Rethinking E-textile Design:
Process, Purpose and Sustainability

RACHAEL WICKENDEN

A thesis submitted in partial fulfilment of the requirements of Nottingham Trent University

for the degree of Doctor of Philosophy

This research was funded by the M3C Doctoral Training Partnership

MARCH 2021

ABSTRACT

The desire to integrate electronic technology into the physical fabric of everyday life has driven both design and technical researchers to create amalgamations of electronics and textiles, known today as E-textiles. The science and engineering community has conducted the bulk of this research prioritising technical goals. E-textiles have experienced limited commercial success, in part attributable to technological, economic, structural, social and regulatory factors. This investigation focused on the role and strategies that textile designers can adopt in a *purpose-led* process by which to design E-textiles for interior spaces.

Textiles go through multiple layers of design before they are used. Each layer manipulates and transforms the work of the previous. However, *textile* designers rarely invent the products that textiles become, instead their involvement is limited to producing a material that fits a specification. This research finds that emerging E-textile technology confounds the conventional textile-product separation. The disruption to the textile design process that E-textiles present is acute with respect to their environmental impact, prompting the thesis to take a stance critical of E-textiles and ask why their development should be led by technology, instead giving priority to their purpose.

It examines the multidisciplinary process of designing E-textiles for the interior spaces in which we live, work, and travel, through four action research *'Design Situations'*. These were an extended period of professional practice, an academic workshop, a student project and an industry workshop with a design response. The *Situations* started at the fuzzy front end of the design process, where both the problem and its solution are unclear. They trialled and evaluated techniques from textile, product and interaction design, grappling with the tension between the focus on E-textiles and a *purpose-led* approach.

The endpoint is a series of insights to inform textile design practice. It proposes that considering *purpose* is a means to critique design outcomes. It invites a shift in thinking from 'E-textiles' to 'Electronic and Textile Systems', composed of electronic and textile elements but with no requirement for physical unity. Thinking of systems increases the range of possibilities and favours integrating electronics only where it best serves a design's purpose. To purposefully design E-textiles requires an expanded textile design practice that engages with different layers of design, encompassing both the constituent elements and considerations of product, people and place.

Acknowledgments

This thesis has not been a lone journey and I would like to take this opportunity to thank the many people who have accompanied me along the way. Firstly, to my supervision team whose guidance made this research possible: Prof Tom Fisher, Dr Katherine Townsend, Prof Tilak Dias and Angharad McLaren, I have truly valued your direction and encouragement.

Thank you to my wonderful partner, David, for your patience, kindness, rhubarb and guidance throughout, and to my parents for your support.

I cannot name all the participants that took part in the *Design Situations*, but you I am grateful to every one of you. Thank you Dr Theo Hughes-Riley, for giving up your time when I got stuck working with electronics, and Giulia Tomassello and Sarah Walker, for your friendship and help, and for introducing me to Dr Marisella Mendoza Ramos and Kerry Truman, to whom I am also grateful for their role in this research. Thank you to Kevin Spurr and Ben Gray of Kitronik, Alice Topple, Daniel Pearce and Dr Julian Robinson for your contributions.

To Tina Downes, thank you for the opportunities you gave me. To David Downes, your combined knowledge of electronics and user interaction has been so valuable, and Dr Anna Piper and Georgie Worker thank you for finding time to answer my questions.

Dr Dorothy Hardy and Angharad McLaren, it was a pleasure working with you on the E-textiles and Sustainability project and through our team effort taking IDEO's 'Introduction to Human Centred Design' course.

I would like to express my gratitude to examiners Dr Elaine Igoe and Prof Anthony Kent for their valued feedback and insight.

Finally, to all the pre-Covid-19 'residents' of Bonington 217, without you this journey would have been far less enjoyable.

Contents

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ABBREVIATIONS

ATRG	Advanced Textiles Research Group
AHRC	Arts and Humanities Research Council
B2B	Business to Business
CMF	Colour Material and Finish
CAD	Computer Aided Design
DfA	Design for All
DfE	Design for the Environment
ECG	Electrocardiogram
ETS	Electronic and Textile System
Georgia Tech	Georgia Institute of Technology
HMW questions	'How Might We' questions
HCD	Human-Centred Design
HCI	Human Computer Interaction
ICT	Information and Communication Technology
ISS	International Space Station
IoT	Internet of Things
LED	Light Emitting Diode
LTM project	Light.Touch.Matters project
MIT	Massachusetts Institute of Technology
MDD	Material Driven Design
M3C	Midlands Three Cities Doctoral Training Partnership
NTU	Nottingham Trent University
OEM	Original Equipment Manufacturer
OLED	Organic Light Emitting Diode
PU	Polyurethane
S-T-E	Science, Technology and Engineering
UHCI project	Universal Home Control Interfaces project
UCD	User Centred Design
UX	User Experience

DEFINITIONS

Conventional textiles	Textiles not combined with conductive materials, smart materials or electronic components.
Electronic and Textile Systems	Textiles and electronic elements working as a functioning whole with or without physical integration.
Emerging Technology	*"A radically novel and relatively fast-growing technology characterised by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions and patterns of interactions among those, along with the associated knowledge production processes. Its most prominent impact, however, lies in the future and so in the emergence phase is still somewhat uncertain and ambiguous"* (Rotolo, Hicks and Martin, 2015).
E-textile	Textiles combined with conductive materials or electronic components through weaving, knitting, printing, embroidery, felting or other textile techniques.
Finishing	Operations carried out after a fabric has been knitted, woven or otherwise constructed to improve its appearance, handle or usefulness including washing, dyeing and other mechanical or chemical processes.
Fuzzy Front End	The point in the design process where both the situation being addressed and the nature of the outcome are unknown.
Rapier	A moving part on an automated weaving loom which carries the yarn across the fabric while the yarn package remains stationary.
Smart Material	A broad category of materials characterised by their ability to sense and react to environmental conditions or stimuli. They include thermochromic materials able to change colour according to temperature. They also include materials that can convert energy from one form to another, such as electroluminescent materials which can convert electricity into light.
Warp	The threads extending lengthwise through the loom when a fabric is woven
Weft	The threads insert horizontally across the loom when a fabric is woven.

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1 INTRODUCTION

Look around you, if you are indoors you will almost inevitably be in contact with a textile. Maybe it's the cover of the chair you are sitting on or the carpet under your feet. Interior environments without textiles often appear stark and cold, sound bouncing off bare walls creating a sense of emptiness (Albers, 1957). The ubiquity of textiles has enticed designers and scientists to investigate the possibilities that arise from combining them with electronic functionality, creating a category known as Electronic or E-textiles. In contrast to rigid electronics, they are seen as a way to introduce technology in a form that, thanks to the textile, is familiar and comforting (Hildebrandt, Brauner and Ziefle, 2015; Black, 2007).

E-textiles can be used to detect the presence and position of a person in a room (Köhler et al., 2012) or in vehicle interiors to monitor the driver's heart rate (Wagner, 2013). They are connected to the concept of ´ubiquitous´ or ´pervasive´ computing popularised by the likes of Mark Weiser (1991) who stated:

> *The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.*
>
> (Weiser, 1991, p.94)

Weiser (ibid.) believed not only that miniaturisation would make computers invisible, but that our interaction with computational technology would become so natural that we would cease to be aware of it, freeing people to focus on "new goals". The seductive use of textile metaphor in Weiser's (ibid.) statement has notable allure for E-textile researchers and has been frequently cited (Poupyrev et al., 2016; Orth, 2001). E-textiles have been described as a way to break computation out of its rigid housing and make it soft, sensuous and tactile (Orth, 2001). They are considered part of the "knowledge age", in which technology is "dematerialised" into everyday objects, giving rise to ambient intelligence (Baurley, 2004, pp. 274–275).

The majority of research into E-textiles has been conducted by material scientists and engineers, developing and improving their functionality, but their commercial success has been limited (Hughes-Riley, Dias and Cork, 2018; Heinzel and Hinestroza, 2020). E-textiles' lack of success may be attributable to technological, economic, structural, social, and regulatory barriers, but they have also been described as "gimmicky" and of limited use (Tandler, 2016, p.20). The common response to this criticism focuses on technical aspects, the assumption being that if only the level of integration between electronic and textile components could be improved through miniaturization, flexible electronics and custom built components, then E-textiles would flourish (Stoppa and Chiolerio, 2014). However, in his essay on intrinsic motivation and Human-Centred

Design (HCD)[1], Krippendorff (2004, p. 43) advocates a "different epistemological path" to the "traditionally object-centred scientific research methods". At E-textiles 2020, both Dr Jacob Skinner (2020) and Dr Jesse Jur (2020), referred to the difficulty they have experienced identifying use cases where E-textiles offer real value. Focusing on solving technical problems ignores the more fundamental issue of purpose.

This thesis takes a critical view of E-textiles[2]. Both the textile and electronics industries are highly polluting and at times exploitative, with many problems to solve (Niinimäki and Hassi, 2011; Cook and Jardim, 2017). Our ability to repair (Hardy, Wickenden and McLaren, 2020), or recycle (Köhler, 2008) and therefore recoup the materials and embodied energy from hybrids of electronics and textiles, is limited. Furthermore, E-textiles used to collect personal data risk compromising people's privacy and security (Sametinger et al., 2019). Designers working in the field of E-textiles have a responsibility to understand *why* they want to make them, as their development risks being a distraction, drawing focus away from and exacerbating the pressing environmental and social issues in which the textile and electronics industries are implicated.

The development of E-textiles has been supported by regional funding bodies with the aim of protecting their local industry from the forces of globalisation and to reverse the decline in profitability of the textile industry (De Baets, 2013; Günther, 2013; Klatt, 2010). Textile companies are also looking to distinguish themselves in a crowded global market based on superior quality and functionality, and smart or E-textiles are viewed as a way to achieve this differentiation (Schwarz et al., 2010).

This thesis focuses on how textile designers might investigate and envisage a purpose for them, and with which to lead their process. Its aim is not to promote, but rather to question the phenomenon. E-textiles require designers to ask what this emerging technology will do and how people will interact with it, adding what I refer to as 'functionality' and changing the boundaries of what constitutes textile design. They also bring with them potential negative social and environmental impacts that need to be weighed against any supposed benefits.

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[1] Human-Centred Design is defined by Giacomin as, "distinct from many traditional design practices because the natural focus of the questions, insights and activities lies with the people for whom the product, system or service is intended, rather than in the designer's personal creative process or within the material and technological substrates of the artefact" (2014, p.610).

[2] The criticality of this thesis is a stance of suspicion relative to E-textiles and is not to be confused with Critical Theory, which in a narrow sense refers to the philosophy and social theories of the Frankfurt School and more broadly to theory which "provides the descriptive and normative bases for social inquiry aimed at decreasing domination and increasing freedom in all their forms." (Bosman, 2021)

1.1 Research question

As this chapter will establish, E-textiles sit between materials and products, sensation and function, and technological change in tension with sustainability. They have few established uses, so we are invited to ask what purpose they might serve in daily life. The uncertainty as to their use challenges the conventional role of the textile designer and invites fresh approaches. My discomfort with E-textiles has led to the focus of this research being on how textile designers might respond to the question: 'Why should I design an E-textile, what would be its purpose?', rather than focusing on making them.

