempting to sell more sustainable fashion items (Black, 2011).

The desired outcome is for consumers to acquire less, use items more conscientiously and dispose responsibly, but brands still need to sell product in order to thrive. This was certainly alluded to by interview informants, who were of the opinion that the continued rate of consumption was a negative force. As can be seen in Table 2, each of the brands interviewed had a clear focus on an outcome which aligned more closely with the idea of consumers making more conscientious choices. The design focus centred around reusing waste as a source material for many of the brands, as well as combining this with sustainable and low impact new materials and fair labour practice. Brand 6 expressed a clear focus on the direct connection of customers with production processes, while Brand 3 also had a social focus as part of a charity, and Brand 4 had a focus on communicating positive political messages. In Table 4 indicates that barriers are presented to promoting more responsible and conscientious consumption due to a lack of consumer awareness and resistance to behaviour change. A challenge is presented to designers to change consumer perceptions and close the ‘value-action gap’, which demonstrates that expressed ethical concerns rarely translate into sustainable purchasing behaviour (Young et al., 2010).

Open Innovation Networks

As stated by Blizzard and Klotz (2012), an essential component of WST is open and effective communication, information sharing and participation by all involved in the design and production process. Social media was the most widely used communication strategy for all informants. Sharing of related content and stories communicated the ethos of brands and designers through non-product or sales related posts. This strategy also had the benefit of targeting an audience that had expressed a prior interest in issues of sustainability, allowing audience feedback, questions and participation. A market research opportunity was also presented through this medium. In-store and face-to-face dialogue was also favoured by informants. This enabled a direct connection with consumers to share stories of how products were made and to provide information about the fashion industry in an engaging and non-confrontational manner. This approach provided a unique, service led shopping experience and enabled brand owners to receive feedback, providing an additional market research opportunity.

As indicated in Table 2, each of the brands interviewed participated in some form of open innovation to varying degrees. Participating in academic research was a common theme for each brand; however, some took this a step further and were active collaborators in academic research projects. Driving this participation was a fundamental belief towards assisting positive developments in the industry as a whole, by integrating standards of sustainability into all fashion and textiles practice. Brands 5 and 8 also worked towards creating sustainability innovation in the mainstream fashion industry through collaborations with larger brands. This collaborative practice enabled the reuse of waste created in-house at multinational companies. Brands 3, 6 and 7 also collaborated directly with their designers, producers, artisans and makers to create participatory design and production decisions, aligning with the ethos of valuing perspectives form all stakeholders in the design process (Blizzard and Klotz, 2012). Further to this ethos, Brand 7 also highlighted feedback from retail buyers as informing design and production. Outlined in Table 4, barriers to the wider adoption of a whole systems approach incorporating sustainability practices, include industry reticence to continually engage with brands working to make positive steps. A lack of wide spread transparency and traceability in the industry creates a siloed approach to thinking, in which designers are not given appropriate agency to make key system decisions, or seek relevant interdisciplinary collaborators. Collaborative efforts from informants to work with larger brands have had limited success in incorporating sustainable practices into the continued working methods of the industry as a whole, in part due to competition driven price reductions (Tyler et al., 2006).

Find New Solutions

In finding new solutions to existing systems of design and production, as shown in Table 2, several of the upcycling brands had created a flexible design formula, in which a ‘patchwork’ pattern cutting style allowed different fabrics to be substituted in at design or manufacturing level, depending on the available source materials at the time of production. This was also often combined with the use of sustainably sourced or recycled fabrics. A design led approach, emphasising style, versatility and artisanship creates products with the durability to weather trends and waves of perceived obsolescence (Packard, 1960). Localised production, in the country of final sale or country of material sourcing as with Brands 1, 3, 6, 7 and 8 also limited the environmental impact associated with increased transportation between sites of cutting, making and trimming.

Along with the support of regional heritage and artisan production, localised practices serve to preserve culture, identity and community; aligning with Blizzard and Klotz's (2012) ethos of valuing place in whole systems design. The focus on fair trade at Brands 4 and 6 also ensured that growers and makers in developing countries benefited from a living wage and social equity (Thomas, 2008). The combination of fair trade principles with artisanship was most prominent at Brand 6, in which the brand owners worked collaboratively on designs with producers, ensuring fair wages and a traceable supply chain. Barriers to finding new solutions are detailed in Table 4. Increased costs from creating small runs of responsibly produced and well researched fashion items can create obstacles to consumer acceptance and again the challenge is presented in effectively communicating the wider benefits of these new solutions to all stakeholders. It was made clear by informants that there was no easy solution to the many difficult challenges presented. Risks are presented if consumer understanding for upcycled products does not fully extend to the entire lifecycle of the garment. If upcycled garments are valued in the same way as low-cost fashion with a high rate of consumption, there is every danger that they will be disposed of in the same way. Some informants described upcycling as functioning as an end-of-pipe solution, which was only a slight deviation from the linear model of consumption. For a fully functioning circular fashion system to be in place, understanding of the entire lifecycle by all participants is required.

Close the Loop

In closing the loop of design, production, use and disposal, or divestment as described by Collins, (2013), the designers utilising upcycling had a strong ethos of reusing waste as a source material for creating new garments and fashion items, presented in Table 3. This closely aligns with the principle of ‘waste as food’ (Braungart and McDonough, 2002), in which the waste of one system becomes the starting point of production for the next system (Svensson, 2007), and the useful lifecycle of products is extended without the need for new material production (Woolridge et al., 2006). Creating a network for potential collaborators and stakeholders along the supply chain to meet, such as at Brands 1 and 6, created new opportunities for co-operative systems thinking practices from multiple perspectives to close design and production loops (Blizzard and Klotz, 2012); efficiently utilising open innovation principles to make best of the capabilities and expertise in a WST network.

Utilising low impact and recyclable materials moves resource impact towards zero, increasing lifecycle efficiency and mimicking natural cycles of biological and technical nutrients returning to the start of the value chain (Ellen MacArthur Foundation, 2013). The use of non-hazardous and non-toxic source material limits negative impacts associated with end-of-life disposal, aligning with the principle of design for the environment in product service systems (Manzini and Vezzoli, 2003), and life-cycle strategies of extended producer responsibility (Hvass, 2014). Current obstacles identified in Table 4 to instigating a closed loop approach utilising WST included uncertain and time consuming sourcing practices, leading to a perception of inconsistent supply by retail buyers. Limited provision for end of life considerations, with no guarantee of full consumer understanding also led to the risk of irresponsible disposal of ethical produced products, negating the closed loop approach. Informants also felt that further actions could be taken by larger brands and governments to create change, by giving designers more agency to implement good practice along the supply chain, and government penalties for bad practice to highlight those acting most irresponsibly.

Establish Standards and Share Knowledge

Informants discussed a lack of industry acceptance of sustainable brands and ethical practices. Despite growing consumer awareness, the fashion industry shows a marked reluctance towards transparency. Leadership and support from larger well-established brands in the industry was felt to be vital to instigate any sort of change. Informants felt that the fashion industry could be doing more to promote sustainability, by allowing designers, product developers and buyers to make use of sustainable options. For the larger well-established brands, it will be necessary to equip their designers with the necessary skills, knowledge and agency to make decisions affecting production, labour and materials, as well as the use phase and end-of-life considerations to truly implement a circular economy fashion system.

All informants expressed personal standards of ethical and sustainable fashion practice, as highlighted in Table 3; however Brands 2 and 4 also shared information on the official standards, certification and accreditation of their material supply and production through their company websites. Brands

5, 6, 7 and 8 also provide some limited information about their studio / workrooms, factories, makers and production online. Brand 3 however utilised completely transparent manufacturing by locating their makers and production on the shop floor of their London premises, enabling customers to see and interact with those making the clothes they were buying. Brands 1, 3, 6 and 7 had also provided accessible spaces to inform consumers about ethical fashion choices and for individuals to learn more about the process of making, mending and maintaining clothing in a sustainable, enjoyable and creative way. Brands 3, 4, 6 and 8 created social benefits through charity fundraising, social, political and environmental advocacy and accessible information sources for consumers and communities. All brands interviewed had strong social media presences, in which shared content communicated not just their product offerings but also their ethos, philosophy and wider issues connected to sustainability, environment and society, creating an accessible societal network for knowledge and learning (Manzini, 2009).

As shown in Table 4, impediments to the wider sharing of information included a lack of mainstream media coverage, with ethical fashion often singled out as a novelty; an issue which several informants found particularly frustrating. Difficulties in identifying the most effective methods to communicate sustainable fashion to consumers stemmed from a lack of information on consumer preferences, expectations, values, motivations and receptiveness. These barriers served as significant obstacles in building in the feedback loops so necessary for effective WST and life-cycle approaches to protect and restore natural social and economic systems (Blizzard and Klotz, 2012). The lack of official policies, such as a corporate social responsibility (CSR) plan, may be in part due to the micro to small size of each enterprise. As stated by (Baumann-Pauly et al., 2013) CSR initiatives are primarily designed for large firms that have the human and financial resources to implement the required procedures into their business operations. Small and micro enterprises have the advantage of implementing sustainability policy as part of their initial business strategy, as opposed to retro fitting the greening of supply chains as an afterthought to business operations, but the communication and scope of such policies is often driven by the resources and size of enterprises.

Conclusions

The results of this study demonstrate that for effective WST in a circular economy, designers must necessarily consider each stage in the cycle, from farmers and seamstresses to designers, marketeers and brand management, plus consumers and textile collectors. Each stakeholder's role and point of view must be considered to ensure harmony and efficiency in a system functioning as a whole. A clear understanding of the needs of users, and a clear and focused voice with which to best communicate the message of sustainable consumption can work towards mitigating the barriers presented by the 'values-action gap'. Open and effective communication, transparency and ready information on design and production processes provide trustworthiness, confidence and understanding for potential consumers on the distant effects of continued consumption (McDonough, 2000). Consumer focus groups would share information and take into account perspectives from users for a whole systems approach which considers the use phase and end of life options. The clearest voice for sustainable fashion is through social media and brand websites. Users are open to receiving information in these forms and ready to interact with new ideas and provide feedback and opinions. Online information is perhaps the most suitable medium for providing details on transparency and provenance, providing individuals with immediate access to the whole supply chain. The majority of the case study companies also had existing links with academia, indicating a conscious commitment to a sustainable worldview. This represents a partnership that has potential for further development.

Social media also provides a platform on which to inform individuals about wider, non-product related issues concerning global social and environmental issues connected to responsible production, and demonstrating each brands ethos and situating them within the sphere of accessible sustainability. The most effective strategy is to establish closed loop and upcycled fashion as stylish and desirable to consumers, over and above mainstream offerings, without having to rely on ethical credentials to sell products. Products should stand up against current mainstream fashion design, being just as well designed, if not better; but emphasise fair wages, positive contributions to local economies, development of artisan skills, negligible environmental impact and end of life options, built into the cycle of use. Take back schemes and online advice for divestment could feed into a mapping of donating, reuse and sourcing options, closing the loop for consumers, brands, designers and manufacturers alike. For integration into the mainstream, ethical fashion should not be singled out as a novelty by retail or media, but considered as part of a whole system, in which all actors must share their information and work co-operatively. In conclusion, the principles of WST are outlined as: (1) Focus on outcomes (2) Open innovation networks (3) Find new solutions (4) Close the loop (5) Establish standards and share knowledge.

