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# Teardown and Redesign: dis- and re-assembling textile blends in the circular economy

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**Abstract**

**Purpose**: exploring the potential of DfD to enhance recyclability in blended textiles

**Design/methodology/approach**: using the creation of blend models as a tool for understanding, followed by free-flowing textile sampling in a redesign process, a thorough understanding of material combinations is distilled into creative textile design practice and leads to experimenting with new ways of constructing textile blends so that they may still be disassembled for recycling at the end-of-life.

**Findings**: validation of the use of DfD within the material itself as conducive to ease of recycling but also in adding functionality or extending the use cycle of products facilitated through the retention of blends

**Research limitations/implications**: a certain level of abstraction has been maintained in the sampling which, while it allows for the samples to serve as models for other practices, also removes them from the reality of recycling systems and the resources that they can take in.

**Practical implications**: these models offer new ways of thinking about material combinations at the textile level and the design-focused perspective allows for the inclusion of these within a creative textile design practice which can be artisanal or industry-driven.

**Originality/value**: the paper presents the creative textile designer as a potential driver for sustainable innovation which rather than suggesting end-of-pipe fixes, proposes to design waste out of the system from the outset.

**Keywords**

Textile Design, Blends, Design for Disassembly, Circular Economy, Redesign, Recycling, Making

**Article Classification**

Research paper

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## Introduction

The 2018 Design Research Society conference was held under the theme 'Design as a Catalyst for Change', placing designers at the spearhead of much needed sustainable innovation. Indeed, a design-led approach to sustainability challenges provides opportunities for radical change in polluting industries, suggesting new products and systems that go beyond a localised fix and reassess the need that these fulfil in the first place. As early as 1960, the designer has been pointed at as enabling futures which require ever increasing consumption (Packard, 1960), this power now needs to be harnessed toward sustainable change in modes of production and consumption. Victor Papanek (1985) goes on to describe how the skills of designers are particularly appropriate in solving problems created by design itself.

Multiple initiatives have therefore suggested approaches which give designers the keys to understanding and addressing these issues. These recommend taking a systems-focused approach, opening-up the designer's perspective to the wider framework involved in any product (Thackara, 2006; Okala, 2014). In the highly polluting and resource wasteful textile industry, this systemic approach needs to be applied to all the phases of the life cycle to allow for materials to be regenerated in safe and efficient ways.

Considering the rising awareness regarding the damage caused to the environment by unsustainable practices in the fashion textiles industry, a general overhaul in production and consumption habits is needed. In the current take-make-waste model, as clothing production has doubled over the past fifteen years, reaching an excess of 100 billion units in 2015, only 0.1% of the materials going into textile production are recovered for regeneration or high value recycling after use, mainly ending up in landfill or incineration (Ellen MacArthur Foundation, 2017). Beyond the systemic barriers to textile collection and recycling, the intrinsic qualities of the materials make them very hard to recycle. Blends of resources that cannot be recycled together are the main barrier to a circular economy for textiles that this research aims to address.

Traci Bahmra describes the redesign process as consisting of two phases. The first one aims to an in-depth understanding of the issues that the original product represents in terms of environmental impacts and functionality in order to pinpoint where meaningful changes may be implemented. In the second phase, the most crucial elements are tinkered with to achieve an optimal review of the original product which provides an efficient balance between functionality and environmental benefits (Bahmra, 2013). Here, practice is used to reach an understanding of existing blends which is then applied to a redesign process for material combinations, experimenting with new textile construction techniques which allow for separation and effective recycling at the end of life.

This paper starts with a study of the context in which unrecyclable blends exist, looking at how they prevent effective recycling, the designer's role in their production and how alternative systems and models such as the circular economy and design for disassembly may provide useful leads. It then goes on to analysing the redesign process as a potential method for devising new approaches to blends which do not hinder recyclability. In the third section, free-flowing making and the samples that come from this approach are assessed as to their potential to present design for disassembly in textiles and to trace thought processes in the making. These are finally discussed against their potential for innovation in the circular economy.

## 1. Blends in the Circular Economy

### *1.1 Barriers to Textile Recycling*

It is generally accepted that textile blends are a hindrance to effective recovery and recycling of the resources they are made of. This is due to the reduced profitability of more complex recycling processes, as well as to the unsuitability of some types of blends for secondary markets (Cupit, 1996). Indeed, to achieve acceptable levels of quality for the input, this must first be separated, whether this is through manual sorting of colour or fibre types, or in a chemical dissolution process. While recycling technology is constantly improving, the solutions which allow for highest grades of value conservation thus mainly concern simple or mono-material textiles and garments. However, an overwhelming majority of our textiles are made from a combination of two or more resources that do not belong in the same recycling system (Wedin et al., 2017), preventing either from being recovered and regenerated. This study therefore looks at ways of re-evaluating the way in which blended materials are designed so that the materials that constitute them may be economically and environmentally sustainably recovered at the end of life.