The research uses a hybrid methodology, detailed in Chapter 3, combining action research and case study research in four interrelated *Design Situations,* each a case made up of design action. All the *Design Situations* are cases where textile designers envisage E-textiles to be used in interior spaces, but the question this thesis poses is just as relevant for wearable applications of the technology. *Design Situation 1*, the first of the four action research *Situations*, served to identify aspects of the conventional textile design process that presented obstacles when working with E-textiles. It culminated in the idea of a *purpose-led* design process and the question this thesis addresses.

How can the textile design process be adapted to create a purpose-led process of designing E-textiles for interior spaces?

Beneath this are the following sub-questions:

What is the role of the textile designer in the purpose-led design of E-textiles?

What strategies can be used for a purpose-led design process for E-textiles?

The term purpose-led has, until now, predominantly been used for business strategy in a manner closely related to corporate social responsibility (Dhanesh, 2020), and is an organisation's reason for being (Hollensbe et al., 2014). In organisational management and this research, the term is connected to the question 'why?'. My adoption of the term in relation to textile design acknowledges this origin, but it was not inspired by it.

Questions of purpose can be answered with varying depth. This thesis does not address questions of a 'higher purpose', rather it uses the term in a manner related to Verganti and Öberg's (2013, p.87) phrase "product meaning", which they coined to indicate "*why* a product is used" not of what it consists. Textiles can be used to make curtains, their purpose in that case is to protect our privacy and allow us to sleep by blocking out light. This investigation aimed to lead the design process not with a textile or E-textile's use, but the underpinning reason why we use it and its meaning to people.

As Chapter 3 expands upon, my approach to answering these questions is informed by modern hermeneutics, the "science or art of interpretation" (Grondin, 1994, p.1; Gadamer, 2013). I drew on this approach to develop the account of the *Design Situations* preserving their narrative dimension. The data the account was developed from is my research diary, audio and video recording of the *Situations*, interviews with participants and questionnaires.

The value of the purposes envisaged can be criticised because of the contexts out of which they arose - a commercial setting, research workshop and a student project - but the validity of whether, for example, E-textiles should be used in vehicle interiors, is not the measure of the investigation. Instead, the insights that this thesis contributes relate to ways in which textile designers can work with emerging E-textile technology and considerations that should be part of that process.

Although the insights from this research apply beyond the sphere of E-textiles for interior spaces, both *Design Situation 1* and *4* took place in commercial interior textile design contexts and all the S*ituations* pertain to interiors. Therefore, the next section outlines the market and role of textiles in interiors to provide a sense of the design space in which the investigation was set.

1.2 Textiles and E-textiles in interior spaces

We spend much of our time indoors and electrical and computational technologies are a means to control the interior spaces we occupy. Research conducted in North America found respondents reported spending 87% of their time in enclosed buildings and 6% of their time in enclosed vehicles (Klepeis et al., 2001)[3]. E-textiles are being proposed for location sensing to support assisted living (Büsgen, 2012; Köhler et al., 2012) and to monitor vital parameters such as heart rate in vehicles (Wagner, 2013). Technological developments, from the electrification of public and domestic spaces at the end of the 19th century (Gooday, 2008), to the more recent introduction of the Internet of Things (IoT) and smart environments, have changed and are changing the ways we can use and interact with interior spaces[4]. The ubiquity of textiles is a key motivating factor for research using fabric as the carrier for "smart engineering" technology (Baurley, 2004), including electronics, but as yet E-textiles have made little impact in the design of interior spaces or more generally (Heinzel and Hinestroza, 2020).

Adding textiles to interior environments has a range of benefits, including sound absorption, sun protection and insulation (Büsgen, 2012; Albers, 1957). The term interior textile is used for fabrics

[3] More recent data on the average time spent outdoors is not available.

[4] The IoT is defined by the Oxford English Dictionary (2021) as a "development of the internet in which many everyday objects are embedded with microchips giving them network connectivity, allowing them to send and receive data".

destined for domestic environments, offices, hospitals, hotels, schools and for aircraft and automotive interiors. The market is divided into home, contract or non-domestic, and transport textiles (Büsgen, 2012). They are an aesthetic and tactile design element that introduces colour, pattern and texture, contrasting with rigid surfaces, and allow the interior of a space to be renewed to suit changing trends or needs (Lasc, 2016).

Textiles play an important role in the expression of identity, through the clothing we wear (Entwistle 2015), as elements in our homes (Edwards, 2016) or by conveying institutional or corporate identity in the built environment (Gagliardi, 1990). Textiles can alter our perception of a space. In hospitals the use of textiles can be directed at improving patient experience (Mogensen, 2018). While in the design of vehicle interiors, textiles reinforce aspects of brand and model identity, communicating luxury in a Mercedes, sportiness in a Golf GTI or fun in a Fiat 500.

For the year 2018, in the EU 16% of textile products were industrial textiles, which includes those for transport interiors, and 15% were home textiles, contributing to an overall turnover for the EU of 144 billion € and an industry employing 1.7 million people (Euratex, 2018) (Figure 1-1). To put this in context, in 2018, globally the EU was the second largest textile exporter by value, surpassed only by China (ibid.). The *Design Situations* of this thesis explored the design process for E-textiles used in transport, public and domestic interiors, stemming from my professional experience as a designer of transport and contract textiles.

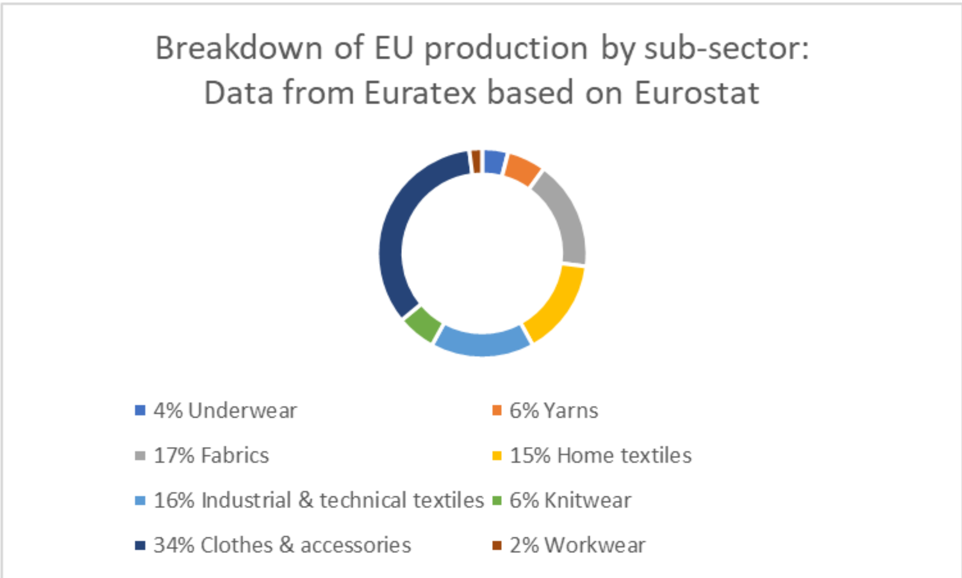

Figure 1-1 Breakdown of EU textile production by sub-sector based on Eurostat (Euratex, 2018)

Sections 1.3 to 1.5 introduce a series of concepts and definitions important for the logic of the thesis. These are: E-textiles as an emerging technology; smart materials; and what is meant by the terms: material; product; application; transformability; and the notion of layers.

1.3 Emerging E-textile and smart technology

Unlike the textiles we encounter every day, the sheets we sleep under and carpets we walk on, E-textiles are an emerging technology, the uses of which are uncertain. Emerging technologies are characterised by their uncertainty, along with their “radical novelty, relatively fast growth, coherence, prominent impact, and ambiguity” (Rotolo, Hicks and Martin, 2015).

E-textile offer novel ways to fulfil a given purpose (Cherenack and Van Pieterson, 2012), radically different from conventional textiles. They have the characteristic of coherence through their persistence as a phenomenon over time and classifications that define them, both as a distinct category and in relation to the broader category of smart textiles (Tao, 2001; Hughes-Riley, Dias and Cork, 2018), discussed in detail below[5]. Pointing to growth and prominent impact, the market for E-textiles across healthcare, fitness, military, protective equipment, fashion and residential and non-residential interior textiles is predicted to be worth over $1.4bn by 2030 (Hayward, 2019). Of all the characteristics that mark E-textiles as an emerging technology, it is the uncertainty and ambiguity as to the potential uses and consequences of E-textiles that present textile designers with a conundrum. This conundrum is central to the thesis because *why* design E-textiles – what is their purpose? – is an open question.

While the categories of E-textiles and smart textiles have significant overlap, as indicated by Hughes-Riley (2018), not all E-textiles fit the definition of ‘smart’. The word smart is used to mean alertness and the ability to make an informed response (Addington and Schodek, 2005). It is used with this meaning at a variety of scales from ‘smart’ buildings to ‘smart’ materials. At the macro scale of buildings and products, the term smart refers to the addition of computation and is closely related to the internet of things (Kortuem et al., 2010; De Silva, Morikawa and Petra, 2012). At the scale of materials, Addington and Schodek (2005, pp.15–18) identify two categories: those that can “undergo changes in one or more of their properties – chemical, mechanical, electrical, magnetic or thermal – in direct response to a change in the external stimuli”, such as thermochromic materials, and those that “can transform energy from one form to an output energy in another form, […] directly and reversibly”, such as piezoelectric materials.

E-textiles can be smart on the macro scale, using computational technology, or be combined with thermochromic and other smart materials, which are smart at the microscale. E-textiles can also have neither form of ‘smartness’, instead consisting of electrical circuitry without computation or

[5] There are early examples of combined textiles and electronics, such as the ‘electric tablecloth’ manufactured between 1902-1905 by Henry Cooper of Bakewell (Field, 2004), but as a field of emerging technology associated with computation, their development started in the early 1990’s with projects such as Orth’s (2001) soft ‘computational objects’ and Park, Mackenzie and Jayaraman’s (2002) ‘wearable motherboard’.

reactive materials, as were the earliest hybrids of electrical circuits and textiles. This thesis considers both smart and non-smart E-textiles.

From a survey, Schwarz *et al.* (2010, p.132) found that the category of 'smart textiles' considered most promising was textiles combined with electro-conductive yarns and electronic components, in other words E-textiles. This reinforces the significant overlap between smart and E-textiles. The same report also found "no strong market pull" for smart textiles (ibid. p. 140). As has been written of smart materials more generally, the lack of clear uses for E-textiles has meant their development is described as "technology-push", in other words "technologies looking for a problem" (Addington and Schodek, 2005, p.11). The ambiguity and uncertainty as to valuable applications for smart materials and E-textiles is a characteristic of their status as emerging technologies. Given the parallels between E-textiles and smart materials, this research also draws on literature regarding the design process for 'smart' materials.

1.4 Layers of design: material, product and application

At this point it is important to discuss the terms layers of design, material, product and application in relation to textiles and their meaning in this thesis. Vallgårda and Redström (2007) use the concept of layers to describe the development of textile artefacts. Although the layers of design are intimately connected, they deal with different issues. They also relate to the levels of consumption described by Igoe (2013, p.28). Textiles are bought as a material by a manufacturer, brand or retailer and then sold to consumers. In the automotive industry, companies that supply directly to vehicle manufacturers are called 'tier ones' which includes the manufacturers of seat structures. Those that supply to tier ones, such as textile manufacturers, are known as 'tier twos' and the yarn manufacturers that supply to them are 'tier threes'. Both tiers and levels are synonyms of layers. Moreover, textiles are often a physical layer placed on a product or an architectural element that is made of a rigid material, such as plastic, metal, concrete or wood. In the design of textiles and E-textiles the idea of layers communicates separation and stratification but also connectedness. The concept of layers of design relates both to organisational structures and to physical ones.