These principles necessitate building in sustainability to business operations from the very beginning of planning and modelling. Designers should seek collaborators with goals closely aligned to their own sustainability principles, to solve holistic, life-cycle focused problems in a circular economy. Transparency, traceability and openness of information should establish standards and policies, setting a precedent for best practice and effectively communicating this to all stakeholders, from workers to consumers, plus all before, beyond and in between. In this way, the industry can work towards mitigating the damage previously meted out by irresponsible over production and continued consumption, and to prevent further detriment by instigating a circular whole systems mindset for sustainable future fashion.

References

Baumann-Pauly, D., Wickert, C., Spence, L. J., Scherer, A. G. (2013) *Organizing Corporate Social Responsibility in Small and Large Firms: Size Matters.* Journal of Business Ethics, pp. 1–13.

Black, S. (2011) *Eco-chic: The Fashion Paradox*. London: Black Dog Publishing.

Blizzard, J. L. and Klotz, L. E. (2012) *A framework for sustainable whole systems design.* Design Studies. UK: Elsevier, 33(5) pp. 456–479.

Braungart, M. and McDonough, W. (2002) *Cradle to Cradle*. London: Vintage.

Bryman, A. (2012) *Social Research Methods*. 4th ed., Oxford: Oxford University Press.

Catarino, J., Henriques, J. J., Maia, A., Alexandre, J., Rodrigues, F., Camocho, D. (2011) *From cleaner production and value management to sustainable value*. International Journal of Sustainable Engineering, 4(2) pp. 96–108. Taylor & Francis.

Charnley, F., Lemon, M. and Evans, S. (2011) *Exploring the process of whole system design.* Design Studies. Location: Elsevier, 32(2) pp. 156–179.

Chesbrough, H. W. (2003) *Open innovation: the new imperative for creating and profiting from technology*. Boston, Mass: Harvard Business School Press.

Collins, R. C. (2013) *Excessive ... But not wasteful? Exploring young people's material consumption through the lens of divestment*. University College London. UCL Press.

Ellen MacArthur Foundation (2013) *Towards the Circular Economy 2: Opportunities for the consumer goods sector*. [Online] https://www.ellenmacarthurfoundation.org/publications.

Ellen MacArthur Foundation (2015a) *Circular economy system diagram*. Ellen MacArthur Foundation. [Online] [Accessed on 20th July 2016] http://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram.

Ellen MacArthur Foundation (2015b) *Delivering the Circular Economy: A Toolkit for Policymakers*. [Online] https://www.ellenmacarthurfoundation.org/publications.

Gam, H. J., Cao, H., Bennett, J., Helmkamp, C., Farr, C. (2011) *Application of design for disassembly in men's jacket: A study on sustainable apparel design*. International Journal of Clothing Science and Technology, 23(2/3) pp. 83–94. Emerald Insight.

Hvass, K. K. (2014) *Post-retail responsibility of garments – a fashion industry perspective.* Journal of Fashion Marketing and Management, 18(4) pp. 413–430. Emerald Insight.

Jankowicz, A. D. (1995) *Business Research Projects*. London: International Thomson Business Press.

Johnston Cobb, D. (2014) *Sustainable Textiles for Apparel: Fact, Fiction and Future Prospects*. www.just-style.com.

Lenzen, M., Murray, J., Sack, F. and Wiedmann, T. (2007) *Shared producer and consumer responsibility - Theory and practice.* Ecological Economics, 61(1) pp. 27–42. Elsevier.

Lindlof, T. R. and Taylor, B. C. (2011) *Qualitative communication research methods*. 3rd ed., London: SAGE.

Manzini, E. (2009) *New design knowledge.* Design Studies. UK: Elsevier, 30(1) pp. 4–12.

Manzini, E. and Vezzoli, C. (2003) *A strategic design approach to develop sustainable product service systems: examples taken from the `environmentally friendly innovation' Italian prize.* Journal of Cleaner Production, 11(8) pp. 851–857. Elsevier.

McDonough, W. (2000) *The Hannover Principles.* The Worlds Fair, p. 60. William McDonough Architects.

Packard, V. O. (1960) *The Waste Makers*. New York: IG Publishing.

Powell, W. W., Grodal, S. (2005) *Network of innovators. In* Fagerberg, J., Mowery, D. C., Nelson, R. R. (eds) *The Oxford Handbook of Innovation*. Oxford University Press, pp. 56–85.

Sempels, C. (2013) *Implementing a circular and performance economy through business model innovation. In* Webster, K., Blériot, J., Johnson, C. (eds) *A new dynamic: effective business in a circular economy*, p. 172. Ellen MacArthur Foundation Publishing.

Stasinopoulos, P. (2008) *Whole system design: an integrated approach to sustainable engineering*. London: Earthscan.

Svensson, G. (2007) *Aspects of sustainable supply chain management (SSCM): conceptual framework and empirical example.* Supply Chain Management: An International Journal, 12(4) pp. 262–266. Emerald Insight.

Thomas, S. (2008) *From Green Blur to Ecofashion: Fashioning an Eco-lexicon.* Fashion Theory: The Journal of Dress, Body & Culture. Taylor & Francis, 12(4) pp. 525–540.

Tyler, D., Heeley, J., Bhamra, T. (2006) *Supply chain influences on new product development in fashion clothing.* Journal of Fashion Marketing and Management, 10(3) pp. 316–328. Emerald Insight.

United Nations (2016) *Sustainable Development Goals*. United Nations. [Online] [Accessed on 20th July 2016] http://www.un.org/sustainabledevelopment/sustainable-development-goals/.

Woolridge, A. C., Ward, G. D., Phillips, P. S., Collins, M., Gandy, S. (2006) *Life cycle assessment for reuse/recycling of donated waste textiles compared to use of virgin material: An UK energy saving perspective. Resources, Conservation and Recycling*, 46(1) pp. 94–103. Science Direct.

Yin, R. K. (2014) *Case Study Research: Design and Methods*. 5th Edition, Los Angeles: SAGE.

Young, W., Hwang, K., McDonald, S. and Oates, C. J. (2010) *Sustainable consumption: Green consumer behaviour when purchasing products. Sustainable Development*, 18(1) pp. 20–31. Wiley.

CIRCULAR
TRANSITIONS

23 – 24 November 2016

Using A 'Five Perspectives of Sustainable Design' Model in Fashion and Textiles

Karen Marie Hasling (Design School Kolding, Denmark)

Abstract

This paper demonstrates how a 'five perspectives of sustainable design' model can be used to discuss, communicate and develop approaches to sustainable fashion and textiles applicable for design education and professionals when dealing with sustainability issues in new products, systems and strategies.

Introduction

This paper proposes a 'five perspectives of sustainable design' model as a way to analyse, discuss, communicate and develop approaches to sustainable fashion and textiles applicable for design education and professionals.

Since the 'Our Common Future' report was published in the late 80s (United Nations, 1987) it has been used as a main reference to discuss and operationalise sustainable development as a concept. Today the value system that defines and shapes this concept has shifted from being mainly objective to increasingly acknowledging subjective dimensions; it has shifted from perceiving sustainable initiatives as primarily singular and non-interactive entities to embracing large and complex systems with constant interactions between human and non-human actors (Bhamra & Lofthouse, 2007; Keitsch, 2015; McLennan, 2004; Vezzoli & Manzini, 2010). The broadening of the scope of sustainable development means that more disciplines take part in a collection of mentalities, methodologies and traditions that both strengthen and dilute the concept. As a consequence, for designers, students as well as professionals, it can be challenging to navigate between approaches to sustainable design such as to identify relevant actions to take and to link these actions to each other.

The 'five perspectives to sustainability design' model

Because many different approaches to sustainable development exist, it is relevant to create a common understanding that can unite approaches rather than make them fight against each other. Consequently, this paper demonstrates, how a 'five perspectives of sustainable design' model can be used to analyse and benchmark, how existing products and companies are dealing with sustainability issues and to overview and map, how to work with sustainability in new materials, products, systems and strategies.

The model operates with five perspectives being:

- The 'raw materials and processes' perspective that refers to environmental impacts of extracting and producing raw materials and manufacturing products in pre-consumption and waste generation processes in post-consumption phases.
- The 'products and use' perspective that broadens the scope of the previous perspective to including impacts of consumption in a 'cradle-to-grave' or lifecycle approach.
- The 'services and systems' perspective that shifts focus from single products and individual consumers to larger systems of material and product flows that can be interchanged and reused between multiple actors.
- The 'strategies and business models' perspective that embraces a holistic understanding, emphasizing economic, environmental and social sustainability in strategic design and corporate business models.
- The 'culture and experience' perspective that emphasises experience and cultural belonging as a means to create value with initiatives that strengthen the consumer-product relationship or that prolong the product lifetime with having multiple consumers.

In the model, the perspectives build on each other as in an onion structure with the 'raw materials and production processes' perspective as the inner core and the 'culture and experience' perspective as the outer shell. In Figure 1 the model is shown.

The model is inspired by Mulder et al.'s concept of 'articulations of sustainable technology' (Ashby & Johnson, 2014; Mulder, et al., 2011) as a way to raise awareness towards positive and negative consequences of given sustainability approaches and how these are connected in larger networks. However, whereas Mulder et al. build on a conventional understanding of sustainable development based on the Triple Bottom Line (Elkington, 1997), the understanding in this model has been extended to a Quadruple Bottom Line (Fleming, 2014; Lowe, 2010) that also includes 'experience'. Here experiential sustainability can relate to for example 'aesthetics' (Couch *et al*, 2015; Harper, 2015; Zafarmand *et al*, 2003), 'emotions' (Chapman, 2009; Desmet, 2008), 'affection' (Barbiero, 2014;

Börjesson, 2006), ‘culture’ (Gouveia, 2002; UNESCO, 2016) and links to ‘social design’ and ‘social innovation’ (Manzini, 2015; *Social Design Pathways*, 2016; Tromp, 2013).