In this study, blends are described as the combination of two or more different fibres in the same yarn or cloth (Hardingham, 1978). The emphasis is particularly placed on the notion that the various fibres combined cannot effectively be recycled in the same process without impacting the quality of the outputs.

There are many reasons for combining fibres, but these can roughly be grouped under the following headings (Hatch, 1993):

- To compensate for weak performance in one of the parts of the blend and improve the overall performance of the output
- To improve the efficiency of processing
- To reduce costs
- To improve or provide different aesthetics

Different material types and applications involve an immense variety of fibre combinations. These can range across various assembly techniques available in knit, weave, or other textile manipulations, adding another layer to the complexity of blends.

### *1.2 Blends and Creativity*

Beyond the output-focused approach to blends, this study also takes on the designer's perspective and argues for the making of a blend as a creative act. This research proposes that, as described by Arthur Koestler (1989), "*the creative act consists in combining previously unrelated structures so that you get more out of the emergent whole than you put in*". This '*bissociative'*, or combination, process as coined by Koestler, is indeed present in textile design creativity through the playful and creative combination and juxtaposition of materials, colours and textures.

As described by Hirshberg (1998) and further developed by Moxey and Studd (2000) regarding the creative process in textiles specifically, '*unprecedented thinking'* involves the connection between apparently disconnected or conflicting elements. Hirshberg goes on to describe the particular feeling experienced by the designer when ideas emerge in this process. This 'sense of lift' is one of the joys of designing and an essential component of this approach. This study therefore looks at ways of maintaining this degree of creativity without involving the permanent combination of incompatible materials. Existing approaches have used mono-materiality as a strategy for ease of recycling such as with Puma's collection of garments made either of 100% polyester or of biodegradable cotton (Puma, 2013). Furthermore, Kate Goldsworthy's research has shown how process innovation allows for extensive creativity in mono-material finishes with laser treatments on polyester. Exploring new approaches to blend recyclability, this research focuses primarily on material construction techniques to circumvent this limitation and maintain the benefits of material combinations while allowing for recyclability.

The approach to textile design used throughout this project uses the constraints of recyclability as a creative impulse. Indeed, it is when the conventional ways of designing materials seem closed off, due to the environmental damage that they cause, that problem solving approaches can be intermingled with aesthetic creativity to produce original outcomes. Dormer (1997) uses metaphors to dance or jazz to highlight how the presence of rules in a field, in his case weaving, can encourage innovation. Indeed, the rules of the circular economy embodied through the two separate cycles for resource reuse provides the frame within which core innovation may take place. Design for disassembly can therefore be used to combine high levels of creativity with compliance to recycling constraints. The positive constraints of designing for the circular economy are described by Tim Brown (Ellen MacArthur Foundation+IDEO, 2016) as providing a 'sense of meaning' in being able to design in a way that not only does not damage the environment but can be carried out perpetually in a regenerative way.

### *1.3 The designer's Responsibility in the Circular Economy Model*

The circular economy has been presented as a framework for decoupling economic growth from resource consumption and pollution. Its main requirements concern the diversion of waste from landfill or incineration and its perpetual reuse as a resource. Following the Cradle-to-Cradle model (McDonough and Braungart, 2002) this relies on the compliance with the specifications of two separate cycles: on the one hand the biological cycle which comprises of materials which can be safely composted at their end-of-use, and on the other, the technical cycle, in which materials that can be regenerated in industrial processes circulate. Any contamination of one cycle by the other leads to the impossibility of economically and environmentally sustainably recycling the resources. Designers must therefore take into account the nature of the materials they use and the type of recycling systems they belong to from the very first stages of the design process.

As described by Fuad-Luke (2009) it is one of the designer's characteristics to be comfortable with dealing with both 'things' and 'systems', this allows to incorporate end of life thinking from the very beginning of the design process to avoid any hindrance to recycling. This holistic view is key to developing sustainable design practices (RSA, 2016) and eventually eradicating the concept of waste to be left only with nutrients for the next lifecycle. With the notion that 80% of a product's environmental impact is defined at the design stage (Graedel and Allenby, 1995), the designer is given a significant responsibility in reshaping the industry. However, this is not limited to the mitigation of environmental harm, in this approach to design-led sustainable innovation, challenges can be seen as business opportunities, leading to innovation, opening up new markets, and enhanced competitiveness (Stahel, 2006).