In industry this separation means a textile designer may know the application of their textile, as do automotive textile designers, but still not be involved with designing the end-product. Their role is to interpret the brief provided by the customer and meet their performance and price specification. Textile designers create materials, while in a separate layer, product, fashion, and interior designers transform textiles into things that people can buy or spaces they may occupy. For textile designers, textiles are the product, the outcome of their process. Whereas, for fashion, interior, product or Colour, Material and Finish (CMF) designers, textiles are materials, the substance of which their designs are made. As Igoe (2013, p.78) writes "textiles enables other designed products to come into existence". Textiles are both the products of one design process and materials for another layer of design, so can be described as designed materials.

On the other hand, the design of a textile and the product it will become can be so intertwined it is difficult to distinguish textile from product, as is the case for sophisticated seamlessly knitted medical devices (Liberski et al., 2016). However, in the areas of transport, home, and contract textiles, that were the focus of this investigation, textiles are mostly produced as 'materials', open to transformation by a separate layer of design into products. The link between textiles and products, as found by Tonuk (2016a, p.139) to be the case for bioplastics, is that of "application". The application of a textile is the use to which it will be put. Textile design students are asked to define the application of their creations and this can be quite generic. It is commonplace for textiles to be proposed for a category such as home textiles, with possibly a season and demographic or customer profile in mind, rather than for a specific product, use-case, and user. As stated in Section 1.1, a textile's end use or application and its purpose are related, but they are not the same thing.

1.5 Transformability

This research examines E-textiles for interior spaces, but the division between E-textiles developed for interiors and those intended to be worn as clothing or accessories is thin. Defining the purpose of textiles has not been central to textile design or engineering, and a similar approach is prevalent in E-textile research, where they are developed as materials rather than the finished product.

New technical possibilities, such as fibre batteries (Zhou et al., 2019), impact how E-textiles can be manufactured, function and perform, and are enabling technologies for interior or wearable applications of E-textiles. Enabling technologies are discoveries made in science and engineering that have the potential to create or improve the performance of a wide range of products (Teece, 2016). Whether for interiors or clothing, E-textiles adopt the same techniques: knitting, weaving, and printing, and use the same building blocks, including conductive polymers or metals. I highlight this flexibility to support my inclusion of examples and comparisons between E-textiles for interior and wearable applications.

The textile industry is accustomed to producing a product that is transformable. Although textiles for clothing and interiors can be categorised separately, the everyday reality of industry is less distinct. Yarn manufacturers such as Teijin, Antex, Sinterama and Südwolle make yarns that are used across interior and apparel textiles, and textile manufacturing groups such as Limonta and Toray produce textiles for a broad range of applications. Artist Menja Stevenson's Bustour project humorously illustrates the adaptable nature of textiles by making clothing from transport fabrics

(Figure 1-2). Although transport textiles are not ideal for clothing, because of their thickness and rigidity, their transformability means they can still be used in this way.

Figure 1-2 "Bustour" by artist Menja Stevenson (Stevenson, 2008)

While a textile may be designed to meet a specification for a category such as upholstery or men's suiting, their transformable nature makes it possible for them to be used in ways their designer did not consider. The precise use of a textile, the 3D form it will take and the environment in which it will be placed, is generally decided by fashion, product, interior or CMF designers, for whom the textile is a material.

E-textiles, on the other hand, are less open to transformation, closer to devices or end-products. A textile designed for upholstery may also be used to make a pair of trainers, but an E-textile designed to function as an antenna cannot also function as a heated textile. The order and structure in which conductive yarns are used alter the textile's electrical properties and therefore functional capabilities, determining the uses to which it can be put. Fisher and Shipton (2009) and Twigger Holroyd (2013) employ the notion of openness to denote designs that suggest alternative uses or invite people to modify or transform the object. The relative openness of textiles compared to E-textiles is not a question, however, of perception. To function as part of an electronic system there are real constraints as to how an E-textiles can and cannot be used.

A conventional textile can be used across a variety of applications, to which it can be more or less suited, but an E-textile simply cannot carry out a function that its design does not permit. E-textiles can thus be considered further up in the layers of design, closer to products than they are raw materials such as cotton. They remain intermediate, open to a degree of transformation but more closed than conventional textiles. Although E-textiles have some ability to be transformed, the fact that they are more closed than conventional textiles signals to designers they require a different approach.

1.6 Textile design in relation to emerging E-textile technology

As an emerging technology, E-textiles challenge the conventional textile design process in several ways, requiring that it be rethought. Textile design draws on a wide variety of skills and has been described as multidisciplinary (Moxey, 1999; Glazzard, 2014, p.8; Kettley, 2016b; Gale and Kaur, 2002, p.37). As defined by Choi and Pak (2006) the term multidisciplinary refers to the skills of multiple disciplines being used in parallel or in sequence. One approach to designing E-textiles taken by textile designers has been to collaborate with or adopt aspects of technical disciplines in a hybrid craft-science approach (Veja, 2014; Robertson, 2011; Townsend et al., 2017). In these projects smart and E-textiles have been developed as a material rather than applied in a product. Designers have investigated the dynamic and interactive capabilities of E-textiles, which go far beyond the gradual ageing of conventional textiles or the changes to their properties that occur between wet and dry states. This has led to explorations of what it means to design textiles with dynamic variables (Worbin, 2010; Jansen, 2015) and “textiles as materials for interaction design” (Persson, 2013).

The focus of this investigation was the ambiguity inherent to the emerging nature of E-textiles, which means that unlike conventional textiles their purpose is yet to be defined and stabilise. Stability, as defined by Suchman (2002, p.101), is “the continuous reproduction of meaning and usefulness in practice” of a technology. Textile designers can take for granted the relationship between conventional textiles, clothing, and interior furnishing, whereas for E-textiles this is not the case.

When designing E-textiles, textile designers have showcased the capabilities of this emerging technology without defining the end use or purpose (Veja, 2014; Robertson, 2011). In the commercial context where this research originated an exploratory approach, in which the purpose of the material is unclear, is less welcome, as elaborated in Chapter 4. If E-textiles are to be commercially developed and that development be justified, a purpose needs to be envisaged for them that will motivate the investment of time and resources. If we can define the purpose for an E-textile, its benefits can be weighed alongside the difficulties of creating it and the implications of its adoption.

Textiles for interiors are often manufactured in a business to business (B2B) context where customers, those companies that manufacture the end product, are the primary source of new design ideas (McAdam and McClelland, 2002; Büsgen, 2012). With E-textiles, as Chapter 4 will detail, customers were unsure what purpose they wished them to serve. In product or interaction design, inspiration to envisage a purpose for new technology often comes from studying potential users of a product or service (Moggridge, 2007a, p.725; Mazé and Redström, 2005, p.8), but in textile design, where materials are the outcome of the process, the user is often a distant and unfamiliar concept (Kettley, 2016a). Although business customers have been referred to as users in textile design research (Niinimäki, 2018) and smart material composites research (Wilkes and Miodownik, 2018, p.12), business customers are better considered stakeholders. They have an interest in various aspects of an E-textile's design as it passes through their manufacturing processes and has a role in their product, but it is not *their* needs or aspirations the E-textile ultimately plays a role in fulfilling. Hence, in this thesis, 'user' refers to the person who will encounter the textile once it is out in the world as part of a product or interior space. As Chapter 4 will detail, the separation between textile designers and the people who would ultimately experience an E-textile product hampers a purpose-led design process.

1.7 E-textiles and associated technological developments

The interpretation presented in this thesis is bound to the historical moment in which the research was conducted and written. Gadamer, the founding father of modern philosophical hermeneutics, declared that, "understanding is, essentially, a historically effected event" (2013, p.310). The past influences our understanding through the preconceived notions we bring to the act of interpretation. The following section defines E-textiles and then presents an account of their development in relation to ubiquitous and affective computing, the IoT and smart environments.

The term E-textiles is used for a heterogeneous group of hybrids in which textile and electronic elements are combined using a variety of processes, including knitting, weaving, printing, and embroidery. Hughes-Riley, Dias and Cork (2018, p.34) frame the various stages of manufacturing at which electronics can be combined with textiles in terms of generations, becoming progressively more seamlessly integrated. The first generation consists of circuits or electronics added during product or garment construction, with wires running through channels and electronics held in pockets or sewn into the textile. The second generation is where electronic or conductive elements are used to make textile structures, and where conductive materials are printed or embroidered onto textiles (Sloma et al., 2014; Post et al., 2000). The third generation of E-textiles is where electronic functionality is added at the level of the yarn to create, among other, E-yarns (Dias and Ratnayake, 2015) and fibre batteries (Zhou et al., 2019).

As previously discussed, although E-textiles are often described as 'smart', those consisting of conductive or semi-conductive materials embedded into textiles to form circuits but without data processing capabilities, do not fit its definition. The electric tablecloth (Figure 1-3) manufactured between 1902 and 1905 by Henry Cooper of Bakewell (Field, 2004) consists of wires sandwiched between two layers of fabric delivering electrical current to the bulbs. An example of a wearable E-textile from the 1880s is Dr Scott's Electric Corset, which promised its wearers the "beneficial effects of Electro-Magnetism" (The New York Public Library Digital Collections, 2020)

Figure 1-3 Edwardian electric tablecloth (Field, 2004)

Still in use today, heated textiles which use electrical resistance to generate warmth via an on/off switch are not smart. The first heated textiles were patented in the early 1910s (Panati, 2016; Carron, 1911). While heated textiles do not possess the novelty of more recent computational E-textiles, their continued use suggests they serve a clear purpose. For suffers of Raynaud's phenomenon, which causes restriction of blood flow to the body's extremities when exposed to cold or stress, or for those working over long periods at low temperatures, heated textiles offer vital relief, and heated blankets are an energy efficient way to keep warm at home (Casey, 2014).

In the late 1990s, research started into computational E-textiles, linked to ´pervasive´ or ´ubiquitous´ computing, meaning computing anytime and anywhere. Park et al. (2002) described this branch of E-textiles as "fabric is the computer", a paradigm in which information processing capability is constructed out of textile structures. Early projects at the Massachusetts Institute of Technology (MIT) and the Georgia Institute of Technology (Georgia Tech) worked to bring pervasive computing to clothing and other textile objects, with projects like Orth's "Sculptured computational objects" (2001) and Park et al.'s "Wearable motherboard" (2002). The term computational is what differentiates this branch of E-textiles, explored over the last 20-years, from those like the electric tablecloth that preceded it.

Projects like Orth's can be seen in part as a reaction to early research into wearable computing shown in Figure 1-4, more details of which can be found in Mann (1997). Orth (2001) was looking to design alternatives to the heavy, bulky, rigid and unattractive boxes and wires that characterised the computers of the time. In her research she sought to create more aesthetically pleasing, sensuous, and tactile versions of computing "to expand and change the role and meaning of technology in people's lives" (Orth, 2001, pp.14–30). She achieved this primarily by combining electronic and textile elements using embroidery.