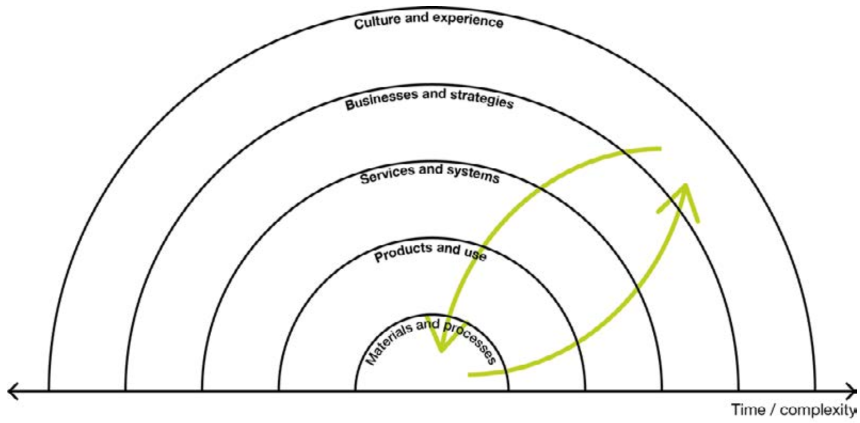


Figure 1: The contents of the model including the perspectives ‘raw materials and production processes’, ‘products and use’, ‘services and systems’, ‘strategies and business models’ and ‘culture and experience’

In the model, sustainability approaches are positioned in the perspectives they relate to, and approaches that relate to or depend on each other are linked with stippled arrows. Initiatives will require different implementation time and have different levels of complexity (Brezet, 1997; Fletcher, 2008; Niinimäki, 2011) and therefore an indicative scale of ‘time/complexity’ is included.

With this basis, the model can be used to argue for the relevance of choices on, how different approaches create synergies and to discover the role of for example ‘experience’ as a means to work with sustainable design. Consequently, it can be used to communicate, how strong sustainable business models often build on multiple collaborating aspects that strengthen each other as well as the business as a whole. From teaching, the experience is that students find the model valuable as a tool to explore and systematise, how sustainable business models can be designed and to acknowledge the complexity of working with sustainable aspects in fashion and textiles. With reference to the topic, ‘Circular Transitions’, here understood as the search for connecting distinct approaches that together can provide larger, stronger and more embedded circular systems of transitions to create a more responsible and conscious fashion and textiles industry, the model can be used to illustrate how these correlate and interact.

Cases from fashion and textiles companies

In the following three cases, fashion and textile companies with sustainable profiles will be presented; first individually and then analysed and discussed together using the model as a frame for exploration. The cases have been selected to demonstrate how the model can be used to clarify entries to working with sustainable fashion and textiles and how companies can use sustainability as a competitive driver and how industry can work with relational thinking in sustainable design as an incentive for communicating or modifying existing business strategies and developing new ones. All three companies build their business models on sustainable transitional thinking, but they do it in different ways and with different depth. Thus, the discussion of the cases does not aim to tell which approaches that are better, but to elaborate on different ways to work with sustainability.

Case: The IOWEYOU-project

The first case is the 'I Owe You'-project (IOU), which is based on Indian woven fabrics made from locally grown cotton, handwoven on traditional looms, converted into unique garments by European artisans and sold via a webpage ("I Owe You webpage," 2016). Figure 2 shows an overview of some of the involved artisans, weavers and others involved in the IOU-project (left) and an example of a full outfit (right). Figure 5 shows the five perspectives model with relevant approaches to sustainability for the IOU case.

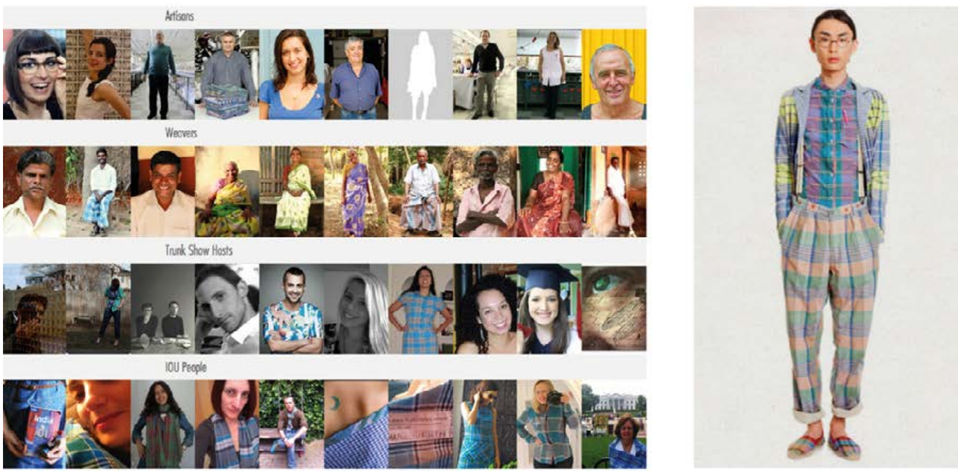


Figure 2: Screenshots from the IOU-webpage showing some of all the involved artisans, weavers and users (left) and an example of a full outfit (right) (www.iouproject.com)

Case: Organic Basics

The second case is Organic Basics, a Danish clothing company started by a group of entrepreneurial friends that were not content with the selection of sustainably friendly alternatives of menswear basic garments ("Organic Basics," 2015). Their business builds on a subscription service, where you receive a new pair of boxer shorts and/or two new pairs of socks within a given interval of own choice. Items can also be purchased individually on the company's webpage and in chosen stores to a slightly higher price. Their first production was financed through the crowd funding platform, Kickstarter, which since has been used to further develop the company's visions. In figure 4, promotional photos of the product are included, while figure 6 shows the five perspectives model with relevant approaches to sustainability for the Organic Basics case.

Figure 3 (left): Promotional photo for Organic Basics (Organic Basics ©)
Figure 4 (right): Promotional photo from Vigga (Vigga ©)

Case: Vigga

The third case is Vigga, a Danish clothing company that offers kidswear with a leasing/subscription service ("Vigga webpage," 2015). The business model for Vigga is that new parents can subscribe to a package of basic wear from their offspring is 0-2 years. When the offspring grows out of the clothes, parents receive a new package with clothes in a bigger size and return the smaller size garments using a parcel service. The company then takes care of laundering and makes smaller repairs on the clothes if necessary. Thereafter the clothes will be sent to a new child that will use it. Figure 6 shows promotional pictures from the company, while Figure 7 shows the five perspectives model with relevant approaches to sustainability for the Vigga case.

Sustainability approaches in the three cases

With basis on the three cases, the following will elaborate on and discuss, how these approaches to sustainable design collaborate and synergise to create sustainable and *holistic* business models. The discussion will be based on selected approaches that are apparent in one or more of the cases and will move progressively from the inner to the outer shell of the model. In figure 5-7, the three cases are illustrated using the five perspectives model as a methodical frame.

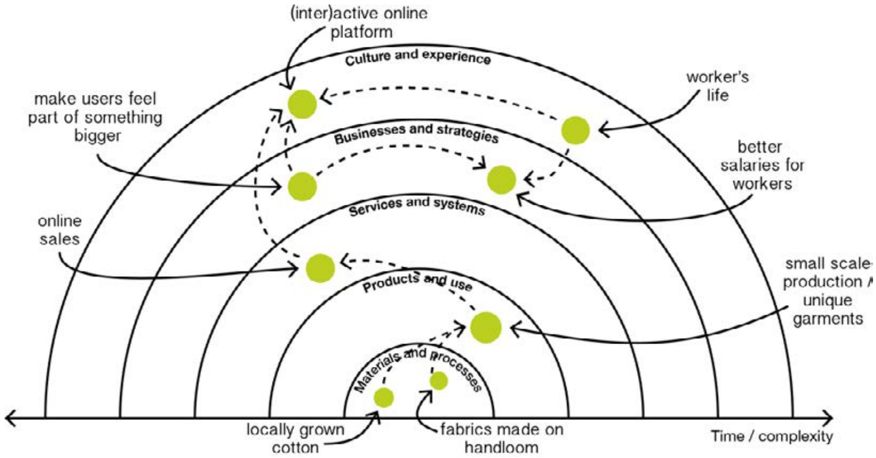


Figure 5: The five perspectives of sustainability model for the IOU case

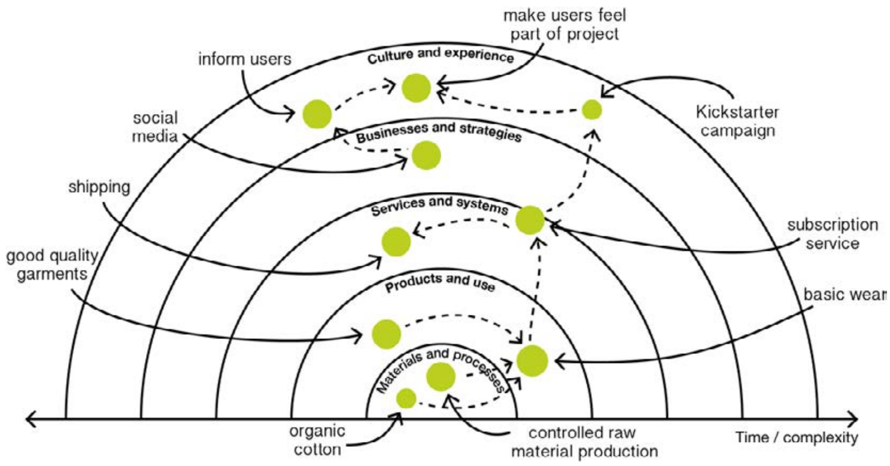


Figure 6: The five perspectives of sustainability model for the Organic Basics case

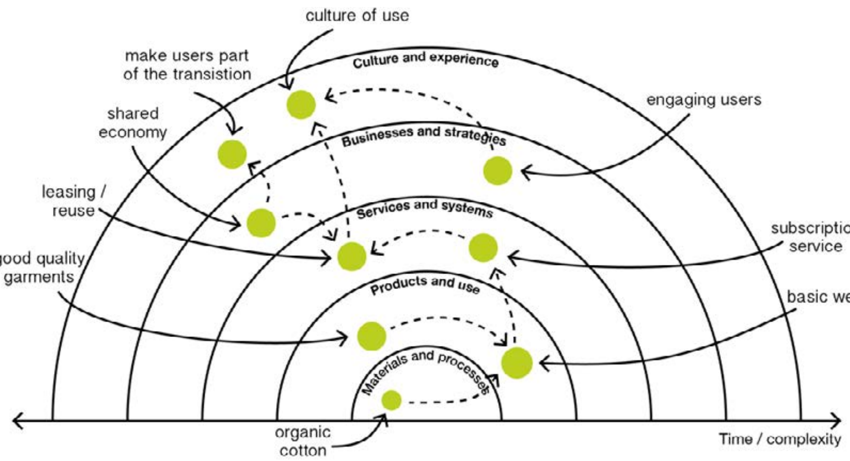


Figure 7: The five perspectives of sustainability model for the Vigga case

Materials and processes

Organic Basics and Vigga both use organic cotton in their products, which is becoming more and more common and by now can be found in a broad range of products. The argument for using organic cotton is evident and relates to environmental but also ethical issues in cotton farming and production. Furthermore, organic cotton is treated and dyed in accordance to certification standards, which prevails harmful chemicals in the garments, which especially for children's clothing is relevant.