### *1.4 Design for Disassembly*

To allow for multi-material creativity in textiles while not impeding the capacity for material recovery, the approach the project explores here is *Design for Disassembly* (DfD). DfD is defined as the creation of materials or products that can be easily and economically taken apart at the end of their useful life (Fletcher, 2008; Manzini; 2008; ISO, 2016) allowing for re-use in appropriate cycles. DfD has mainly been developed in product design as a response to Extended Producer Responsibility (EPR) regulation (Lindhqvist and Lidgren, 1990). As designers and manufacturers are required to think beyond the end-of-life of products, a systems-thinking approach to design involving DfD will become necessary (Ellen MacArthur Foundation, 2013).

This technical approach to DfD in products was mainly developed in Chiodo's work on active disassembly using smart materials (2012) and Ziout's approach to disassembly for sustainable product recovery (2014). Using shape memory, or other smart materials, this engineering approach to DfD follows EPR guidelines, allowing for efficient recovery of valuable technical components from complex objects. Active disassembly is offered as a model for cost-effective disassembly of technical products made of many different elements. This allows for sorting into same material categories and maximal value recovery at the end of the product’s life. This can be achieved using technologies such as biodegradable layers, thermally-reversible adhesives or shape memory materials. While this approach is different from the more intuitive and craft-design led position of this research, it provides many insights into DfD systems and inspiration for textile design practice.

Apart for two specific examples: the Climatex DuaCycle textile lock, and Interface’s EcoMeTex carpet system, DfD is practically non-existent at the textile level. There seems to be two main reasons for this. Firstly, textiles being embedded within products, the assessment of their life-cycle and recycling process are complex matters. The complexity of systems is seen as a barrier to recyclability in many fields (Murray, 2002), in the long supply chains of the textile industry, this is only exacerbated. The second barrier to the use of DfD in textiles could be related to the scale of the elements and the ways in which they are combined. While connections in electronic goods are often limited to a small number of points such as a series of screws, in textiles the connections between different elements are far more complex and sometimes not even visible to the naked eye. Vezzoli’s Design for incompatible materials disassembly list (2014), while providing important guidelines such as the need to prioritise the recovery of elements with higher economic value for example, also suggests a number of strategies, such as the use of snap-fit connections or of hexagonal headed screws, which do not apply to textile design. There is therefore a need to develop guidelines for the recovery of the materials which enter the composition of textile blends.

While the need to recover metals and rare minerals has become obvious, as reflected in policies such as the Waste Electrical and Electronic Equipment regulations (WEEE), similar frameworks are still needed to enhance the potential for recyclability of textiles. The components that come into the making of a textile blend all have their own levels of embedded energy and associated environmental impacts, and in the same way that we strive to keep metals in circulation, polyester and viscose should also be valued as resources. Intrinsic material lifespans need to be considered as part of the product’s or, in this case, of the blend’s lifespan (Earley and Goldsworthy, 2015). This research therefore aims at overcoming the barriers perceived for DfD in textiles, shifting techniques and scale to enable a shift from product design concepts to the field of textiles.

## 2. Teardown and Redesign

### *2.1 Teardown: Understanding Through Making*

As part of the H2020, European Union funded Trash-2-Cash project, a team of researchers analysed approximately one tonne of non-re-wearable textile waste to test the efficiency of near infrared spectroscopy (NIR) for sorting processes. This trial revealed the presence of 90 different materials, of which 14 were mono-materials and 76 consisted of different fibre blends (Wedin et al., 2017). Considering that this was only a small, non-representative sample which excluded multi-layered, unlabelled, or garments containing more than 3 fibre types, the complexity of blends cannot be overstated. A full quantitative assessment of the different types of textile blends at end-of-life has not been identified in this review, however, various reports signal that cotton, and cotton/polyester blends represent a large proportion of blends (Chang et al. 1999; Ward et al., 2013).

The high levels of complexity involved in blends are often seen as a barrier to the implementation of recyclability strategies, there is therefore a need to clarify the different parameters involved in problematic blends so as to point to opportunities for improvement. Bahmra (2013) describes different levels of sustainable design, ranging from an incremental approach through the improvement of products and services, to more radical strategies such as systems innovation. According to these descriptions, DfD classifies as a redesign approach. It involves the careful consideration of the product which is in need of changes to identify the sections of its lifecycle which have the most potential to reduce its environmental impact. In this project, existing blends have been studied through the lens of a creative textile designer’s perspective to pinpoint the ways in which DfD may provide benefits in terms of use as well as recyclability.

Few studies provide an overview of blend types as reviews often focus on a specific system or commercial application. Moreover, the information is often given from an engineering perspective, and removed from the experience of a textile designer which revolves around more aesthetic and tactile qualities. For this study, an exploration of the field was therefore carried out using making as a way of analysing textile blend constructions. Using colour coded elements: threads for fibres, cord for yarns and foam for fabric, enlarged representations of archetypal blends were made to chart the different ways in which resources are combined in textile blends in a way which is easily communicable to designers. The black and blue elements stand in for any type of materials which might be used together and help in showing at which level these occur within knitted, woven or laminated textiles. The making of these representations itself has been a crucial part of the understanding, allow for reflection in action (Schön, 1983) over the complexity of combinations.