Figure 1-4 Steve Mann's experiments with wearable computing in the mid-1990s (Mann, 2013)

1.7.1 Ubiquitous computing

E-textiles are a small part of the wider trend that has seen information and communication technology moving into all aspects of our lives. With his vision of ubiquitous computing, Mark Weiser (1991) foresaw the networked world of Wi-Fi, Bluetooth, RFID, voice recognition and cloud computing we inhabit today. A world in which devices communicate with each other and information can be accessed whenever and wherever through tablets, smart phones, and watches. Although Weiser made no explicit reference to E-textiles, his text is laced with textile metaphors inviting the E-textile research that started in the late 1990s (Orth, 2001; Park, Mackenzie and Jayaraman, 2002)

When research into computational E-textiles began, smart phones such as Apple's iPhone, launched in 2007 (Pothitos, 2016), were still several years away. This created a different technical landscape from the one we find today and researchers placed high priority on incorporating as much as possible of the electronic system into the textile (Hughes-Riley, Dias and Cork, 2018, p. 8). Despite extensive research, E-textiles have experienced only limited commercial success (Heinzel and Hinestroza, 2020) and their performance and features are still largely considered unsatisfactory at a consumer level (Heo et al., 2018; Townsend, Kettley and Walker, 2020). While the story of ubiquitous computing in the form of the smart phone is one of triumph, with about 83% of the UK population over 16 owning one (King, 2019), the same cannot be said of E-textiles.

1.7.2 The Internet of Things

Part of the ubiquitous computing paradigm is the IoT which as imagined by Poupyrev *et al.* (2016) includes E-textiles. The IoT refers to everyday objects with added networked computational capabilities which allow them to send, receive, and process data resulting in phones, watches, fridges, and thermostats that are 'smart'. The commercial realisation of the IoT means we can now buy fridges that allow us to look inside them when at the supermarket (Samsung UK, 2020) and thermostats we can remotely control (Google Store, 2020).

In Weiser's vision ubiquitous computing resided "in the human world", "vanishing into the background", and posing "no barrier to personal interactions" (1991, pp.94, 104). Following the advent of smartphones and social media platforms including Facebook and Twitter, launched to the public in 2007 (Edosomwan et al., 2011), by 2009 'digital detoxing' started to be promoted to increase well-being by taking time away from electronic devices (Morrison and Gomez, 2014). This suggests that ubiquitous computing does not always reside in the human world as Weiser (1991) had hoped. Instead, software applications have been developed to help individuals control the time they spend using devices, offering a technology solution to a technology problem. Since their inception E-textiles have been viewed as a way to introduce technology that is familiar and comforting (Black, 2007; Ziefle, Brauner and van Heck, 2016) and an antidote to rigid screen-based technology (Heinzel, 2014; Orth, 2001), but we are yet to see these benefits.

1.7.3 Smart environments

Both ubiquitous computing and the IoT are integral to the concept of smart environments and ambient intelligence. In smart environments networked devices sense, monitor and communicate to adapt and respond to occupants' behaviour, and allow direct control (Marikyan, Papagiannidis and Alamanos, 2019). Smart environments have been proposed to prevent accidents in children and the elderly, improve energy efficiency, increase security and for entertainment, promising convenience, comfort, personalisation, and adaptability (ibid.). Research into user interface preferences for smart homes at RWTH Aachen (Hildebrandt, Brauner and Ziefle, 2015) found textiles to be the preferred input medium over smartphones or electronic boxes. The authors recognise that because their results were obtained via an online survey, the responses may have differed had respondents interacted with E-textile or other interface types. They concluded that the familiarity of textiles would make E-textiles a more acceptable carrier of technology to less technophile users than rigid electronic interfaces, while acknowledging that achieving a high level of integration between electronics and textiles is highly challenging.

In smart environments, 'affective computing', meaning machines that can recognize, express, communicate, and respond to humans using emotions, is being designed to predict human behaviour and adapt environments accordingly (Schwark, 2015). This can be achieved using video and audio recording to recognise facial expressions, and identify vocal and ambulatory patterns (Harrison and Dalton, 2011). In a blurring between body and space, wearable sensors can provide additional information to the system about an individual's psychophysical condition based on their heart rate or skin conductance. Applications of affective computing have been suggested for automotive interiors (Eyben et al., 2010), healthcare environments (Dalton and McCartney, 2011) and robotics (Rhim et al., 2019) to better match an environment with its occupants' emotional states.

The automotive industry and its suppliers showed early interest in the development of E-textiles. Research into their possible applications in the field started around 2007 with the Insitex and Seatsen projects funded by the German Federal Ministry of Education and Research (BMBF) (Scheibner, 2011; Wagner, 2013). These initial projects were carried out to test whether E-textiles could reliably measure physiological parameters, such as heart rate (Wagner, 2013), or function as switches to replace rigid components (Tielas Macía, Martinez and Piñeyro, 2010; Scheibner, 2011). Between 2006 and 2013 automotive manufacturers and their suppliers were also involved in the EU funded STELLA[6] and PLACE-it[7] projects, which produced interior lighting prototypes, and the PASTA[8] project that led to an E-textile seat heating component. From my knowledge of the industry, to date E-textile have only been used in vehicle interiors as seat heating pads placed under a layer of conventional textile upholstery.

The automotive industry's interest in E-textiles and E-textile developers' desire to exploit this market are the drivers that led to *Design Situation 1* documented in Chapter 4. The automotive industry is moving steadily towards a world in which vehicles will be autonomously driven (Bertoncello and Wee, 2015) and powered by new, more environmentally sustainable energy sources (IEA, 2019). These changes offer great scope for the automotive design and engineering community to redefine the vehicle interior (Stuart, 2015). E-textiles may be a technology that will allow for novel design solutions that would otherwise have been impossible to realise. In addition, automotive textile manufacturing is highly competitive. The ability to offer E-textiles as part of a

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[6] The STELLA project ran from 2006-2010 investigating 'Stretchable Electronics for Large Area Applications'. The demonstrators created included a pressure measurement band to be used with compression garments for the treatment of venous and lymphatic disease and a car interior lighting component (Klatt, 2010).

[7] The PLACE-it (Platform for Large Area Conformable Electronics by Integration) project followed on from STELLA running from 2010-2013 developing multiple prototypes including a renal function monitor and a car sun visor vanity light (Günther, 2013).

[8] The PASTA (Platform for Advanced Smart Textile Applications) project also followed STELLA from 2010-2013 and produce demonstrators including a urine and sweat sensor for smart bedlinen and a car seat heater design to reduce power consumption, cost and weight (De Baets, 2013).

product portfolio would allow an automotive textile company to compete on grounds other than price, using innovation as a market differentiator.

1.7.4 E-textiles and the smart home

In an online survey conducted by Hildebrandt, Brauner and Ziefle (2015) the researchers found resistance to ambient intelligence in smart homes and proposed E-textiles as a way to increase acceptance. Hildebrandt, Brauner and Ziefle (2015) did not consider voice control in their study, the technology currently leading the market for connected home products. Using E-textiles does not resolve the tension between the home as a private intimate space and smart technology as sensing and communicating sensitive personal data. Smart or connected home technologies potentially compromise the modern concept of domesticity by projecting private information about the home and its occupants beyond its boundaries (Heinzel, 2018).

There is currently no means to test the idea that E-textiles would increase smart home technology adoption because few products are commercially available. Rather than a desire for familiarity and tactile input, interest in voice control, primarily smart speakers, is the main driver of growth in the market for smart home technology (King, 2019). Although concerns about privacy are a factor counting against smart home products, more importantly, many people simply deem them unnecessary (King, 2019). This means that while E-textile developers need to be aware of the privacy and data protection issues of the products they design, there also needs to be a clear purpose behind these developments if they are to find a lasting role in everyday life.

1.8 Manufacturing E-textiles

In the 20-years since research into computational E-textiles began huge technological advances have been made in ubiquitous computing, the IoT, and smart home technology. In comparison, E-textiles have remained on the fringe of these domains experiencing limited success, but why is this the case? A visit to a textile manufacturing facility, such as those producing automotive and contract textiles where I have worked, compared with the opportunity I was given in October 2018 to observe electronics being produced at electronic kit manufacturers Kitronik provides the starting point for this discussion[9].

During the manufacturing process, textiles are exposed to dust, water, heat and mechanical stress as they are pulled through washing and heat setting machinery in batches that can be hundreds of metres long, and quality tolerances are measured in millimetres and centimetres. By contrast, the

[9] I visited Kitronik's Nottingham production facility in preparation for teaching a session dedicated to E-textiles for MA Fashion, Textiles and Knitwear students. I wanted to gain a better understanding of the manufacturing process of electronics and available materials and devices to inform the development of the PhD.

production of electronics is carried out in clean, dry environments and to tight tolerances falling between 0.1 mm and one micron, equal to 0.001 mm (Eurocircuits, 2020), requiring precise manufacturing processes.

Textiles drape, fold and stretch, whereas electronics have traditionally functioned best when stable and protected within a rigid exterior, a limitation which has driven research into flexible electronics (Nathan et al., 2012). Combining electronics and textiles also presents challenges during the use phase because their durability is compromised by mechanical stress and exposure to water or chemicals when textiles are cleaned. As acknowledged by Lund et al. (2018), the difficulty of marrying these two worlds goes some way to explain why E-textiles have not become more commonplace.

To make a useable E-textile product requires many challenges to be overcome and even then, they remain primitive and limited compared to the computation power, versatility, and customisability of even a basic smart phone. It is against this backdrop of limited commercial success and acceptance that this investigation of E-textiles for interior spaces took place. If academics and companies wish to overcome the technical barriers to the development of E-textiles, as recommended by Schwarz (2010), the link between the technology being developed and its purpose needs to be stronger. It is this link between the technology and the discovery of purposeful applications born out of understanding of human behaviour, needs and aspirations, tempered by concern for the environmental impact of their adoption, that is the focus of this research.

1.9 Purpose-led design for E-textiles

As an emerging technology, our relationship to E-textiles and their role in our lives is still being defined. Textiles have symbolic meaning and through pattern, form, colour and texture are used for personal expression. Textile designers are well versed in this visual and tactile language (Gale and Kaur, 2002, pp.37–39). Moving from the design of conventional textiles to E-textiles introduces new considerations of purpose, because they can do things, but it is not yet clear what we want them to do. Purpose-led, in this research, refers to a textile design process that starts by understanding the people and place for which we are designing to envisage a purpose, instead of the possibilities offered by materials and manufacturing process.

Textile designers and manufacturers must continually balance aesthetics – meant as visual and tactile beauty – with performance and price. They are also increasingly under pressure to give greater importance to sustainability and other social responsibilities. In this thesis, E-textiles are a conduit to investigate these tensions. A major reason for the textile industry's interest in developing E-textiles, openly acknowledged (Schwarz et al., 2010; Büsgen, 2012), is to maintain or increase profitability and market share by competing through innovation in a highly competitive global industry. Kirstein (2013) warns that the desire to innovate using E-textiles is at times misplaced, and innovators should look at systems to assess whether they are really adding value.