IOU and Organic Basics emphasize local production of their products, here meant as materials having been little transported from being produced to being processed and sewn into garments; IOU produce their garments in India, while Organic Basics have their production in Turkey. It furthermore means, according to Organic Basics, that production is easier to control.

From materials and processes to products and use

Organic Basics and Vigga work with what they refer to as basic wear in good quality to enhance the lifetime of their garments, which both refer to product durability. For Organic Basics the aim is to make the products in their basic wear collection last longer and be intensively used with a proposed lifetime of their boxer shorts of 10 years. For Vigga the aim is to ensure that their garments can be reused and take part of the closed loop system without being worn out too fast. Consequently, this relates to choosing materials; fibres, yarns and fabrics, with appropriate properties when it comes to wear and tear. Furthermore, especially for Vigga, this refers to designs and pattern making taking into account how the products are used, how it can be repaired and how it can be flexible enough to fit multiple users.

For IOU, the approach is that fabrics are handmade and only made in small quantities (~5 meters), which create unique garments.

From products and use to services and systems

All three companies are online-based and have no physical stores, but their services and systems are approached in different ways. IOU has a 'conventional' online store, with a product portfolio and with customers that buy specific products, at Organic Basics customers subscribe to receiving new and neutral products in an interval of own choice, while at Vigga users subscribe to a leasing deal, where they receive a package of neutral garments in a bigger size and return a similar package of garments to the company. Consequently, IOU and Organic Basics work with single user systems, while Vigga works multiple user or shared product systems.

From services and systems to strategies and business models

All three companies have built their business models on sustainable transitions, which means that all other approaches somehow can be traced back to their strategies. The companies have their primary activities online, which lower retail expenses and leaves a larger margin of the sales price to the company. IOU uses part of this margin to pay weavers and artisans a higher price for the products they manufacture and to allow that materials and products might be comparatively expensive. For Vigga, the online platform is an essential part of the business model and it would not make sense to have physical stores. Here the larger margin has been allocated and distributed into other parts of the company to make it feasible and economically sustainable.

From strategies and business models to cultures and experience

The three companies also share characteristics in the way they incorporate and emphasise the role of experience and culture in their business. Organic Basics are very active on social media and use it as a way to promote and create a sense of authenticity in their products through for example Instagram; for Vigga it is vital to understand the culture of use of the products in order to make the business model work and she invites users to share their experiences with her and other users, and IOU has an interactive online platform, where actors involved in the company (artisans, weavers, users etc.) can connect and feel becoming part of a community. Consequently, all businesses emphasise the role of the user as an active player in the success and further development of the business.

Discussion

In the services and systems perspective, it was highlighted that the companies are different in the ways they refer to single users or multiple users and to the boundary between private and social design. Organic Basics provides private products, but engages users through e.g. crowd funding campaigns; IOU provides private products, but put a lot of resources on a shared platform for people to engage; and Vigga offers a system for people to share products. This means that much attention is put on the intended user(s); when it comes to using the product as a physical artefact and to appreciating the systems and communities the companies represent.

The culture and experience of taking part of a sharing economy system and the culture of use are at first hand to different things, but in reality, it's two sides of the same coin. Whereas culture of use can be regarded as the inward and thus individual practice in homes, culture as the experience of belonging to a community can be regarded as the outward and social practice in a society. In order for a business model like Vigga's to work, these two 'modes' of practices need to interact and adjust to each other. The culture of use needs to adjust to the fact that the clothes need to be used by others afterwards, which means that it should be taken properly care of and that it in some ways should be regarded as just 'borrowed'. Similarly, the social culture needs to respond to the thought of sharing something that to many is rather intimate and connected to personal memories.

All three cases orient themselves multiple places in the model and have taken many different and related approaches to working sustainably; they have chosen elaborate materials, processes, products and services, and they make these graspable for the user via *storytelling* and *authenticity.* When Fletcher among others points at the relation between depth of action, time needed and positive impacts (Brezet, 1997; Fletcher, 2008; Niinimäki, 2011) it also points forward the complexity and paradox of the industry. If a company wants to have a large positive impact, it will most likely have to develop a complex, but also sophisticated business model that corresponds to the system it seeks to take part of. Based on the model and the presented cases, it can be argued that even when companies aim high, they should not forget to establish a good base to lean on and that this base most likely will become part of the argument for the system and the business strategy.

Conclusion

The paper introduces a 'five perspectives of sustainable design' model to discuss different ways to work with sustainable design. This model can help to highlight how business models can be strengthened by emphasising how different ways, or approaches, to work with sustainability in fashion and textiles interact and create synergies. The model is demonstrated by three cases that in different ways challenge the current system. Based on the model it can be argued that, when companies are represented in all, or at least many, of the perspectives, their business strategy appears stronger and approaches to sustainability seem better integrated in the company's identity. Consequently, with reference to the Our Common Future Report, the model can be used to clarify 'what' should be approached, 'why' it should be approached, and 'how' it should be approached as articulation that have been jointly developed in a holistic business model become stronger together.

References

Ashby, M. F. & K. Johnson. (2014) Materials and Design: The Art and Science of Material Selection in Product Design. 3rd ed., Oxford: Butterworth-Heinemann

Barbiero, G. (2014) Affective Ecology for Sustainability. Visions for Sustainability, vol. 1, pp. 20–30

Bhamra, T. & Lofthouse, V. (2007) Design for Sustainability: A Practical Approach. Aldershot: Gower

Börjesson, K. (2006) The affective sustainability of objects; a search for causal connections. Studies of theory, processes and practice related to timelessness as a phenomenon. University of the Arts. London

Brezet, H. (1997) Dynamics of ecodesign practice. January-June, UNEP Industry and Environment, pp. 21–24

Chapman, J. (2009) Design for (Emotional) Durability. Design Issues, vol. 25, no. 4, pp. 29–35

Couch, C., et a. (2015) An introduction to sustainability and aesthetics: The arts and design for the environment. Boca Raton: Brown Walker Press

Desmet, P. M. A. (2008) Product Emotion. Product Experience, edited by H. N. J. Schifferstein & P. Hekkert, Oxford: Elsevier, pp. 379–398.

Elkington, J. (1997) Cannibals with forks - The triple bottom line of the 21st century business. North Mankato: Capstone Publishing Ltd

Fleming, R. M. (2014) Integral Theory: An Expanded and Holistic Framework for Sustainability. Integrative Approaches to Sustainable Development at University Level, edited by W. L. Filho et al, Heidelberg: Springer, pp. 259–274.

Fletcher, K. (2008) Sustainable Fashion & Textiles - Design Journeys. London: Earthscan

Gouveia, V. V. (2002) Self, Culture, and Sustainable Development. Psychology of Sustainable Development, edited by Peter Schmuck and Wesley P. Schultz, Boston: Springer, pp. 151–174.

Harper, K. (2015) Aesthetic Sustainability [Æstetisk bæredygtighed]. Samfundslitteratur. I Owe You webpage. www.iou.com (2016-07-29)

Keitsch, M. (2015) Sustainable Design - Concepts, methods and practices. Routledge International Handbook of Sustainable Design, edited by Michael Redclift and Delyse Springett, New York: Routledge, pp.164–178.

Lowe, N. S. (2010) Aesthetic Sustainability: The Fourth Bottom Line Orienting Sustainable Buildings and Development. Houston: Empire Advertising & Design

Manzini, E. (2015) Design, When Everybody Designs: An Introduction to Design for Social Innovation. Cambridge: MIT Press

Mclennan, J. F. (2004) The Philosophy of Sustainable Design: The Future of Architecture. Kansas City: Ecotone Publishing Company

Mulder, K., et al., editors. (2011) What is sustainable technology? What is Sustainable Technology? Perceptions, Paradoxes and Possibilities, Abingdon: Greenleaf

Niinimäki, K. (2015) From Disposable to Sustainable. Aalto University

Organic Basics webpage (2015). http://organicbasics.dk (2015-07-24)

Social design pathways. (2016) www.socialdesignpathways.com

Tromp, N. (2013) Social Design - How products and services can help us act in ways that benefit society (PhD dissertation). Delft University of Technology

UNESCO (2016) The Global Report on Culture and Sustainable Urban Development. UNESCO

United Nations (1987) Our Common Future - Report of the World Commission on Environment and Development. United Nations World Commission on Environment and Development

Vezzoli, C., Manzini, E. (2010) Design for Environmental Sustainability. London: Springer

Vigga (2015) www.vigga.us (2015-07-24)

Zafarmand, S. J., et al (2003) Aesthetic and Sustainability: The Aesthetic Attributes Promoting Product Sustainability. Journal of Sustainable Product Design, vol. 3, no. 3-4, pp. 173–18.

Material Futures: Crafting Circular Conversations

Jen Ballie (Glasgow School of Art, UK)

Abstract

This paper discusses the need to design for a circular economy. Identifying six emerging design principles for design researchers to consider when facilitating conversations around the circular economy and reflecting on their implications on the role of the textile designer, we aim to make scalable recommendations for future research and practice to support closed-loop innovation in the textile sector, and explore how the findings might be expanded upon to craft circular conversations to support emerging designers.

Introduction

Heightened awareness of the economic value being lost through waste coupled with a rise in resourcing risks have elevated business interest in the circular economy. While the term 'circular economy' is becoming appropriated on a global scale to address a wide range of issues regarding waste, there is little evidence available to demonstrate how this might be applied by small to medium enterprises (SMEs) and understood by Higher Education (HE). Rising resource risks and the growing recognition of the economic value being lost in waste have raised business interest in the circular economy. A recent study by McKinsey (2015) titled *Growth within: A circular economy vision for a competitive Europe* identified that resource productivity remains hugely under exploited as a source of wealth, competitiveness, and renewal. They argue that a circular economy, enabled by the technology revolution, would allow Europe to grow resource productivity by up to 3 percent annually. Within the UK, the Scottish Government have been lobbying policy initiatives to implement a £70million European Regional Development fund with a £17million Circular Economy Investment fund to help SME's to catalyse innovative approaches to design, fostering repair and reuse and encouraging service and leasing models for material recovery, with the premise of supporting closed loop systems, most notably, additional support for collaboration; the evaluation of different methods; and further understanding of future material ecologies. Concurring with the RSA's perspective, we propose that design-led approaches can play a key role to play addressing these challenges:

> The skills that must be developed in the new circular economy [...] They are new behaviours, new ways of collaborating and new ways of seeing. And for these to be learned and ingrained, they must first be tested and actively encouraged. (RSA, 2016: 41)

This paper will explore the work in the area of *Material Futures* – undertaken by a research collective based at The Glasgow School of Art (GSA). Throughout this work the researchers seeks to raise awareness of the circular economy to support the Scottish textile sector. By identifying the most appropriate design-led approaches for crafting conversations that attend to addressing gaps in knowledge and practice, these seek to connect textile designers with other stakeholders across the supply chain. Through positing the research question 'which design principles are required to craft conversations around the circular economy?', We begin by discussing current debates within the textiles and craft industries and outline the challenges of articulating the applications of a circular economy.