Figure 1. Types of blend archetypes

These representations were subsequently used in a mapping process (Figure 2) to shed light on the different levels of complexity in textile construction and the number of steps separating them from the mono-material or recyclable components that need to be recovered for regeneration processes. This mapping work in a similar way to a family tree, tracing the different types of blends back to the original mono-materials which might have entered their composition. This return to the mono-material state in the mapping also reflects the aim of the DfD process in taking the components apart for recycling. The different levels represent stages in which the complexity of the blends increases, due to the combination of a blended element with another blended or mono-material element as part of the material, thus adding another stage before the return to mono-materiality.

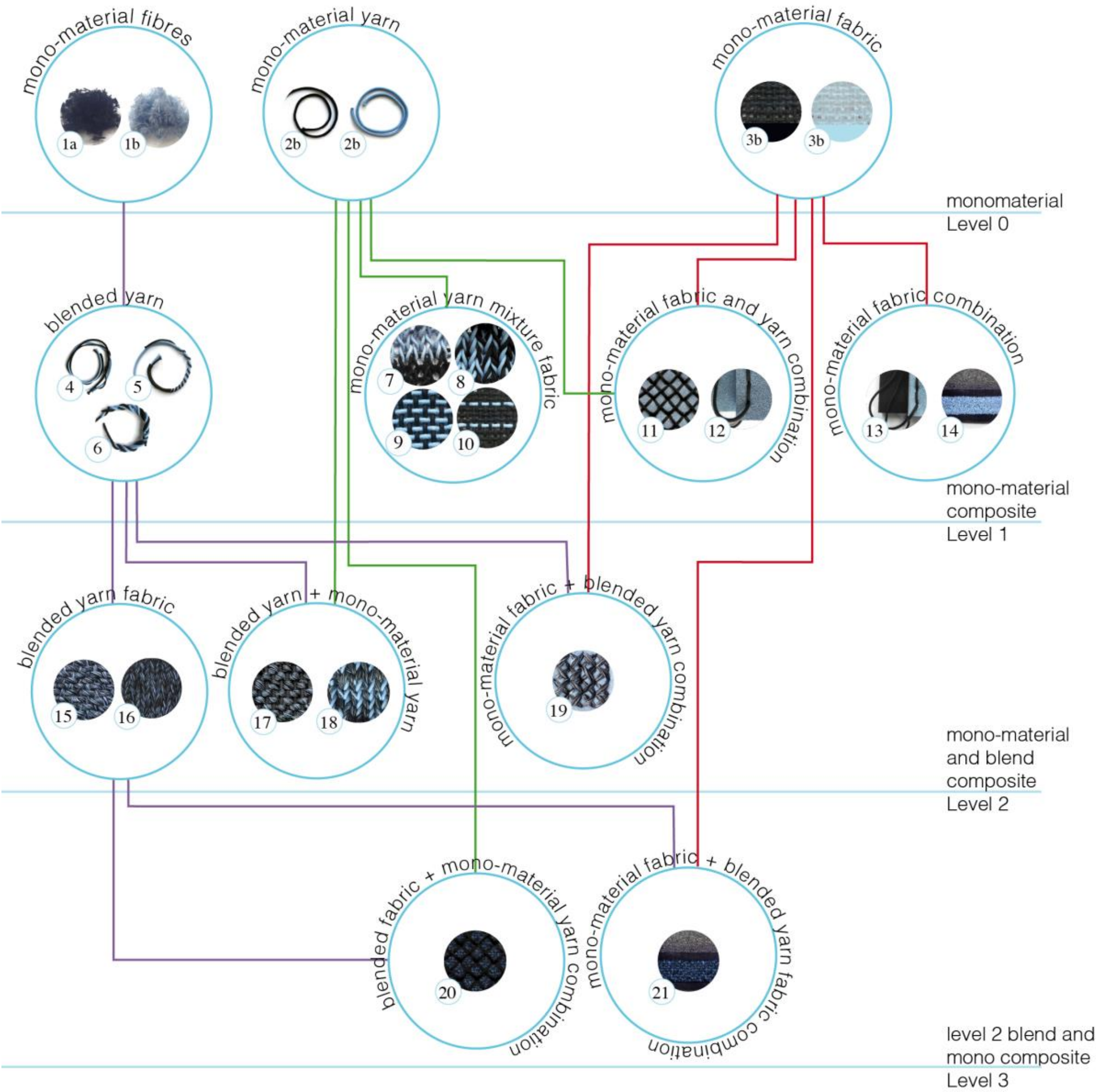


Figure 2. Mapping the levels of complexity in textile blends

The main insight from this process was to identify the specific type of blends that may be addressed in the redesign process within the limits of a creative textile designer's skills. Indeed, the first level of blends comprises of structures that bring materials together in ways in which the individual components are still recognisable at the scale at which a designer is used to experiencing materials. It is at this level that the creative 'bissociative' process is most relevant, in the combination of materials whose individual qualities are perceived as potential elements of an original effect in a blend. It is therefore at this level of combination that the subsequent sampling phase took place.