E-textiles bring with them a series of environmental concerns, from their lack of recyclability and repairability to the risks to human health and the environment of nanoparticles and other harmful substances found in textiles and electronics and used during their manufacture (Köhler, 2013b)[10]. Additionally, where E-textiles form part of a system that collects and transmits data there are concerns about privacy and security. The EU WEAR sustain project, funded under Horizon 2020, sought to address environmental and social concerns surrounding wearable technology and E-textiles by mentoring developers to define and encourage best practice (Sametinger et al., 2019). Armed with this information, the role of textile designers developing E-textiles is not simple, navigating between often conflicting goals, where the integration of technology can impact durability, repairability or recyclability, and price and aesthetics can be pitted against sustainability.

The bulk of research into E-textiles has been orientated towards narrowly focused technical objectives related to functional capabilities (Dias and Paulo Silva Cunha, 2018; Weng et al., 2016; Zhou et al., 2019). Technical objectives relate, for example, to achieving continuous conductive tracks (Karim et al., 2017). Motivating technical research are statements, such as electrochromic performance needs to be improved because there is a "strong interest for consumer products" and "electroluminescent devices can provide bright signs whenever and wherever" (Weng et al., 2016, pp.6152–6153). Technical researchers have rarely questioned these motivations or examined the implications of E-textiles for society and the environment.

While there is a drive towards an ever tighter union between textiles and electronics, with the ultimate goal of seamless integration (Perry et al., 2017; Berzowska, 2005), there is a growing acknowledgement of the environmental and social risks that E-textiles present (Sametinger et al., 2019; Veske et al., 2019; Goncu-Berk, 2019; Hardy, Wickenden and McLaren, 2020). Heinzel and Hinestroza (2020) ask science and technology researchers to broaden their rather narrow optimistic perspective and call for greater acknowledgment of the complexity of the world's problems.

For the time being these concerns are only occasionally represented in scientific literature on E-textiles, although researchers are beginning to acknowledge that seamless integration may be "unfavourable for sustainability reasons" (Hughes-Riley, Dias and Cork, 2018, p. 8). E-textiles are a

[10] The risks posed by E-textiles are discussed extensively in the doctoral thesis of Andreas Köhler (2013b)

growing field and the E-textile network, managed by the University of Southampton, was founded in 2018 to “promote the development of E-textiles technology” (E-textiles Network, 2020). On Google Scholar, the search term ‘E-textiles’ returns 72 results for the period 2000-2001 growing to 1,810 for 2018-2019. Since this project began in 2015, the number of commercially available E-textile products beyond heated textiles has also increased. Examples include Siren’s (2018) temperature sensing socks and products resulting from the Google Jacquard project, which include collaborations with Levi’s® and Yves Saint Laurent (Google, 2020). Yet, there are also examples of E-textile products that are no longer on the market such as Orth’s (2009) textile switches or several sportswear products listed by Hughes-Riley, Dias and Cork (2018). The ongoing research and commercial interest in E-textiles make understanding their purpose and desirability pressing issues.

The *Design Situations* of this thesis build on each other in search of ways the design of E-textiles could become purpose-led, starting by understanding of the contexts for which E-textiles could be used and the people who would use them.

1.10 Thesis structure

This first chapter has presented the background to this investigation, providing definitions and indicating the challenges of working with emerging E-textile technology. It then gives an account of E-textiles in relation to the development of ubiquitous computing, the IoT and smart environments, before closing with the summary statement that follows this structure outline.

Chapter 2 positions discussion of the textile design process in relation to the broader design process literature and reviews approaches to designing E-textiles and smart materials. It concludes by defining the design orientation of this research.

Chapter 3 details the paradigm in which this research operates and explains the hybrid action research and case study research methodology. It positions the investigation relative to other work in the field and clarifies, theoretically and practically, the interpretive approach.

Chapters 4 to 7 each detail one of the four *Design Situations* that were the core of this investigation. The *Situations* examine the design process of E-textiles for interior spaces in industry, academia, and undergraduate education, assuming a relationship between education and professional design practice. Lawson and Dorst (2009, p.62) state that “an important part of design practice is mimicked in the educational environment” but the teaching of basic trade skills is only one aspect. Design education and academic research also have an important role in anticipating “new conditions of practice” (Buchanan, 1998, p. 65). Technological innovation, the need to reduce human impact on the environment and the forces of globalization are changing the professional textile design landscape and making it increasingly interdisciplinary[11] (Nimkulrat, Ræbild and Piper, 2018). Building a picture of the effect on the textile design process of collaboration when working with emerging E-textile technology is important both to inform the development of higher education curricula and to guide changes in industry practice.

Chapter 4 - *Design Situation 1* is an account of the MPhil stage of this investigation, consisting of three years researching E-textiles for automotive interiors while in full-time employment as 'Advanced Textile Designer' at the automotive textile manufacturer referred to as Company X[12]. Although the original intent was that the research would be concluded as an MPhil, in the context of this thesis Design Situation *1* should be seen as diagnostic, leading to the research question that guided the subsequent *Design Situations*.

Chapter 5 - *Design Situation 2* was a two-day workshop involving students and academics attending an ArcInTex network event[13]. The aim of the workshop was for the participants to design an E-textile for a non-domestic interior space.

Chapter 6 - *Design Situation 3* was a six-week collaborative project involving second-year BA (Hons) product design and textile design students titled 'E-textiles for Micro-Living'. The aim for the students over the course of the project was to create an E-textile design proposal for a domestic interior space of only 18 metres squared. This *Situation* made apparent contradictions between a purpose-led design process and one that is tied to a specific family of technology. To partially resolve the tension, this chapter concludes by proposing Electronic and Textile Systems (ETSs) as a more flexible, open way to conceive the hybridisation of these two technologies that does not assume any degree of physical unity. Instead, ETSs are associated elements that together make up a more complex whole, each element used as best serves the design's purpose.

Chapter 7 - *Design Situation 4* closes the investigation with a return to the transport interior textile industry. It was formed of two parts, the first being the one-day 'Design Thinking' workshop, the name of which was coined by Company Y, the European transport seating system and textile manufacturer that took part. The second part of the *Situation* was my creation of three ETS design proposals from the data created during the workshop, which were evaluated by the company.

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[11] As defined by Choi and Pak (Choi and Pak, 2006), interdisplinarity is where the boundaries between multiple disciplines become blurred.

[12] The company has been anonymised due to commercial confidentiality.

[13] ArcInTex is an academic network that links the researchers from the fields of architecture, interaction design, and textile design, to explore techniques, methods and perspectives on building, dwelling, and living (ArcInTex, n.d.)

Chapter 8 draws together the insights that emerged from the four *Design Situations*. Concluding that giving priority to purpose in the design of E-textiles exposes the need for a system level approach. As one of the broader implications of the research, this chapter shows through a series of examples how purpose can be used as a means of critique. It discusses the implications of this investigation for the role of the textile designer in the development of E-textiles and recommends strategies textile designers might use in a purpose-led design process.

1.11 Adapting textile design roles and processes for E-textiles

The journey from fibre to product for textiles in industry and education has traditionally been an endeavour in which each layer of design is responsible for a small section of the process. E-textiles require the current divisions to be rethought (Nilsson, Vallgårda and Worbin, 2011). The purpose-led development of E-textiles requires a broader view with the ability to move between the examination of context, users, and the overall system and its constituent elements. As noted by Köhler (2013), we are currently at the fuzzy front end of E-textile innovation where both the situation being addressed, and the nature of the outcome, are unknown. Textile designers need tools that allow them to explore possibilities and envisage the role of E-textiles. The fuzzy front end of the design process is characterised by a high level of uncertainty about what will be made, how it will be made, for whom and why, inviting broad open-ended questions (Sanders and Stappers, 2008). To answer the question '*why?*' requires textile designers to move from the material layer to which they are accustomed to the layers of product, people and place, a journey this thesis investigates.

2 CONTEXT

This thesis reconsiders the starting point for designing E-textiles, the sources of inspiration and the motivation for the process. The following chapter first examines how, in broad terms, the design process is understood, its starting point and how these concepts relate to the design of textiles. It reflects on the new demands E-textiles place on textile designers and how they have so far adapted to them. In search of fresh approaches to designing E-textiles and given the broad overlap between these and smart materials, discussed in the previous chapter, I review how non-textile designers have assisted in the development of smart materials. For example, bringing the perspective of the user into the process, but I have already explained that hitherto the perspective of the users has not been a dominant voice in the textile design process. I examine different orientations to design and innovation, highlighting their strengths and weakness for this investigation and close by detailing the implications for this research.

2.1 What is the 'problem'?

Design has been described as a process of problem solving, an iterative journey navigating from problem to solution through stages of analysis, synthesis, execution, and evaluation (Swann, 2002; Lawson, 2005, p.49)[1]. Design problems have been characterised as ill-defined (Archer, 1979) and yet situated (Suchman, 1987; Dorst, 2006). The process of solving design problems differs from that of science, which is directed at finding an optimised solution to a well-defined problem, but "less effective when the parameters are indistinct" (Philpott, 2011, p. 36). Design is a "process of pattern synthesis rather than pattern recognition", where the solution "has to be actively constructed by the designer's own efforts" (Cross, 2006, p.8). Design problems are moving targets, which evolve together with their solution (Dorst and Cross, 2001; Dorst, 2019) in what Schön (1992, p.4) calls "a reflective conversation with the situation".

From the belief that design is a special category of problem solving has come the term design thinking. The main idea of which Kimbell (2011, p.285) explains, "is that the ways professional designers problem-solve is of value to firms trying to innovate and to societies trying to make change happen." Design thinking, as advocated by the likes of design firm IDEO (Brown, 2008), is closely associated with human-centred approaches to problem solving (Dosi, Rosati and Vignoli, 2018), using ethnographically inspired techniques to understand the "users perspective and situated actions" (Kimbell, 2011, p.295). If design thinking is about understanding users, it

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[1] Lawson considers execution as part of synthesis, the response to analysis and evaluation which can take the form of a sketch, prototype, sample or model.

excludes what most textile designers do. However, Kimbell (2011, pp. 300–301) criticises the general conception of design thinking for distinguishing between “thinking and action” and “the design and the context”, its focus being overly on the commonality between designers instead of recognising the diversity of “situated, embodied material practices.”

In situations of uncertainty, Schön (1983, pp.40–41) identified problem setting as a necessary condition for problem solving. It is by this process that a practitioner selects what they will consider important, what they plan to achieve and how it might be accomplished, thus framing the problem within its situation. In this investigation, I first diagnosed the limitations of conventional textile design problem setting and then explored alternatives which might emphasise understanding people and place to envisage a purpose for E-textiles.

Engineering, industrial design (Cross, Christiaans and Dorst, 1996) and architecture (Lawson, 1979) were the areas first studied to build an understanding of the design process, while others such as fashion and textile design have received limited attention (Gericke and Blessing, 2011; Britt and Stephen-Cran, 2014; Igoe, 2013, pp.25–31). The concept of a problem as the starting point of the textile design process, although adopted by the likes of Moxey (1999) and Wilson (2001), is not necessarily recognised by textile designers (Igoe, 2013, pp.91–103), including myself at the start of this investigation.