From this point, we present a case study derived from textile design research in order to extrapolate the ways in which creative and participatory design approaches can be used to stimulate productive dialogue around both the circular economy, and broader environmental issues. This has allowed us to identify six emerging design principles for design researchers to consider when facilitating such conversations. We then reflect on the implications of these principles for future research around the circular economy and the role of the textile designer therein, and highlight the significance of design-led approaches in strengthening communication, promoting creative action, and embedding collaborative ways of working.

Designing for circularity: a UK perspective

Within the UK textile sector, there is increasing awareness of the requirement for new textile initiatives to be linked with the concept of the circular economy (Goldsworthy 2012; 2013), but there is a lack of practical knowledge and accessible evidence available to provide support in the textile sector. Moving forward knowledge exchange will be essential alongside innovative tools to mediate dialogue and support joined-up thinking to connect all stakeholders involved in the supply chain of fashion and textiles.

According to Scottish Enterprise, the textile sector of the business community have highlighted there is a lack of resources for R&D and business model innovation (Scottish Enterprise 2013). While Scottish based fashion / textile SME's (small to medium enterprises) are currently adding value to previously discarded textile waste by applying their practical skills, knowledge and expertise to rework and reuse (Simonella 2016; Kent 2016; Taylor 2015). From a broader perspective fashion and textile designers have been adopting sustainable design principles and strategies, with a plethora of innovative examples emerging within the last decade, demonstrating new concepts such as; zero waste pattern cutting (Gwilt and Rissanen 2011; Rissanen and McQuillain 2015), design for disassembly (Van Balgooi 2015) and upcycling (Earley 2015; DeCastro 2015). Those working with post-consumer textile waste highlight the scope of redesign is often influenced by the first lifecycle of the garment or textile. The circular economy posits a new position by arguing a case for closed loop innovation from the outset.

To achieve a circular model, we propose a more holistic approach, with circular design discussed at the front end of the innovation process. Furthermore, design for multiple cyclical iterations or loops of use at the outset could fully optimise lifecycles and reduce post-consumer waste, expanding upon the research undertaken by Payne (2011), as shown in Figure 1.

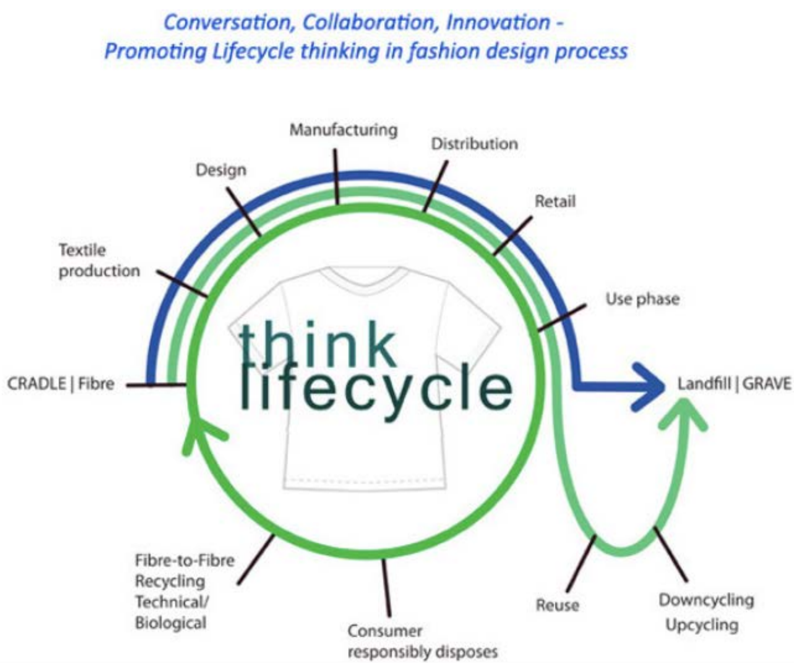


Figure 1: Mapping out the lifecycles of a fashion garment. Promoting lifecycle thinking in fashion. Alice Payne (2011)

Whilst design capabilities have been sustained within the UK, our manufacturing skills have not (Taylor and Townsend 2014). This posits a dilemma for UK businesses that must not only begin to address the issue of skill shortages but also develop new business models that take account of provenance, longevity, environmental impacts and end of life (Thomas 2015).

Bearing in mind these insights around production, process, and ethical awareness in the context of textile design, we now go on to present two case studies in which design-led approaches are applied to enhance participants' awareness of and capacity to respond creatively to the concept of a circular economy.

Communicating Circularity: design-led approaches in action

The case study presented in this section provide descriptive accounts of two established research projects in which design approaches have been developed to engage diverse groups of people in conversations around pertinent environmental issues. This offers an overview of work carried out specifically in the context of the circular economy, in which creative and generative materials were developed to unpack perceptions of and envisage strategies to enhance the circular economy with a group of textile designers. These accounts set the scene from which we then focus on how creative and participatory approaches were configured in each case to render often abstract concepts tangible and accessible, and identify guiding design principles for crafting conversations around the circular economy in the final section.

Case Study: Re-thinking through Making – The Circular Fashion System Conversation

This example refers to a workshop activity within a master class titled *Design Better Things: Do Better things* hosted by Zero Waste Scotland (Feb 2016). The brief was to stimulate conversation around circular innovation with participants across the UK textile sector. A simple tool was designed – containing a linear supply chain that participants were encouraged to 'hack' into a circular loop to connect the flow of materials to ideate opportunities around material efficiency and reuse. This task mediated 're-thinking through making' as an approach and allowed individuals to work within groups to visually depict new material journeys. This effectively provoked debate around new possibilities, alongside identifying barriers and opportunities for future development. It became clear that while we can invest our collective energy, efforts, expertise into designing and doing good things – can this have a true and meaningful impact within a world proliferated with too much stuff?

There has recently been a lot of discussion in design around the circular economy towards developing dematerialised consumption patterns by shifting the focus in design from material possessions to accessibility and services (Shayler 2016). HYBRID MATTERs, for example, is a network that brings together researchers from the fields of art and science to explore the intersection of environmental conditions and human activities, and question how a ‘hybrid ecology’ (Hybrid Matters 2015) of humans and non-humans can have transformational affect on both local and global scales. In this, Ståhl and Lindström draw simultaneously from participatory design practices and academic research into the formation of ‘plastiglomerates’ from plastic debris pollution, beach sediment, and lava fragments (Corcoran et al 2014); and the use of common mealworms to biodegrade polystyrene (Yang et al 2015) as a basis towards staging two strands of public engagement events across the Nordic countries. These sought to give form to and make visible environmental issues inherent in everyday life as a means of enhancing public awareness and interrogating society’s collective capabilities to respond creatively to these challenges.

Acknowledging, however, a notable lack of interventions focusing specifically on circular fashion and textile systems, the Circular Fashion Systems Conversation highlighted the potential for exploring ways that textile and or fashion designers might begin to replace the need for constant consumption by offering viable alternatives. It was evident that we must begin to view a product as something that will forever need completion, and the designer’s role as one of facilitation of this process as opposed to the finalisation of a product. Additionally, if we want to see changes in the consumption patterns of fashion or the attitudes among consumers we will have to design systems which includes them and takes their role in the lifecycle of clothing seriously.

We also require more examples of circular fashion systems in all scales, from the local and unique to the global and mass-produced. Fashion and textile designer will need to take a look sideways to the other design disciplines to re-invent itself with new forms of fashion service designs – and make these services really fashionable.

Insights and Reflections: six design emerging principles for crafting conversations around the circular economy

In the following section, we draw together insights and reflections from surrounding design-based literature in parallel with the conversational approach taken in the case study. With reference to Figure 2, we discuss how these contribute to our identification of six emerging design principles that we believe have the potential to support design researchers in crafting productive conversations around the circular economy.

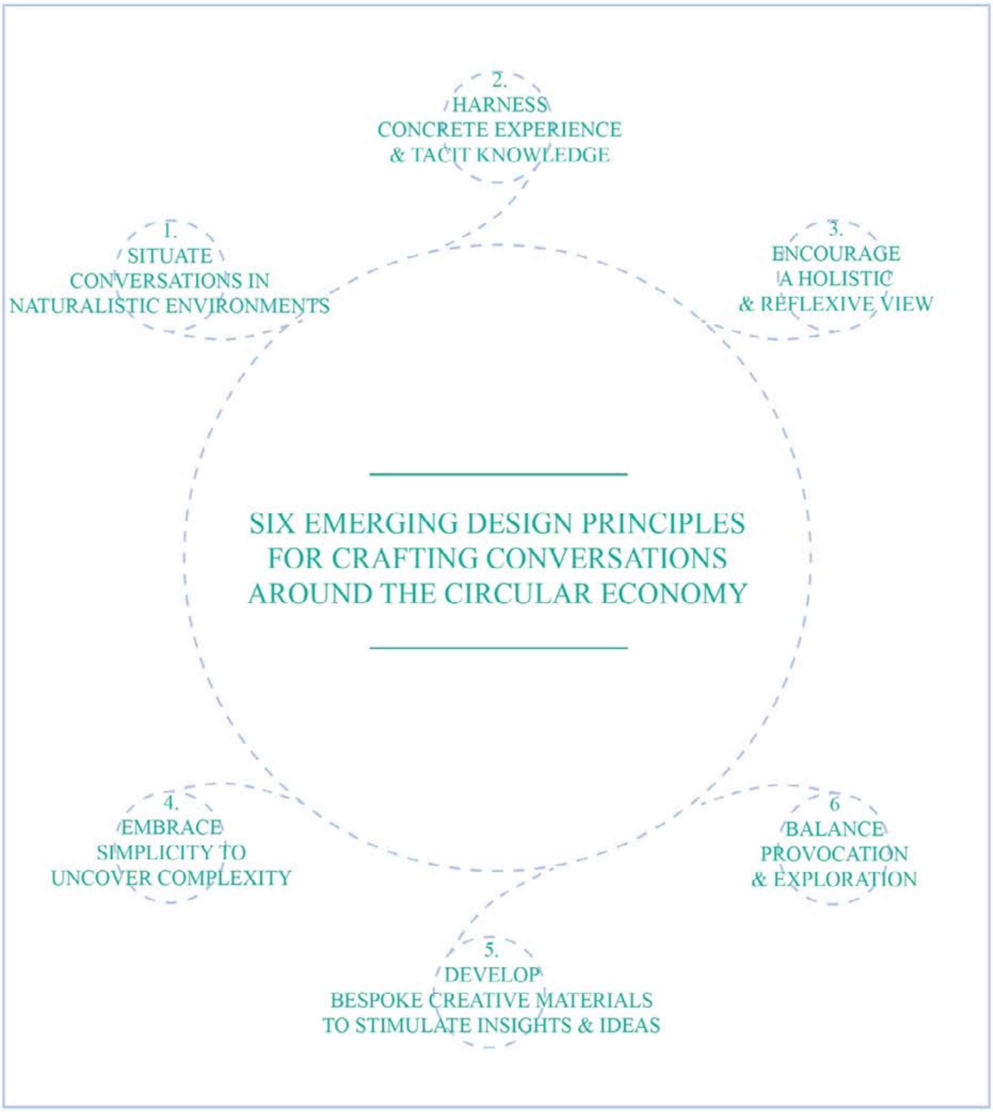


Figure 2: Six Emerging Design Principles for Crafting Conversations around the Circular Economy

Principle 1. Situate Conversations in Naturalistic Environments

We propose that the experiential qualities of the natural environment offer an immersive setting for participatory activities and can situate conversations within the context that they seek to address.