### *2.2 Proactive Approach*

Relating to Bahmra's listing of sustainable design strategies (2013), this research explores how designers may be able to provide new approaches to barriers in recycling by taking on a redesign process. Current solutions in development for improving the recovery and recycling of textiles are mainly technology driven, looking at ways of fixing the issues in the existing system, thus employing Bahmra's 'systems innovation' perspective. The very promising work in chemical recycling of blends pioneered by Worn Again, for example, shows a way in which existing non-recyclable blends may be decomposed into recyclable polymers before regeneration through a chemical process. While progress in this field will provide a solution for vast quantities of waste textiles, this research project attempts to look upstream of the creation of blends which prevent effective recycling. The work therefore takes a proactive approach which, rather than addressing the system, aims at designing products which fit in the existing recycling streams and potentially to design waste out of the system from the very first stages of the process. Textile design practice must therefore take on board the inherent recycling criteria for each material. Kate Goldsworthy's (2014) work with polyester is a striking example of how proactive lifecycle thinking can remove obstacles to the recovery and regeneration of resources at the outset of the design process. In the same way, materials that belong to the biological cycle or to other industrial processes must be treated in ways which consider these end-of-life options.

Material recyclability is however a complex domain, there are no comprehensive roadmaps for how to recycle different types of resources as this will depend highly on the local industrial context, available partners and their requirements. This approach to DfD in materials therefore retains an element of abstraction which may allow to project context specific parameters when applying the strategies. To develop the range of samples, a best-case scenario was imagined in which resources would be allowed to return to systems such as depolymerisation or composting at their end-of-life. In a real-world situation, however, the elements of the blends here represented by placeholder materials, would need to be identified and the paths to their optimal recycling stream should be mapped to allow for effective recovery and reuse or recycling.

### *2.3 Redesign: Exploring New Ways of Combining Textiles*

Following from the understanding of blends gained from hands-on experimentation with archetypal blend structures, a second phase of making was initiated to test the hypothesis of DfD in this redesign context. This practice-led research is driven by experimentation with textile construction in the studio, following a 'free-flowing' or 'playful' approach (Philpott, 2013; Marr & Hoyes, 2016). Series of samples were produced to test the applicability of DfD strategies at the textile construction scale. The sampling was carried out in parallel to the theoretical studies and used two main techniques: laser cutting and more broadly, textile manipulation on the one hand, and on the other, weaving on a semi-electronic dobby loom.

The constraints of recyclability are used as a creative challenge and a driver to innovation, emphasising the opportunities brought on by a circular economy brief over the limitations it may seem to entail. This phase of making was similar to a discovery phase as described in the design innovation double diamond, testing the array of opportunities offered by the brief. The indications for this phase of making were derived from the analysis of a series of interviews with experts in the field of textile recycling. This gave two broad directions in which to take the experimentation: the inclusion of elasticity, and the creation of layered materials.

In a redesign framework, this allows to explore the alternatives to the conventional approach which is being challenged. In this case, the take on this process does not merely suggest partial improvements on elements of the initial design, but considers the essence of material combinations and structures as the starting point for a new design. The tacit knowledge involved in skills regarding textile techniques here is essential as it allows a creative approach to the design of new structures which do not hinder the recovery of the recyclable components at the end of life. The brief is therefore the impulse for innovation in both the recyclability aspects and the aesthetic and functional characteristics of the material.

## 3. Sampling Hypotheses for Design for Disassembly in Textiles

### *3.1 Textile Design Practice*

As described by Csikszentmihalyi (1990), flow is a form of mind-set which can induce breakthroughs in multiple types of creative practices. It involves a balance between the level of skill of the practitioner and the challenge at hand that maintains a level of tension conducive to innovation. The practice here relies highly on tacit knowledge that is expressed in the application and combination of traditional textile techniques, the state of flow is therefore essential to allow for the expression and combination of these different types of knowledge. In textile designer Rachel Philpott's work, these conditions are exemplified through the 'washing line' method in which all samples are correlated to draw impulses for the next iterations (Philpott, 2013). In this way, the abstract space of the 'studio' combines the necessary conditions for flowing creative practice. This is mainly a place to visualise inspirational examples, pictures, or texts, the access to prototyping tools and surfaces to spread previous samples out for an overview of the work in progress.