Valentine *et al.* (2017, p.S966) described textile design as distinctive from other areas of design in that it “is guided by emotive, haptic, sensorial and tactile qualities”[2]. Textile design, even in its industrial form, remains closely linked to craft (Dormer, 1997) and applied art. Writing about the design process for smart textiles, Kettley (2016a, p. 40) uses the term “studio practice” to label the textile design process, contrasting it with user-centred design and interaction design[3]. She describes how the aim of studio practice can be “to devise the most effective method to produce a particular texture” (2016a, p.45) and points out that the ‘user’ is rarely a consideration. Kettley (ibid.) refers to the “textile artist”, but even in my experience of designing automotive textiles, which would appear far removed from textile design as an art or craft practice, these aims and the absence of the user resonate. The desire to explore a material or technique is hard to connect with the word problem in the sense it is commonly used to mean “a matter or situation considered unwelcome, harmful [or] wrong” (Oxford English Dictionary, 2019). Instead, it would be better understood using the definition of a problem as a puzzle or an enigmatic statement.

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[2] Haptics relate to the touch sensation produced by a textile, for example whether it is rough or smooth.

[3] User-centred design (UCD) is closely linked to Human-Centred Design (HCD) which is discussed in Section 2.6.2.

If textile design is closely connected to art and craft, what then is its relationship with other areas of the discipline? Dorst and Lawson (2009, p.41) suggest that art is free from requirements whereas design is "grounded by functionality". Although this definition may fit the context of its authors, there are areas of design that challenge this idea, such as critical design (Dunne and Raby, 2001; Malpass, 2017) or indeed textile design. The work of the textile designer can require consideration of functional criteria, but aesthetics are equally if not more important. Freedom in creating ideas is more limited by technical constraints imposed by processes, materials, or market criteria than functionality. Taking the example of a woven or printed textile, a designer can radically change the fabric's appearance in terms of pattern and colour without in any way modifying its performance properties. In this case, whether one design *functions* better than another comes down to a combination of subjective aesthetic evaluation and market criteria.

Compared to the dozens of design process models created in other areas, only a few have looked specifically at that of textiles or non-apparel textile products[4] (Calamari and Hyllegard, 2015; LaBat and Sokolowski, 1999; Studd, 2002; Veja, 2014; Wilson, 2001). LaBat and Sokolowski's (1999) model is the only one for which the starting point is labelled a 'problem'[5]. The design process their study analysed was a student re-design of an existing textile product, an ankle brace, one component of which was repeatedly failing. The aim was to correct this product failure, which makes it easy to see why they adopted the term problem.

Other textile design process models variously describe the starting point as a trigger, design objective or need (Studd, 2002; Calamari and Hyllegard, 2015; Veja, 2014). The terms trigger or objective more easily fit the earlier description of textile design's aims relating to material and process exploration. Textile design is not alone in its difficulty with the term problem. Dorst (2006, p.17) proposes the idea of "design as the resolution of paradoxes between discourses in a design situation", but accepts that the wide spread vernacular use of the term 'problem' makes it foolish to ignore. This thesis accepts a qualified notion of the design process starting with a problem, but recognises that even within textile design its nature can be radically different depending on the situation.

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[4] The textile design process has also been considered within the apparel design process (Shih, Agrafiotes and Sinha, 2014) or as part of the commercial textile innovation process (Lottersberger, 2012), but these models were developed in relation to commercial innovation and so are not included. Given this investigation focused on interior spaces, models for textiles design within the apparel design process have also been excluded.

[5] LaBat and Sokolowski, 1999 offer an extensive comparison of their own design model with others from environment design, engineering design, industrial/product design and clothing design.

As introduced in Section 1.3, E-textiles are an emerging technology. Their role, unlike the textiles we encounter every day, is still being explored and only a limited range of commercial products exist. A textile designer cannot take the role of an E-textile for granted, it will not simply be a curtain to block out light and prying eyes. If we were to design an E-textile curtain, what would its function be? For Coelho and Maes (2009, p.13), the answer was that it would offer “precise control of ventilation, daylight incidence” and display information. For Flacke (2009), who designed a curtain with electroluminescent cables couched on its surface, it was to provide decorative illumination. As these examples show, questions of function and purpose take on new importance in the design of E-textiles.

E-textiles are also less open to transformation than conventional textiles. The curtains designed by Coelho and Maes (2009) and Flacke (2009) could not be used interchangeably for the purposes each was conceived. They required different constructions and could not be transformed one into the other. By contrast, many fabrics can serve the purpose of blocking out light, whether that was the function they were designed for or not. It is problematic to make an E-textile without first conceiving its purpose, because the requirements for its design are intertwined with the purpose it can serve. The need to define what an E-textile will do presents a distinct starting point from the design of conventional textiles.

Textile designers have explored the possibilities offered by E-textiles without defining their purpose (Veja, 2014; Robertson, 2011), but given the many sustainability issues associated with E-textiles (Köhler, 2013a) this thesis argues it is problematic not to consider purpose. This investigation also gave cause to believe that consideration of purpose in textile design could benefit innovation in the sector beyond the specific area of E-textiles. The mismatch between the conventional textile design process and that of E-textiles documented in Chapter 4 – which details *Design Situation 1* – culminated in the question that subsequently guided the research. It became an inquiry into how purpose can become integral to designing E-textiles. This represents a shift in the nature of the problem being addressed and so requires different inputs and strategies to move through the design process.

2.2 Discussion of design process models

Having qualified the notion of the design problem as the starting point, the following section examines models that have been used to describe the design process. It is worth stating that graphical depictions have imitations and are not the only means of representation. Igoe (2010) created metaphors for textile design thinking and processes, crafted to be open to multiple readings according to an individual designer’s practice and context. The intent of this thesis is not to create a new model, but to provide rich insights that can inform future projects involving emerging material technologies and the design of textiles more generally.

The most common depiction of the design process is a linear series of stages. These models show consensus at the abstract level of the design stages (Gericke and Blessing, 2011; Howard, Culley and Dekoninck, 2008), but at a more detailed level differences emerge as to what occurs at each stage. In their review of design process literature, Gericke and Blessing (2011) concluded that abstracted linear models of the design process can help the planning and management of design. In education they can be used to locate assessment points, as was the case in *Design Situation 3.* However, they also contend that these models cannot represent multidisciplinary design processes as they result in separate flows for the overall design and the design of its parts, that can be understood by considering the layers of design.

The design process, described as a journey from problem to solution, has been depicted in a multitude of ways (Dubberley, 2007; Bobbe, Krzywinski and Woelfel, 2016). The Double Diamond model (Design Council, 2019a) was created in 2004 with the start labelled 'problem' and the end point 'solution'. The most recent iteration is shown in Figure 2-1 and offers a neat depiction, while the Design Squiggle (Newman, 2002), shown in Figure 2-2, visually describes a more disorderly iterative process. The Design Council and others have been clear to state that despite the many models that show linear progression, the design process should be considered iterative (Design Council, 2019b; Howard, Culley and Dekoninck, 2008). Both the Design Squiggle and the Double Diamond show a process that diverges and converges. One in which the many ideas that initially emerge are evaluated and then whittled down to a single solution or, as may be the case for textiles, a range or collection of solutions.

To show the co-evolution of a design problem and its solution, Lawson's (2005, p. 49) illustration of the design process (Figure 2-3) does not depict a starting point or directional flow. However, the role of a designer is ultimately to produce a design response or solution to the situation or 'problem' they encounter. Therefore, the progression and stages shown in linear models of the design process, such as the Double Diamond, can be tentatively accepted, if we acknowledge the stages are not as discreet or sequential as this form of representation suggests and need to be customised according to context (Design Council, 2007).

Creating a design process model that applies across disciplines, noted by Gericke and Blessing (2011), inevitably requires a level of abstraction that removes the details that differentiate them. These models obscure the ways different areas of design to move through the process. For example, textile design and software design create notably different outcomes. Although there may be similarities at a macro level, a more granular view set in context would reveal that the activities conducted at each stage look very different. If the representation of discrete sequential stages is inaccurate and the stages lack detail, then we should expect challenges to arise when different design disciplines collaborate that these models do not describe.

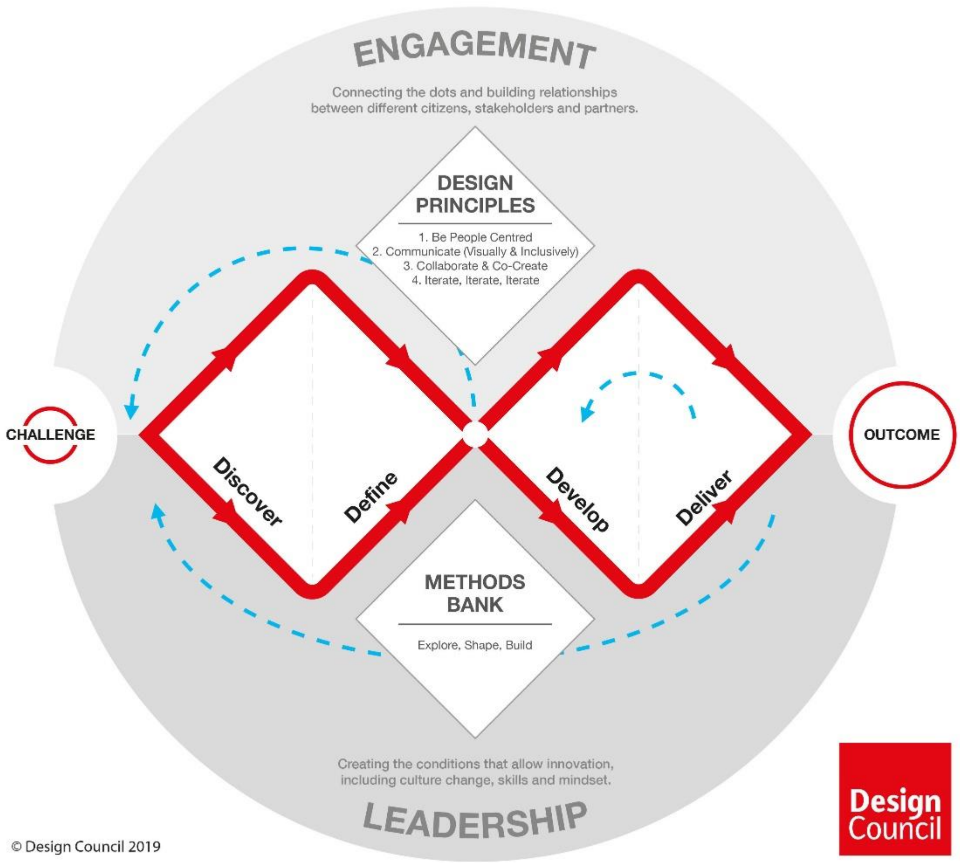

Figure 2-1 The Double Diamond Design Process Model created in 2004 (Design Council, 2019a)

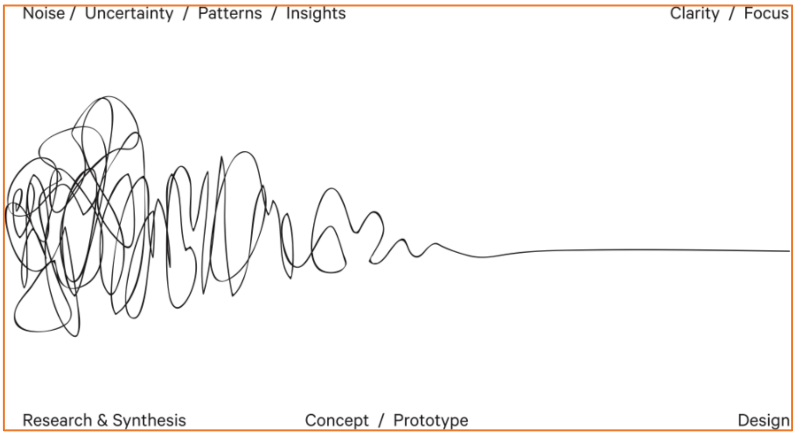

Figure 2-2 The Design Squiggle illustration of the design process (Newman, 2002)