In Ståhl and Lindström's work, members of the public were invited to take part in a series of walks in search of plastiglomerates. Participant groups were provided with the space to consider how such artefacts are created by both natural and technical forces; the potential impacts they afford; and how they could be utilized in different ways in the future, thus connecting the often distant, abstract qualities of marine pollution to the familiarity of an everyday walk on the beach.

Whilst the Circular Fashion System Conversation took place in a relatively conventional workshop setting, there is a vibrant and rich range of natural environments that could be used to situate conversations around the noble fibers in the Scottish textile sector from; crofts, weaving and knitwear mills.

Principle 2. Harness Concrete Experience and Tacit Knowledge

In supporting participants to share their experiences and collectively consider ways to address complex societal challenges, design researchers must develop approaches to harness concrete experience and tacit knowledge.

Through a series of workshops, Ståhl and Lindström framed global environmental issues within participants' domestic settings by equipping them with prototype composter devices comprising a mealworm colony and a piece of polystyrene inside a large glass jar. Through tending to the prototypes for two week periods and observing the mealworms' visible impact on the material, participants gained an insight into the extent to which nature can intervene into humankind's self-made challenges, as well as raising questions around the sustainability of radical new composting strategies on a larger scale.

Similarly, the Circular Fashion System Conversation was deeply enhanced through the rich plethora of skills and material literacy embodied within the textile designers in the group. Their knowledge mediated the exchange of insights and assets, and others helped to identify solutions to make suggestions for foraging new connections and identifying potential new solutions.

Principle 3. Encourage a Holistic and Reflexive View

By bringing together a diverse range of people and developing bespoke methods and approaches to spark dialogue, the focus of circular conversations should focus on both the intricacies of the challenge at hand, and their implications on a systemic, global scale.

Appropriating stones, litter, driftwood as well as plastiglomerates themselves, Ståhl and Lindström made use of found objects as props to prompt and punctuate conversations and provide material touch-points around which participants considered issues of human intention, society's collective capabilities to respond and adjust our behaviours, and how we define the waste materials that can be used as resources (Ståhl and Lindström 2015b).

Applying their collective knowledge and experiences of operating across the supply chain, the participants in the Circular Fashion System Conversation physically constructed a closed loop process and as they discussed its implications. This provided them with a broad view of the wider fashion system. We propose that such a holistic perspective can enhance how participants position themselves within the system as both part of the problem, and part of the solution; and underpin their abilities to reflexively negotiate their role within the system and their capacity to take action.

Principle 4. Balance Provocation and Exploration

Design approaches are flexible and malleable, and can be tailored to correspond to open and exploratory activities, as well as to accompany targeted forms of questioning.

Indicative of how provocative approaches can prompt an emotional response, Ståhl and Lindström noted that participants often experienced a tension over whether to treat the mealworms as 'pests or pets' [Personal Communication 2016], and that using the composter as a form of design tool itself foregrounded considerations of social responsibility and power relations.

Within the Circular Fashion System Conversation a linear supply chain was 'hacked' to encourage closed loop innovation. From this point it became apparent that the designer does not have as much influence as one would imagine. In some instances, 1,000 pairs of hands touch a piece of clothing before it reaches a consumer (Lee 2008).

Principle 5. Develop Bespoke Creative Materials to Stimulate Insights and Ideas

As a means of enacting the future, rich conversations can be mediated through evoking the hands-on, generative nature of participatory design approaches (Brandt et al 2013).

Whilst the physical craft materials used in the Circular Fashion System Conversation provided participants with stimuli to talk through a closed loop innovation, applying the hacking metaphor to subvert a linear supply chain using lo-fi craft materials that could easily be re-configured as conversation emerged. In this sense, design researchers have a role to play in developing materials, methods, tools, and approaches in response to the local objectives underpinning their specific project and the aims governing the wider research.

Principle 6. Embrace Simplicity to Uncover Complexity

We recommend that methods and approaches for crafting conversations around the circular economy consider the premises of Eriksen's participatory design tools as basic materials and pre-designed images and artefacts (2009).

Lucero et al. observe that a diverse array of materials with varying levels of simplicity, specificity, and provocation gave way to 'a relaxed atmosphere since participants are not forced into activities they are not comfortable with", and stimulated "a structured but flexible way in order to spark dialogue between the co-design participants and thus support idea generation' (2012: 19–20). Such observations reinforce the use of the prototype composter as a material manifestation of a hybrid ecology – 'a thought vehicle which enables us to expand our concept of the environment, to re-evaluate our idea of an external nature and to rethink our relationship to the world.' (HYBRID MATTERs 2015).

The Circular Fashion System Conversation encouraged deep reflection on our individual and collective roles in addressing these grand challenges. Akin to ecology, systems design requires a complex understanding of a wider ecosystem and awareness of the embedded components. Conversational tools have the potential to unearth some of deeper issues and foster new insights.

Closing the Loop: implications for the textile sector

With a focus on methodological approaches, the six emerging design principles emphasise the need for creative and participatory methods and approaches to enhance cross-disciplinary, cross-sector awareness and understanding of the need to design for a circular economy. With 80% of a product's impact determined at the design phase, there is a compelling case to explore the role that designers can play (RSA Great Recovery 2014). Design for sustainability theorists (Manzini and Vezzoli 2008) believe it is more efficient to work with preventative solutions rather than adopt systems that deal with damage control. Designers are learning that co-creation and co-design, rather than individual authorship, is becoming a more effective way to understand and meet social needs and new tools and platforms are becoming more effective than finished artefacts (Thackara 2013). This is part of a shift towards transmaterialisation, where service design concepts are evolving in parallel to product design development to construct to scenarios of use, reuse, design and redesign. To work this way, designers need to acquire new skills, knowledge and experience to enable them to act as social innovators and become agents of change. Instead of designing from the constrained perspective of the client's brief, designers now accommodate the complexities of designing for society and embrace new collaborative ways of working, as designers Chick and Micklethwaite summarise:

> A design outcome may not always be a physical, tangible product. It may be a service or a new way of doing things. In some cases, we may not need a new product, just a better way of integrating the products we already have in order to serve our needs. Design is also too important, and too useful, to be used only by professional designers. The active participation of users in the design process can ensure more successful design outcomes. The emergence of open-source design is creating a collaborative remix culture in which the originator of an idea passes it on to others to take in new directions. (Chick and Micklethwaite 2011: 35)

In spite of such shifts within the broader discipline of design, there is limited literature relating to the role of the specifics of ethics within the fashion or textile industry from a designers' perspective; acknowledging their responsibility within the supply chain and the lifecycle of a garment. Traditionally fashion designers do not write, or theorise; they cut and make (Thomas 2001: 4). Desires to rationalise design can be seen to overshadow the practitioner's skill and agency, and as Dorst substantiates, the discipline's preoccupation with understanding processes and methods disregards the individual designer's ability to negotiate complexity in diverse social, cultural, and environmental settings (2008: 5, 8). Whilst interrogating the modus operandi of the fashion industry, there could also be an interrogation of sustainability and the circular economy, and what it could mean if universally adopted by design practitioners, and by the fashion/textile industry in general.

Conclusions

The reviewed literature has highlighted that currently, there are limited practical examples of circular innovation within the textile sector, and designers will require support moving forward. Practically, designers have the potential to unlock hidden potential within supply chains and materials. The research presented within this paper highlights the importance of acknowledging that the circular economy goes beyond the capabilities of specific design disciplines and is it a joint responsibility that cannot be undertaken in isolation. This will require the input of material scientists, business experts, waste managers and policy makers alongside other stakeholders and those undertaking roles that have not yet been identified.

We have conceptualised the Six Emerging Design Principles in response to our engagement with diverse resources and initiatives across design research and practice, and are grounded in our experience of undertaking designing and delivering The Circular Fashion System Conversation to support discussion that transcends traditional paradigms. Whilst emerging and broadly applicable to a broad range of design-led contexts and inquiries, the principles provide a framework to mediate the facilitation of crafting circular conversations to continue to discuss how we might expand upon the role, skills and capabilities of the textile designer in the future to equip them to operate within a circular economy. Future research will seek to apply, evaluate, and iterate the principles through further participatory activities, and explore their flexibility and transferability when developed by other design researchers situated in similar contexts of inquiry.

References

Andrews, D. (2015) 'The circular economy, design thinking and education for sustainability'. Local Economy, 30:3, pp305–315. Sage Publication.

Ballie, J. (2014) 'e-Co-Textile Design: How can textile design and making be combined with social media to promote sustainable fast fashion futures?'. PhD diss. London: University of the Arts London.

Bakker, C, A., R. Wever, C. Teoh, S. Clercq. (2010) 'Designing cradle-to-cradle products: a reality check'. International Journal of Sustainable Engineering, 3:1. pp2–8.

Black, S. and H. Alexander (2012) 'The Sustainable Fashion Handbook', London: Thames and Hudson.

Brandt, E., T. Binder and E.B.N. Sanders (2013) 'Ways to Engage, Telling, Making and Enacting'. International Handbook of Participatory Design, Oxford: Routledge, 145–181.

Braungart, M., W. Mcdonough, A. Bollinger (2007) 'Cradle-to-cradle design: creating healthy emissions–a strategy for eco-effective product and system design'. Journal of cleaner production, 15:13. pp1337–1348.

Chapman, J. (2005) 'Emotionally durable design: objects, experiences and empathy'. London: Earthscan.

Chick, A. and P. Micklethwaite (2011) 'Design for Sustainable Change: How design and designers can drive the sustainability agenda'. Worthing: AVA Academic.

Concoran, P.L., C.J. Moore, and K. Jazvac (2014) 'An anthropogenic marker horizon in the future rock record'. GSA Today, 24.6. pp4–8.

Cho, S. and J.H. Lee (2015) 'Development of Zero Waste Fashion Design Process Guideline from an Educational Perspective'. Journal of the Korean Society of Costume, 65:4. pp 91–108.

Decastro, O. (2014) 'Upcycling.' Keynote at Scottish Textile Symposium. Glasgow, Scotland, November.

Dorst, K. (2008) 'Design Research: a revolution-waiting-to-happen'. Design Studies, 29:3. pp4–11.