Studio practice goes beyond the making of samples, it is also a way of thinking that is influenced by the practice and is specific to the designer. These sampling sessions embodied Schön's concept of action research as a 'conversation with the materials of the moment' (1983) in allowing to materialise imagined solutions for textiles for disassembly and thereby providing props for further reflection and evaluation of the potential of the DfD hypothesis. As described by Harrisson (1978) this form of creativity is inherent to the exploration of making: setting out without a specific idea of what the desired outcome is exactly and letting it materialise through various iterations. Rowe (1987) describes this approach as generate-and-test, a more controlled and self-aware approach to trial-and-error which builds on observations of each iteration and uses the tacit sense of adequacy described by Schön to gradually achieve an optimal outcome. Following these principles, innovative approaches to textile combinations may be achieved through a hands-on process which would not have been accessed through a more methodical approach as in technical problem-solving methods. The value of hands-on experimentation can be recognised in the exacerbated possibility of dealing with uncertainty which is itself an essential characteristic of design-led approaches when grappling with wicked problems. Using the specifics of this approach to making which is also defined as 'textile thinking' (Igoe, 2013), a series of samples were made to explore the ways in which DfD could be applied to materials themselves.

### *3.2 Sampling Textiles for Disassembly*

The laser cutting and textile manipulation was carried out in a community-led maker space, which allowed to span out the making sessions over several months, returning several times at weeks of interval to use the machines. These samples are the most directly related to the use of DfD in product design, transferring modularity concepts and assembly techniques from a furniture to a textile scale. Using the principles observed in various examples of modular design whether in architecture, product or fashion design, different types of combinations were tested as can be seen in Figures 3 and 4 where a form of dovetail assembly usually found in wooden products is adapted to the weight and scale of felt and canvas. In other samples, technical approaches such as hot-melt polyester welding are adapted to the craft-based prototyping techniques used here, as in Figure 5 with needle felting. Overall these trialled various ways of combining materials with contrasting characteristics such as thickness or stretch in ways which allow them to be pulled apart when needed for recycling or upgrading of the item. As in the case studies that inspired these techniques, the new structures prescribed by the DfD brief create original patterns and textures that can have use and aesthetic benefits beyond the ability of the material to be disassembled for recycling.