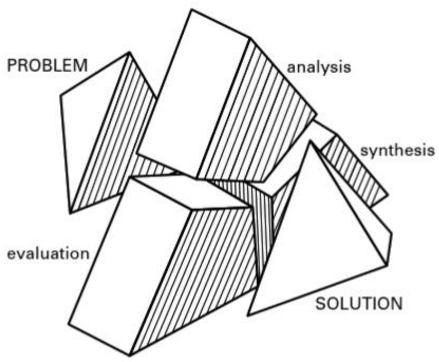

Figure 2-3 Lawson's (2005, p. 49) non-linear design process model

Existing design process models tend to assume the starting point is a customer request or identified market need, rather than an emerging technology looking for applications (Howard, Culley and Dekoninck, 2008; Gericke and Blessing, 2011). Where the driver of design and innovation is not a clearly defined market-need but new technological capabilities, it is described as technology-push (Rothwell, 1994). E-textiles are a host of material and engineering developments, including smart materials, miniaturized and flexible electronics, and the adaptation of these to textiles via printing, embroidery and other textile techniques (Torah et al., 2019; Dias and Paulo Silva Cunha, 2018), that are being pushed in search of applications. As they are an emerging technology, designers must search for the purpose E-textiles could serve or design without a need or purpose in mind. This thesis takes the view that purpose is crucial and explores the gap in understanding where the design process for emerging E-textile technologies is concerned.

Reviewing existing design process models has highlighted several limitations for this investigation. Most importantly, these abstract depictions offer little in the way of practical steps a designer can take to navigate through the process. Additionally, the broad category of E-textiles is inherently multidisciplinary, meaning existing models struggle to capture what is occurring during their design. This thesis addresses these shortcomings by examining the role and strategies textile designers can use to design E-textiles purposefully and produces insights that can serve academia and industry.

The practical level at which this investigation operated, and the other limitations described in this section, mean design process models were of limited use in answering its research question. They did, however, provide general orientation. In *Design Situation 3* the product design tutors used the Double Diamond to locate the project's assessment points and in *Design Situation 4* it served to manage the expectations of the industry participants. This use fits with suggestions that despite their limitations linear stage models, such as the Double Diamond, "are effective for teaching novice designers and for managing the design process" (Gericke and Blessing, 2011).

2.3 Challenges in the textile design process when working with E-textiles

As the previous section outlines, the level of abstraction required for generically applicable models means they do not offer strategies or explain the differences between designing textiles and other artefacts. Therefore, this section will detail in practical terms how textile designers move through the design process and point to the limitations of these strategies when applied to E-textiles.

The starting point of the textile design process is often a brief provided by a client or for students by their tutors, alternatively, a designer may construct their own brief. Using the language of the

Double Diamond model, research to *Discover* a textile design direction can involve: sketching, visits to museums or archives; collecting images from the internet, magazines or photography; examining fabrics produced by others or from a designer's own archive; gathering information about new materials and processes; and consulting trend forecasting resources (Clarke, 2011; Briggs-Goode and Townsend, 2011).

Previous studies of the textile design process show that the main methods used to sort information and define design directions are brainstorming, mood boards and sketchbooks (Studd, 2002; Wilson, 2001; Calamari and Hyllegard, 2015; Clarke, 2011). These tools are employed primarily to develop the fabric's appearance, texture, and handle. Textile designers develop their direction using their understanding of yarns and manufacturing processes, hand sketching, mixed media, painting, or Computer Aided Design (CAD), all informed by tacit knowledge, to deliver designs that meet aesthetic, commercial and technical requirements. Tacit knowledge is a designer's intuitive, unspoken understanding of what direction to take (Mareis, 2012; Igoe, 2010). As previously stated, the user and the product the textile will become are rarely foreground considerations during the process. For this reason, the conventional textile design process can only superficially address the design of E-textiles, which require "temporality, dynamic forms, and acts of use" (Dumitrescu et al., 2018, p.72) to be considered.

Differences between textiles and E-textiles can also be seen in the outputs of the design process. For conventional textiles Studd (2002) and Calamari and Hyllegard (2015) talk of samples and collections being produced, whereas Veja (2014), who was creating woven E-textiles, refers to prototypes. The change of language, from sample or collection to prototype, highlights a key difference between textiles and E-textiles. A sample is a small quantity of a substance or material, whereas a prototype is a model or representation of an object. On its own a sample cannot reveal functional, temporal, or interactive capability. For those aspects to be expressed, it needs to be connected to a power source and other components that together in an organised grouping or system allow the E-textile to function.

A challenge facing those seeking to design E-textiles is the lack of design precedents or references. Design precedents can be past or current products or a designer's episodic knowledge, their personal archive of experience from the projects on which they have worked. Knowledge and understanding of precedents help designers navigate between the problem and solution (Lawson and Dorst, 2009). When creating conventional textiles, designers have a vast array of recent and historical examples to draw upon as inspiration for pattern, structure, or colour. By contrast, there are only a limited number of E-textiles for designers to reference and few people have experienced design them. Textile designers, particularly when first working with E-textiles, need to find ways to move through the process without being conditioned by the few existing precedents. Rather than serve as inspiration, over reliance on this limited range could narrow thinking due to a phenomenon known as fixation (Jansson and Smith, 1991).

The design 'solution' produced by a textile designer following a brief is often not one design but a collection from which a client makes their own selection and textile design education teaches students to produce this type of outcome. In commercial textile design, a client's selection can be based on aesthetics, price, performance criteria, such as abrasion resistance and colour fastness, or any combination of these. Selecting one design does not exclude others from being chosen, but a large proportion of textile designs never go into production. Igoe (2013, p.77) suggests that the fact textile designers create a collection, so offering multiple solutions, gives them greater creative autonomy and freedom to explore. This contrasts with other areas of design, such as architecture or product design, where the drive is towards a single outcome. As E-textiles occupy a liminal space between conventional textiles and devices or products, the outcome of an E-textile design process may also be more focused on a single outcome.

Textiles are complex designed materials with a structural hierarchy of fibres transformed into yarns and then into fabric (Lomov, Huysmans and Verpoest, 2001; Tandler, 2016). They are also, most commonly, destined to become part of another entity. Nilsson's (2015, pp.12–13) research found that the design processes for textiles and the products they become can interact in several ways: construction; alteration; selection; and specification. A new textile can be *constructed* or an existing one *altered* as part of a product design process. Alternatively, once a product has been designed an existing textile can be *selected* or a new textile *specified* to meet the requirements of the product.

Many textiles are selected by a homeowner, product designer or interior designer only when the textile design process is complete. Therefore, the design of the product is not part of the process of designing the textile. A textile designer might know or decide a general area, for example contract upholstery or womenswear, but precisely what the product will be is unlikely to be known. Interior textiles are often presented to potential buyers as a range in a catalogue from which they can select, accompanied by a technical specification. The transformability of textiles means they can be used in a manner for which they were not originally intended.

Where a textile is specified, it is again the product designer, engineer, architect, interior designer, or householder who defines the textile's use, rather than the textile designer. Here the textile designer must respond to requirements once the product's design is near finalised or complete. An example of specification is Anni Albers design of the textile used for the public auditorium of the Trade Union School in Bernau (Fer, Coxon and Müller-Schareck, 2018). Conscious of the space, she created a discreet design using cellophane in the front of the structure to reflect light and illuminate the space and chenille in the back to provide soundproofing (ibid.). The space for which it had been commissioned informed the design of the textile rather than the other way round.

There are many examples of one fabric sold and used across garments, accessories and interiors, the properties and appearance of the fabric serving the intention of the designer that defined its final 3D form. In cases like this, the textile becomes a commodity, a product manufactured by many that is used as a material. By contrast, E-textiles are not simply commodities and so their development requires changes in mentality and working practice. Textile designers should challenge the conventional separation between the design of textiles and products so we can understand the purposes for which we wish to use E-textiles.

The next section reviews approaches taken to the creation of E-textiles, not only by textile designers but also by other areas of design, engineering, and material science.

2.4 The design and development of E-textiles

Most electronic textile research has been conducted from the perspective, as coined by Schön, of technical rationality (1995), using the scientific method to develop and improve functional capabilities, performance, and increasing the level of integration between electronics and textiles[6] (Dias and Ratnayake, 2015). Veja (2014, p. 6) categorises this stream of research as the "technical materials approach", while Berglin (2008, p.16) describes it as being focused on "function and technology".

The capabilities being researched include energy generation, energy storage as batteries and supercapacitors, electrochromism, electroluminescence, electromechanical behaviour, sensors and combinations of the aforementioned described as "multifunctional electronic textiles" (Weng *et al.*, 2016, p. 6158). In this approach to research, technical motivations are often not questioned. For example, stating that electrochromic performance needs to be improved because there is "strong interest for consumer products" (ibid*.* p. 6152), without asking whether electrochromic consumer products are desirable or what purpose they would serve. The challenges this area of research attempts to address include large-scale production, mechanical resistance, washability, and increasing user acceptance through cost reduction, improved reliability, unobtrusive integration and haptic perception of the textile (Zysset et al., 2013; Schwarz et al., 2010; Stoppa and Chiolerio, 2014).

[6] Gauch (2003, p.409) states that the key feature of the scientific method is "that the hypotheses are confronted by data, leading to convergence on the truth about physical reality". For scientific research into E-textiles the truth to be arrived at is the solution to a narrowly defined technical problem, such as how can E-textile wash robustness be improved (Ojuroye, Torah and Beeby, 2019). The success of the solution can be evaluated though repeatable testing, observation and measurement.

Hughes-Riley, Dias and Cork (2018) frame the level of integration between textiles and electronics in terms of generations (Section 1.7). By describing integration in these terms, given that in the development of technology later generations signify increased capabilities and sophistication, they imply that greater integration correlates with improvement. However, they acknowledge that “complete integration of the electronics may […] be unfavourable for sustainability reasons” (ibid. p. 8). They also indicate that the arrival of smart phones has changed the context that motivated the early ideal of systems fully embedded in textiles (ibid.). For the time being these concerns remain peripheral and are little represented in the technical E-textile research literature.

Research by textile designers can have features in common with the technical rationalist approach. Textile designers in industry and academia often use quantitative data, the basis for validation in the scientific method, in combination with qualitative assessments (Glazzard, 2014; Robertson, 2011). The multiple roles of the textile designer as artist, craftsperson, engineer, and programmer play out in E-textile (Robertson, 2011; Veja, 2014; Worbin, 2010) and textile design research (Glazzard, 2014; Taylor, 2015; Tandler, 2016; Matthews, 2013). The difference between the technical rationalist and textile design approach is the overall assessment criteria. Qualitative and aesthetic values are of primary importance in textile design research, whereas technical rational approaches to E-textiles focus on quantitative values such as conductivity or breaking strength.