Earley, R. and K. Goldsworthy (2014) 'TED's Ten'. Keynote at Circular by Design Chiasma, Design in Action. Edinburgh, Scotland, March.

Earley, R. (2007) 'The new designers: working towards our eco fashion future'. In Dressing Rooms: Current Perspectives on Fashion and Textiles Conference, Oslo, Norway. 14–16.

Eriksen, A. (2009) 'Engaging design materials, formats and framings in specific, situated codesigning – A Micro-material perspective'. Proceedings of 2009 Nordes conference, Engaging Artifacts, Oslo, Norway. 1–10.

Fletcher, K., L. Grose, P. Hawken (2010) 'Fashion & sustainability: Design for change'. London: Laurence King.

Fletcher, K. (2011) 'Sustainable fashion and textiles: design journeys'. London: Routledge.

Goldsworthy, K. (2012) ‘Laser-finishing: a new process for designing recyclability in synthetic textiles’. PhD diss. London: University of the Arts London.

Goldsworthy, K. (2014) ‘Design for Cyclability: pro-active approaches for maximising material recovery’, Making Futures, 3.

Gwilt, A. and T. Rissanen. (2011) ‘Shaping Sustainable Fashion: changing the way we make and use clothes’. London: Routledge.

HYBRID MATTERS (2015) ‘HYBRID MATTERs – about’, HYBRID MATTERS, Accessed July 29. http://hybridmatters.net/pages/about

Kent, A. (2016). http://aimeekent.com accessed July 27th

Lucero, A., K. Vaajakallio, P. Dalsgaard (2012) ‘The dialogue-labs method: process, space and materials as structuring elements to spark dialogue in co-design events’. CoDesign, 8:1. pp1–23.

Manzini, E (2005) Network, Localismo cosmopolitan. Prospective per uno sviluppo locale sostenibile ed ipotesi sul ruolo del design, Milano: Agenzia SDI. D.E.S.I.S. and London, UAL.

Vezzoli, C.A. and Manzini, E. (2011) ‘Design for environmental sustainability’. Springer Science & Business Media.

Mckinsey (2015) ‘Growth within: A circular economy vision for a competitive Europe’ https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

Payne, A. (2011) ‘The life-cycle of the fashion garment and the role of Australian mass market designers’. The International Journal of Environmental, Cultural, Economic and Social Sustainability. 7(3), pp.237-246.

RSA and The Great Recovery. (2014). Accessed May 12. http://www.greatrecovery.org.uk

Sanders, E.B.N. and P.J. Stappers (2008) ‘Co-creation and the new landscapes of design’. CoDesign, 4:1. pp.5–18.

Scottish Enterprise (2013) ‘Scottish Textiles Skills Survey’. January. Accessed July 28th. http://www.stla.uk.com/wp-content/uploads/2013/09/Scottish-Textiles-Skills-Survey-Report.pdf

Shayler, M. and Maslin, R. (2015) ‘Service Design for a Circular Economy’. The RSA Great Recovery. January 19th. Accessed May 12.
http://www.greatrecovery.org.uk/service-design-for-a-circular-economy/

Simonella, A. (2016) ‘Allenomis’ http://www.allenomis.com accessed 27.07.16

Ståhl, A. and K. Lindström. (2015a) ‘About Invitations’ HYBRID MATTERs, Accessed 29.7. http://invitations.hybridmatters.net/pages/about-invitations

Ståhl, A. and K. Lindström (2015b) ‘Plastiglomerate Walk Replot’. HYBRID MATTERs. Accessed July 29. http://invitations.hybridmatters.net/events/plastiglomerate-walk-replot

Steen, M. (2011) ‘Tensions in human-centred design’. CoDesign 7:1. pp45–60.

Taylor, N. (2016) ‘The Top Project’, http://thetopproject.com accessed 27.7.16

Taylor, J. and K. Townsend (2014) 'Reprogramming the hand: Bridging the craft skills gap in 3d/digital fashion knitwear design'. Craft Research, 5:2. pp.155–174.

Tham, M, and T. Jones (2008) 'Metadesign tools. Designing the seeds for a shared process of change'. Changing the Change Conference. An international conference on the role and potential of design research in the transition towards sustainability. Torino, Italy. July 10-12.

Thomas, S. (2015) 'Hacking the Circular Economy.' The RSA Great Recovery Blog, April 2nd, 2015. Accessed May 12. https://www.thersa.org/discover/publications-and-articles/rsa-blogs/2015/04/hacking-the-circular-economy/

Thakara, J. (2014) 'A Whole New Cloth: Politics and the Fashion system.' Routledge Handbook of Sustainability and Fashion. London: Routledge, pp.43–46.

Van Balgooi, F. (2015) 'Master class one: Design for Dissassembly'. Zero Waste Scotland Public Lecture. University of Dundee. 2nd December

Yang, Y., J. Yang, W.M. WU, J. Zhao, Y. Song, L., Gao. (2015) 'Polystyrene by Plastic-Eating Mealworms: Part 1'. Chemical and Physical Characterization and Isotopic Tests. Environmental science & technology, 49:20. pp.12080–12086.

CENTRE for CIRCULAR DESIGN

CIRCULAR
TRANSITIONS

23 – 24 November 2016

Circular Speeds: towards a new understanding of designing for fashion textile rhythms

Kay Politowicz, Kate Goldsworthy, Rebecca Earley
(University of the Arts London, UK)

Abstract

During the first phase of the Mistra Future Fashion project researchers, from the University of the Arts London, identified a gap in knowledge. Although 'lifecycle thinking' had become a widely adopted and tested approach in academic and industry contexts, the dimension of 'time' or 'speed' was not fully resolved as a factor within existing guidelines for design. Thus 'circular speed' became the focus of the research as it moved into the second four-year phase of the project (2015–2019). This paper represents the results of an academic review of the literature conducted during 2015–2016 in order to better understand the challenges this may bring to design and to prepare for an action research phase, including workshops held with participants in the UK, Sweden and USA, as well as the development of design research prototypes.

Introduction

Design and production has changed to meet the need for speed, growing populations and the cultivated fast fashion appetite. Conversely, the idea of designing durable and long-lasting fashion textiles has been a part of the fashion industry from the outset – long before product obsolescence had been dreamt up in the 1950's, yet the idea of slow fashion has been promoted in recent years as a new counter approach to fast fashion.

In this paper the authors propose another way of viewing the speed of fashion products by building on the ground-breaking work of Fletcher & Tham around rhythms (2004), drawing insights from their practice-based work during Mistra Future Fashion phase one (2011-2015).

Carl Honoré's 'In Praise of Slow' (2004) proposed that we seek balance - the right speed – and that we question the notion that faster is always better. Rather than pursue this polarised approach to viewing 'speed of use', the authors here argue that a more nuanced method of analysing speed is needed which acknowledges the entire lifecycle of a product. We should in fact be considering the right speed for each garment within specific lifecycle stages. We need tools to help designers with this.

In this paper the authors set the scene for Mistra Future Fashion phase two research. The intention is to develop the discourse on from simply fast and slow, to a level where multiple and proportionate speeds can be both understood, tested via LCA and ultimately engineered, to improve the circular efficiency of a product. The idea presented here is that we consider both long-life (slow) and short-life (fast) as models for clothing to suit a broad range of user contexts - different needs, tastes, incomes and styles.

The results from this research will feed into the ongoing research programme, which will publish design guidelines for the circular fashion industry in 2018.

Fashion & Circularity

The concept of 'fashion and circularity' has come into prominence as a result of the sustainability discourse and its critical relationship to fashion. Historically, the study of fashion did little to identify the economic, social and environmental implications of production, as outlined by Barthes (1999). For the modern designer, theories from many disciplines provide insight into the current problems in the fashion system and point towards directions for strategic reform. Without a comprehensive overview of factors contributing to their knowledge, designers obviously have difficulty in trying to identify a sustainable course of action within any specific context. It is essential that definitions of sustainability need to be continually revised for effective action, to achieve system based, long term, ethical design (Madge 1997; Fry 2008; Tonkinwise 2015).

The 20th century was characterised by an expanding materials economy for the most industrialised societies. Governments have been enthusiastic in their support of scientific research and technical production, while the resulting physical impacts on the environment have been slower to be acknowledged. Kuchler & Drazin (2015) assert that, although the environmental damage associated with production is now universally recognised, the potential social consequences of new materials, especially composites, are less discussed and therefore not fully understood. In the C21st climate of uncertainty, designers are trying to develop sustainability strategies in 'best design practice' for diverse global manufacture, where the nature of the material itself and its characteristics are key to design development. In materials science, the selection of a material for manufacture from its performance in tests, is less concerned with the selection of the 'right' material than an avoidance of the 'wrong' material (Ashby & Johnson 2009).

Integral to the development of good design practices are the current ideas from relevant disciplines: anthropology, business studies, materials science, behavioural economics, design studies, histories of dress and theories of sustainability. This multi-disciplinary integration is at the very heart of the Mistra Future Fashion project. Systemic solutions, the goal of the project, cannot be nurtured and developed in academic silos and so research is being developed in four discipline-crossing themes in order to promote a truly collaborative process.

The Role of Design

A creative and collaborative methodology

In 1986, Appadurai described the social role of artists as critical as 'they are thinking about new ways to arrange things'. He commends their ability to imagine new possibilities and form alliances with other disciplines, which can have practical applications. To benefit social progress, the imagination of artists and designers needs to be connected to innovation in science and technology. In an interview, Tonkinwise (2015) pointed out that the job of design is not confined to "the creation of artifacts, whether communications, products, or environments. But the practice of design is actually about persuading a wide range of actors – fellow designers, suppliers, investors, logistics managers, users in households, workplaces or public spaces, etc. – to work together on materializing a future in which such an artifact exists."

Design can play a pivotal role in improving performance at every stage of the socio-material lifecycle. By working in communities of practice designers can identify both the physical and psychological barriers to more sustainable solutions, translating them into creative proposals for transformation.

The overwhelming complexity and lack of transparency of environmental problems can be discouraging. But designers have an ability to apply systems thinking, in a creative method that Ackoff (2006) terms 'problem dissolving', which shifts the problem into a new context. Designers can then construct new approaches based on reflection, logic and the generation of creative, speculative ideas. To do this, the poetic and lateral-thinking outcomes of the design process are best achieved in collaborative communities of practice. In order to be influential to innovation on a large scale, design outcomes need to be pre-emptive rather than reactive and locate physical products as part of material and immaterial systems.

In Mistra Future Fashion we are seeking to relate these material (in the broadest sense) choices appropriately to a specific lifecycle context. All garment journeys are not the same and all users are not uniform in their behavior and wardrobe curation. Each fashion consumer will have a complex and varied collection of garments in their care and this variety and complexity is difficult to pin down.