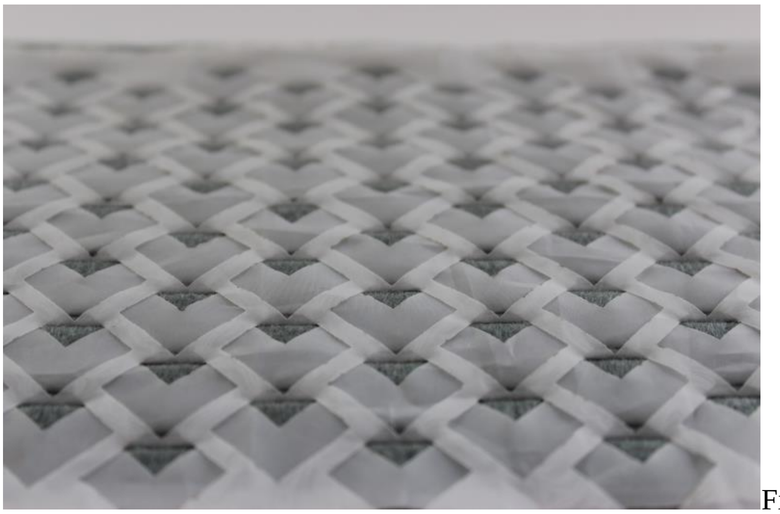
Figure 3. Dovetail assembly sample

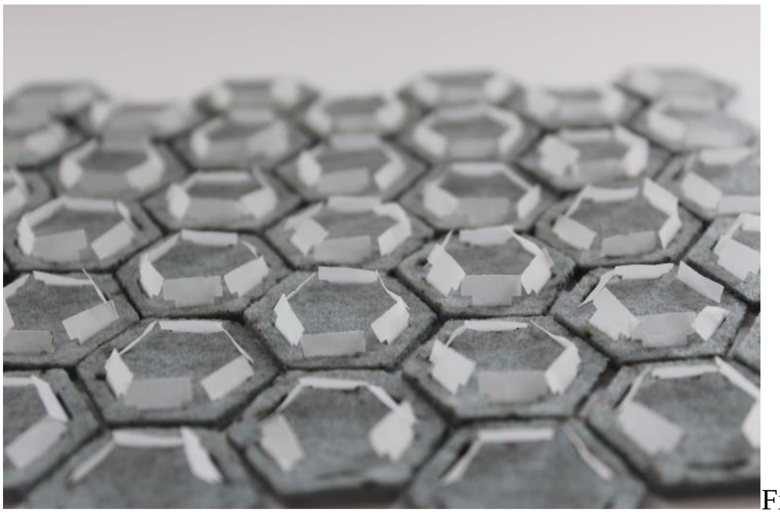
Figure 4. Hexagon modular sample

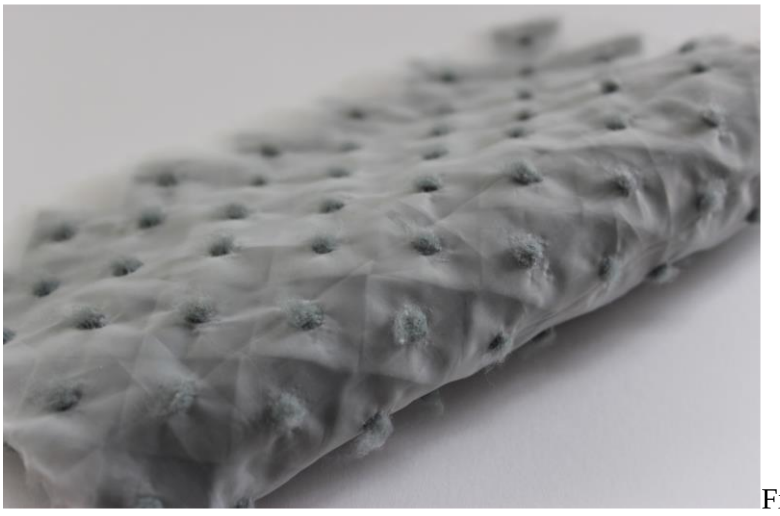
Figure 5. Felted tiles sample

The weaving was carried out in a condensed week-long access to a dobby loom at Chelsea College of Arts. This timeframe brought on a different way of planning and thinking through the making process. A plain set-up and warp was used to experiment with techniques in layering a base against a 'décor weft' which could provide structure or properties similar to those of coating or lamination to the material. Here the extra layer is either a protective or reinforcing element, or it provides elasticity without intimately blending the non-recyclable stretch element with the main body of the material. Experimenting with weaving allowed to test the DfD principles at the smaller scale of yarns as opposed to fabric elements in the felting and laser cutting. This leads to a series of samples which can be more easily projected into a fashion context whereas the sculptural aspect of the previous, laser-cut or felted samples displayed the DfD concepts in a more dramatic way.


Figure 6. Woven layered sample


Figure 7. Woven elasticity sample

Across the different techniques, these samples all use place-holder materials which in themselves do not have any particular recyclability characteristics but are instead used as codes in the same way as with the enlarged blend archetype models. This lays the ground for the application of these strategies in different product types. Indeed, the level of abstraction maintained throughout the experimentation keeps options open for fashion as much as for interior uses. The samples highlight how a textile design approach which is led by a haptic bissociative creative process can generate new ways of combining materials which not only provide clear paths to recycling, but also build in new aesthetic or functional characteristics for the material.

### *3.3 Tracing Thinking Processes Through Samples*

As well as formulating hypotheses, the samples are a way of keeping track of the thought process involved in the making. Indeed, techniques and concepts can be traced back chronologically through the various iterations, showing how the use of the DfD brief influences the design process and highlights the way in which design processes more broadly can be influenced in following such strategies. The constraint of only combining elements of the textiles in ways that allow them to be taken apart has guided the creative process and forced the making into unexplored paths. Textiles are a particularly rich field in this regard as the discipline already relies on a variety of technical constraints linked to the tools or the materials used (Dormer, 1997; Sutton and Sheehan, 1989).

In several instances whether in the laser-cut or the woven samples, the evolution of the techniques can be traced from the initial inspiration found in case studies, through several iterations to adapt the form and scale of the components to the materiality of textiles, experimenting with different types of combinations until the idea runs out of breath or a level of satisfaction or of frustration in the results is achieved that allows to move on to a new concept.

In this first stage of prototyping, there is no set industry brief to define the criteria for the textiles, instead their qualities are entirely defined by the DfD function. This means that the DfD concepts drive the creative process and dictate the aesthetics as well as the structural or functional aspects of the textile. The samples that are produced in this way are raw ideas, prototypes that are ready to be used as the starting point for applied sampling.

## 4. Collateral Innovation

### *4.1 Innovating at the Material Level*

Rather than suggesting new construction methods for garments, this work proposes new ways of thinking about textile structures that can be applied to different types of design practice. Indeed, DfD strategies have already been applied in textile products to disrupt production and consumption habits, such as in the Post-Couture Collective collections (http://www.postcouture.cc/), or to allow for end-of-life recycling as with the Resortecs project (https://resortecs.com/). This project suggests innovation by taking this approach deeper into the material itself and fundamentally challenging the use of default or traditional material combinations.

As described in setting the context for this work, the emphasis here is on the appropriate use of resources to avoid contamination which hinders recyclability. However, implementing DfD strategies in a redesign process may have potential for additional benefits. In reviewing the field, the potential of DfD to elicit parallel design features in objects was noticed as an important characteristic of the strategy. Indeed, the redesign of a product can be an opportunity to improve its function or re-think the scenarios in which it is used. Several of the design examples analysed as case studies in the initial literature and practice review seemed to display DfD features as 'accidental' aspects that occurred as a side effect of other intensions such as allowing for customisation or modular possibilities in the object. Reversely, as DfD strategies are applied to materials in the samples, they may produce collateral effects which can trigger new ways of using the material or of including it in an object. This points at the high potential for redesign and specifically for DfD to suggest meaningful innovation.

In sampling and testing DfD in textiles, these characteristics seem to have been effectively transferred to a material scale. What's more, the potential of such techniques to become tools in material driven design provides exciting prospects for the application of DfD in design for the circular economy, but also more broadly in providing opportunities to challenge the status quo in product and materials production and consumption

### *4.2 Collateral Benefits of DfD*

During the initial literature review, which analysed 21 examples of design across different fields which represented different ways of applying DfD strategies, several common themes were found to bring together various examples. These were mainly based on who enacts the disassembly and at what point in the product's life cycle the disassembly occurs. On one end of the spectrum for example, DfD aims at enabling the recovery of the resources, usually in the form of a pulp or of fibres which can then be regenerated into new materials. At the other end, DfD involves the user into the product's life cycle and extends it as much as possible with features such as upgradability or an approach to material lifespans which considers the longevity of resources as part of a poetic evolution of the objects through time. Similarly, the different techniques used for DfD in the textile sampling provided different opportunities at the point of disassembly.

The strategy developed in the woven samples can be closely related to Climatex's textile lock, allowing to recover the resources in the state of yarns which can then be introduced to a mono-material chemical or mechanical recycling process. This type of approach provides little change to the use of the material; however, this redesign may be used as an opportunity to enhance the functional characteristics of the material. For instance, the type of stretch or of reinforcement achieved is quite different when the functional element is not blended-in uniformly as with conventional materials, but is instead added on as an extra layer. No testing has yet been carried out on these samples to assess the difference in functional characteristics, however, the Climatex DuaCycle mentioned previously shows an example of enhanced wicking properties from the fibres being woven side by side for disassembly rather than intimately blended together.

In the case of the larger scale samples with reversible connection such as the laser cut samples, the modularity and upgradability concepts seen in product and fashion design translate in a direct way to the material scale, thus allowing for more interaction between the user and the textile's life cycle. This allows to imagine uses for the materials in which they enable life cycle extension by for example suggesting that worn elements be replaced by the user without needing to replace the whole product. On top of providing this practical way of making products last longer and therefore reduce waste, the involvement of the user in the reconfiguration of the objects has been argued as creating attachment which further postpones emotional obsolescence (Chapman, 2005).

Overall, the way that DfD is adapted to the textile scale in these samples suggest the potential for innovation at the material level. By embedding the possibility for disassembly within the material, new behaviour patterns for the use of the objects they are part of may emerge. Moreover, the abstract nature of the samples which at this stage use placeholder materials leaves room for the application of these principles to many different products and situations.

**Conclusion**

This paper has laid out the potential of a redesign strategy to provide solutions to improve the recyclability of blended materials. By asserting the responsibility of the designer, and moreover, their capacity to provide valuable skills in this process, the 'teardown and redesign' process can be taken on to challenge the status quo for materials creation in the wasteful and polluting textile and fashion industry.

The importance of understanding the issue at hand from a creative textile designer's perspective, using a scale and representation methods which are familiar to this field, is particularly important in pointing at the levels at which the designer's set of skills may have a meaningful impact. This in-depth understanding then translates into the prototyping phase when experimenting with solution hypotheses. In this case, free-flowing experimentation with DfD in textiles through various techniques such as weaving, felting or laser cutting explored how the combination of different textile elements following the rules of DfD for the circular economy may lead to original effects in terms of functionality and aesthetics. This paper argues for the value of textile thinking and playful methods in the design process, enabling a thorough exploration of the potential of DfD at the textile scale, both in terms of the quality of the output and regarding the richness of the creative process.

While there may be some limitations to this study due to the abstract nature of the sampling, its disconnect from real recycling systems and the use of the materials within products, DfD presents a major opportunity for innovation in many fields. Furthermore, this paper argues that through the implementation of circular economy rules as a constraint to the creative process, potentially unforeseen benefits may occur as collateral features of the new material or product. This high potential for innovation shows one of the essential values in a redesign process for the circular economy.

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