Circular Design through the Prototype

Designers are intrinsically connected to materials in proposing their transformation into objects, which have both meaning and practical application. However, a 21st century understanding of the expenditure of energy, water and valuable material commodities to make artefacts, is also leading us to seek 'immaterial' extensions of objects in use, as propositions to lighten the material load. A way forward for the fashion designer is to study the preferences and behaviour of a particular social group. Understanding their aspirations and the triggers to purchases can enable designers to propose desirable models for an improved fashion system. To achieve sustainability and circularity through design, an understanding of impacts through all stages of the life-cycle must be understood in order to tackle the reduction of damage resulting from existing practices. A product can be redesigned to improve its overall performance, by understanding its context in this lifecycle system. 'Re-directive practice' results in what Fry describes as design 're-coding': 'the exposure of the unsustainable and the declaration of means of sustainment' (2009). When this is embodied in a prototype, the reflective 'conversation' takes place in a series of project revisions. As a result of surprise realisations or 'backtalk' from the prototype, the designer can test, redesign and collaborate with other disciplines and ultimately, with the consumer, who can become part of the prototype community (Winograd 1996).

In the proposed project we are using the prototype alongside multi-disciplinary collaboration in order to question and find insight on these circular models. First to expose the unsustainable elements in order to then design them out of the system.

But how can designers know that they are not simply sustaining the unsustainable, in working towards reduced impacts? Perhaps they cannot. Popper summarized the dilemma: "It is important that we realise just how little we know about these unforeseeable consequences of our actions. The best means available to us is still trial and error: trials that are often dangerous and even more dangerous errors…. What remains is the problem of selecting among our tentative solutions, 'our guesses' according to a method that is open to us." (1984:4-28). Designers can only integrate the components they believe are necessary for sustainability, while making key trade-offs in search of better design solutions. The 're-direction' of generic design observed in all individual and social activity, is best complemented and reinforced by a systems approach in 'transition design' (Irwin, Tonkinwise and Kossoff 2015).

However, as design researchers, we are mitigating this uncertainty through developing relationships between the hard and soft elements of the research. By working closely with both science and industry partners on the project we aim to reveal deeper insight and map metrics into the design process (Goldsworthy, 2016; Earley, 2016). Further work with stakeholder groups and a programme of designers-in residence (both with science and industry partners) will expand and evolve the understanding of issues.

Multiple Fashion Speeds

In Textile Toolbox (2014) we explored design for circularity in ten prototype concepts and in the analysis of the concepts a striking polarity in approaches to product longevity (or speeds) became apparent. In the current research we are seeking to dissolve these seemingly opposite approaches and find a more related and systemic framework.

Technological change, accelerated in the 20th century, has resulted in a new acceptance of speed in society and economics. Anne Thorpe (2010) suggested that sustainability does not have any place in a modern world if it is dominated by fast thinking, as it does not allow for a variety of approaches. But designers have a particular range of skills that enables to work with fast or slow knowledge, which can serve as a bridge between the two. To arrive at a position equivalent to ecosystem resilience in the design of materials, the speed of lifecycles is critical. In nature, 'small and fast' lifecycles developed in combination with 'large and slow,' to arrive at a suitable ecosystem for survival. The combination of different natural speeds related to durability enables the entire system to continue. Brand (1999) proposes that we should adopt this approach in the imaginative design of systems.

The contradictory elements inherent in our relationship to materials, fashion and consumption suggest that a variety of approaches to speeds is critical to sustainability. Design to embrace wide variety of speeds of use is currently the only reasonable ecology. A range of approaches aiming to achieve a smaller material footprint in specific contexts, form a continuous 'sliding scale'. They range from long-life strategies: mendable, transformable, adaptable garments; to short-life proposals: disposable, compostable, recoverable and re-manufacture-able features. Services are proposed, to replace or support all points on the dial for speeds of use in a plurality of approaches, which can be connected and cross-disciplinary in concept and delivery.

The environmental problems associated with the industrial production of fashion are particularly suitable for reform through technology. The loss of energy that occurs in products as matter degrades, makes it crucial that designers investigate ways to disconnect production from consumption, creating the idea of a product through a service. If manufacturers are selling 'performance' rather than consumer durables, investment is required by brands to offer services, which extend their tangible products into intangible ones (van Hinte, 1997). The ability to rent or replace household products has greatly accelerated since 1997. Through Internet technologies, sharing and leasing services with a product thrown in, are increasingly viable.

However, when the statistics are for a physical 'product-based' economy are connected with an immaterial 'experience economy', Trentmann (2016) finds the environmental improvement 'inconveniently less clear'. In his study of consumption Trentmann questions whether digital solutions will automatically lead to greater sustainability, as currently the internet itself contributes 2 to 2.5 % of all greenhouse gas emissions and is rising fast. In design terms, solutions require the complex problem to be reduced to a series of imaginative components, requiring direct action. But when taken as a whole, solutions are rarely 'impact-free'. For example, when a society encourages lower consumption of goods, how are people's resources redirected?

Walker (2006; p.302) calls our attention to the need for product stability in our conception of past and future time. Solutions to issues of sustainability are really existential questions of meaning, as physical products will decay, but their meaning remains. How we think about time also affects how we think about the products in our lives. To tie physical products to a concept of time is to demonstrate technological, functional and aesthetic obsolescence in the context of today's shifting value systems. The shifting patterns of work and education, coupled with a technological landscape have taken certainty, locality and tradition and fused them with multi-culturalism, speed and change. It is easy to see why, in the current landscape, the present is even more fleeting and immaterial than before, whereas the future is constant and infinite. So, designers need to manage the appropriation and adaptation of goods in their forward trajectory, within the multi-connected world of consumers.

Designers are uniquely placed to be a catalyst for change, rethinking and remaking the products, services and systems that shape communities, by addressing the social issues that affect the quality of daily life. An approach to designing sustainable products has been further encouraged by the need for modern households to do something with the mounting collections of objects they own. Sentimental attachments to products, a thriving market for vintage models and a 'siege mentality' in the context of constant change, is said to be responsible for many people choosing to store their stuff and not the least contents of their wardrobes. Real estate, marketed for storage, has become the fastest growing sector in the US property market, as there is a marked reluctance to relinquish personal ownership.

Amongst speculative designers, who can develop innovative products from an understanding of sustainable imperatives, some will make robust, scalable businesses models. Not just the designed object but also its relationship to a system and its speeds must be exploited to its advantage. According to research by U.K.-based organization WRAP (2015), extending the average life of clothes by just three months of active use per item leads to a 5 per cent to 10 per cent reduction in each of the carbon, water and waste footprints. Imaginative possibilities for extending the life of materials and garments in the existing fashion system include methods, which develop a range of services. A structure is needed that can include products with both fast and slow lifespans, to take their place in the ecology of a sustainable world. This proposes a future in which functionality and technological progress are fused with meaning and value.

Conclusion

The ideas and theories to reduce the damage connected to production use and disposal of fashion must be translated into garments with features, which allow them to serve the wide range of needs and purposes required. The changes in behaviour so often described in sustainable design need to have a supporting offer to accommodate them, to uncover meanings, to contextualise and communicate them. A mixed economy for fashion and textile design can then be developed that relies on a range of engagements with users. Local and decentralised production can be connected to highly technological solutions (Walker 2006). Certain clothes in our wardrobe can be the ‘quality’ agents we need to carry the bonds to permanence and connect to memories. They improve in value with age and are cherished. Others can be designed to be durable and connect with a system for revision, repair and renewal, where the whole or in part they could be replaced and redesigned. Others can function in a way that engages us in collective interaction, provides services and operates through temporary ownership to allow us ‘guardianship’ for a specific period. Still more can be the outcome of mass production for a positive form of ‘planned obsolescence’, where the material is recovered for re-manufacture, after a short time in use, because the purpose of the artefact has been served and the polluting effects of laundry outweigh the effects of production. The meaning of an object is timeless, whereas an individual garment might last only weeks before ‘recovery’.

These themes will be tested during 2017-2018 through a series of industry workshops, scientific collaborations and design-research prototypes which will ultimately lead to a set of ‘guidelines for circular fashion design’ to be published in 2018.

References

Ackoff, R. (2006) *Idealised Design*. Financial Times Press

Appadurai, A. (1986) *The Social life of Things*. Cambridge, Cambridge University Press

Ashby, M. & Johnson, K. (2009) *Materials and Design: The Art and Science of Material Selection in Product Design*. London: Butterworth-Heinemann

Barthes, R. (1990) *The Fashion System*. London: Cape

Brand, S. (1985) *The Clock of the Long Now: Time and Responsibility*. New York: Basic Books.

Fry, T. (2008) *Sustainability, ethics and new practice*. Berg Publishers Ltd: Oxford. (p.190)

Fry, T. (2009) *Design Futuring: Sustainability, Ethics and New Practice*.

Popper,K. (1984) In Search of a Better World: Lectures & Essays. Routledge.

Irwin, T., Kossoff, G. and Tonkinwise, C. (2015) *Design Philosophy Papers,* Vol. 13, no. 1, 3–11 School of Design, Carnegie Mellon University, Pittsburgh, USA (available at http://dx.doi.org/10.1080/14487136.2015.1085688)

Kuchler, S. & Drazin, A. (eds). (2015) *The Social life of Materials: studies in materials and society*. Bloomsbury (p. 279 Materials the Story of Use)

Madge, P. (1997) *Ecological Design: A New Critique*. Design Issues, Vol. 13, No. 2, A Critical Condition: Design and Its Criticism (Summer, 1997), Published by: The MIT Press (pp. 44-54)

Thorpe, A. (2010), *Design's Role in Sustainable Consumption* Source: Design Issues, Vol. 26, No. 2 pp. 3-16 Published by: The MIT Press Stable (available at http://www.jstor.org/stable/20749938 Accessed: 20-06-2016 10:46) UTC

Tonkinwise, C. (2015) *Responses for "21st Century. Design After Design*", XXI Triennale di Milano (available at https://cmu.academia.edu/camerontonkinwise)

Trentmann, F. (2016) *The Empire of Things,* Allen Lane; Penguin Books, Random House, UK. (p.684)

van Hinte, E (Ed) (1997) *Eternally Yours: Visions on product Endurance, Matter Matters: A Spectre is Haunting Design*. Verbeek,P & Petran Kockelkoren. Pub:The Netherlands (Pp.100-115)

Walker, S. (2006) *Sustainable by Design: Explorations in theory and practice.* London: Earthscan Publications.

Winograd,T. Ed. (1996) *Bringing Design to Softwear. Reflective Conversation with Materials.* Donald Schon & John Bennett. Addison-Wesley. Stanford University Press.

WRAP (2015) *Valuing our Clothes; the true cost of how we design, use and dispose of clothing in the UK*, Published by WRAP UK, Available at http://www.wrap.org.uk/sites/files/wrap/VoC%20FINAL%20online%202012%2007%2011.pdf [Accessed: 20-06-2016 11.45]

CENTRE
for CIRCULAR
DESIGN