In developing E-textiles, textile designers often take an artistic concept or material as the starting inspiration rather than an analysis of human needs or aspirations. In common with technical materials researchers, textile designers have explored E-textiles as materials, independent of their ultimate use (Veja, 2014; Townsend *et al.*, 2017). They have also created artistic outcomes where questions of use are more abstract (Orth, 2001; Worbin, 2010; Persson, 2013; Robertson, 2011; Berzowska, 2005). The overall emphasis in textile design research is less on the end-application and user and more on the capabilities of materials and processes (Glazzard, 2014; Matthews, 2013; Philpott, 2011). This means that, as it has been defined in this thesis, it is a process that is *not* purpose-led.

Although E-textiles are predominantly developed using a process from which the user is absent, there are exceptions. Heinzel (2014, p. 1) presents the “methodological model for the development of electronic textiles for smart homes” from the Universal Home Control Interfaces (UHCI) project which adopted Henderson’s (1960) model of needs. During the UHCI project, a methodology emerged comprised of six stages: brainstorming, storyboarding, rapid prototyping, experimental design, parallel design and finally evaluation and analysis. Users were not actively involved, but the researchers brought their perspective into the research process by storyboarding scenarios of imagined individuals living with E-textiles. Heinzel (2014) describes the research as aiming towards HCD, while also applying design creativity from a realist perspective by considering existing uses of textiles and ways of living.

While the UHCI project (Heinzel, 2014) aimed towards HCD but limited user involvement to the sphere of imagination, the MATUROLIFE project actively involved potential and existing users of assistive technology. These participants took part in a series of workshops to generate insights and inspire innovative assistive products using E-textiles (Moody et al., 2019). The motivation to consider E-textiles for this purpose was that assistive technology is often unsightly and leaves users feeling stigmatized. This focus gave a clear user group, providing a pathway to investigate the problems they experienced. In the UHCI project, the user was anyone with a home, too broad a category to identify a group of participant with whom to explore needs (Heinzel, 2014). The challenge to using HCD approaches with emerging technologies is to identify contexts or problems to investigate, for without this it is impossible to know with any clarity who potential users are.

Mazé and Redström (2005) state that when there is a lack of fundamental understanding of an object, because it belongs to a new and unfamiliar category, the study of use cases and user needs has become the method of choice. However, this is rarely the case in the design of textiles and textile designers are not familiar with these methods. A barrier to their adoption in the development of textiles, or E-textiles, is again that whether they are for interiors or fashion textiles are rarely the finished product. As Igoe (Igoe, 2013, p.28) shows, there are two levels of consumption for textiles and textile manufacturers are seldom in direct contact with the end customer or 'user'. Instead, manufacturers and their designers are a link in a supply chain and their direct customer is another business, meaning 'customer needs' are often process related, for example ease of sewing. Key factors that dictate how the user will experience a textile are not defined until the fabric takes its form from the garment it is sewn into or product it is applied to. The lack of proximity to the user means textile companies and designers have limited experience using HCD or user-directed strategies to understand the purpose of their designs.

2.5 The role of designers in the development of smart materials

The following section looks to other areas of design in search of strategies that might be adopted by textile designers to create E-textiles. Designers have been identified as having key skills that can support scientists taking new materials from laboratory to commercial application (Cox, 2005), but what are the specific skills required when working with emerging E-textile technology? For possibilities, this section looks to the area of smart materials, defined in section 1.3, and examines how these possibilities fit conventional textile design practice.

Governments and companies are keen to accelerate the development and commercialisation of smart materials, including electronic textiles, as exemplified by EU funded projects. The

Light.Touch.Matters (LTM) project explored a hybrid of piezoelectric plastics and flexible Organic Light Emitting Diodes (OLEDs) which the project called a 'material' and is shown in Figure 2-4 and Figure 2-5. However, this 'material' would have been better characterised as a component that could light up in response to touch (Tempelman, 2016; Dell'Era et al., 2016). The Solar-Design project investigated novel solar cells (Adamovic, 2016) and the PASTA project examined the design of electronic components and interconnection technologies for E-textiles (De Baets, 2013). Aside from the technical or commercial difficulties, a challenge for the adoption of smart materials is identifying what purpose they might serve. To this end, designers were brought into the LTM project to shift the conventional technical material science approach (Dell'Era et al., 2016).

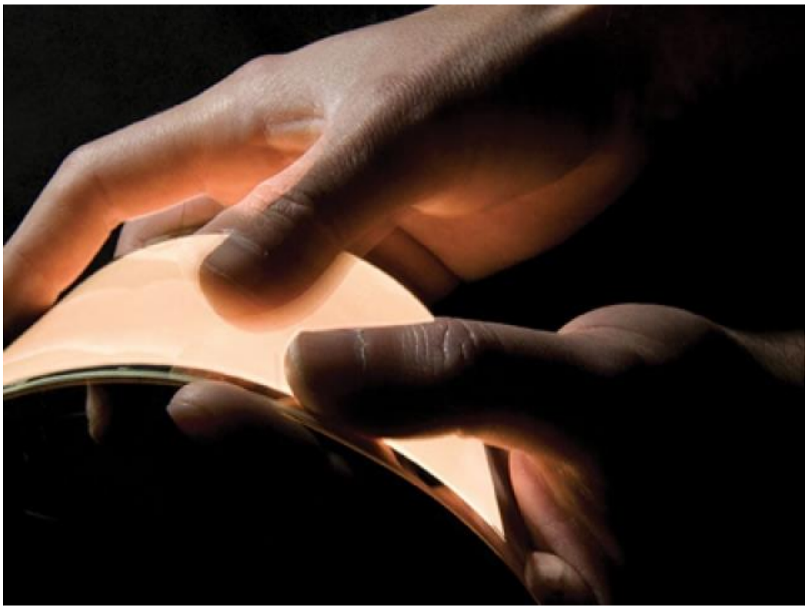

Figure 2-4 LTM composite combining flexible piezoelectric polymers and Organic Light-Emitting Diodes (OLEDs) (Institute of Making, n.d.a)

Figure 2-5 Prototype sensory glove designed to be used to support physical rehabilitation (Institute of Making, n.d.b)

The development of new materials can start where there is a design problem to be solved. The Institute of Making was set up to facilitate the development of materials that “solve real world, complex problems” (Miodownik, 2013, p.458). It combines an extensive material library with a workshop where prototypes can be developed. Using this approach, emerging technologies like E-textiles may eventually find an application, but for a host of reasons, including that no suitable design problem is ever presented, they may remain unexplored and therefore never be adopted.

In relation to flexible electronics, a field which overlaps with E-textiles, Nathan *et al.* (2012) propose seven ways in which designers can support the development of new materials, shown in Figure 2-6. On the LTM project all seven of these contributions by designers were recognized (Tempelman, 2016, p. 7). Additionally, during the LTM project, the designers assisted the material scientists in identifying where technical goals were unnecessary for successful realisation of design ideas, thus avoiding over-specification.

	Design’s support in new material development
1	Assisting in the fabrication and development of models and prototypes
2	Bringing the perspective of users and the marketplace to research
3	Communicating the potential of new technology to stakeholders through visualisation
4	Exploring and demonstrating applications for new technology
5	Identifying routes to commercialisation
6	Providing early insight into practical issues
7	Influencing the research direction
8	Avoiding over-specification

Figure 2-6 Designers’ support of new material development, adapted from Tempelman, 2016.

Items one and two on this list raise the question of how designers working with novel designed materials can identify the problem they wish to address. To make a prototype or bring in the perspective of users requires a prior decision as to the overall design aim. The researchers involved in the LTM project chose to focus on health, well-being and comfort, but the project was ultimately criticised by Wilkes and Miodownik (2018) for failing to bring in the user’s perspective, due partly to its design/material driven orientation, explained in Sections 2.6.3 and 2.6.4.

Similar to the situation I have outlined existing in the textile industry (Section 2.4), in the LTM project “users were broadly conceived of as manufacturing companies or brands that would take up the new materials and products” (Wilkes and Miodownik, 2018, p.12). The project’s primary aim was to speed up the journey of new materials from laboratory to market, leading it to be described as “market-orientated” rather than human or user-centred (ibid.).

It is unclear what initial research led to the selection of health and well-being as the application area for the LTM project. No critique of the direction the project took was published, so it is impossible to know the extent to which it was considered a success. Omitting how this choice was arrived at or any critique of the direction is unhelpful. Communication by the researchers on the LTM project and others developing emerging technologies of the strategies they use to select a direction would be beneficial to researchers aiming to move E-textile design practice forward.

The choice to focus on health and well-being raises several considerations. Manzini and Vezzoli (2008, pp.16–17) describe the concept of well-being as “complex and controversial”. They criticise the predominant view of well-being as boiling down to the equation “well-being = more products”, an equation that is inherently environmentally and socially unsustainable and will ultimately lead to suffering. Had those on the LTM project wished to involve users in the design process, a more defined aim than health and well-being, such as that of the MATUROLIFE project (Moody et al., 2019), would have been required to make the identity of potential users apparent. Finally, in selecting health and well-being other potential areas, such as safety, were ignored.

Returning to the list of ways designers can support the development of new materials (Figure 2-6), analysis of the textile design process in Section 2.4 shows that several items present a particular challenge to textile designers. Regarding item one, textile designers have traditionally produced samples and collections, rather than models and prototypes. In relation to items two and four, textile designers focus on the design of textiles as materials, rather than their application, and the user is absent from the process. This makes it difficult for textile designers to explore applications or bring the user’s perspective into the process unless they change their practice.

As per item five, textile designers have had an important role in the commercialisation of new materials, from Nylon to Tencel. They can transform cheap synthetic fibres into dramatic, natural looking or glamorous fabrics or make delicate natural fibres perform to high performance specifications. Smart materials present new challenges to this aspect of a textile designer’s role because conventionally their skill in this area comes from their understanding of material behaviour. Smart materials, including E-textiles have properties that cannot be felt or seen, such as conductivity, so textile designers need to find new ways to understand them if they are to aid their commercialisation. Textile designers’ reliance on practical knowledge of their craft and focus on materials, techniques, and manufacturing processes may also be a barrier to future envisioning, where the task is to imagine what could be.

Considering item three, textile designers can communicate their ideas through visualisation and have ways, such as half garments (Igoe, 2013, p.76), to create open-ended representations that other designers or users can interpret. Artistic outcomes of E-textile design research (Berzina, n.d.; Loop.Ph, n.d.; Posch and Kurbak, 2018) or E-textiles as ‘raw’ materials (Dumitrescu et al., 2014; Veja, 2014; Robertson, 2011) can communicate the potential of E-textiles. Textile designers also have in-depth knowledge of materials and processes so are well placed to provide insight into practical issues, as recommended by item six. In line with item seven, on the Heat Harvest project, which investigated energy harvesting materials, the textile designer was the first to notice the semiconductor properties of the zinc oxide yarn under investigation, therefore influencing the research direction (Townsend et al., 2017).

In response to the final item on the list of ways designers can support new material development, textile designers can also help to avoid over-specification. Over specification in the LTM project related to the material scientists’ focus on achieving the thinnest possible result, but this was not required for any of the products envisaged by the design team. For E-textiles, avoiding over-specification might relate to questioning the seamless integration of electronics. This technical goal could result in less durable and functional outcomes. It could also relate to less focus on single multifunctional E-textile products, in favour of more deconstructed approaches, such as the wearable “constellations” recommended from the Electric Corset project (Townsend, Kettley and Walker, 2020, p. 100), and in line with the “hybrid systems composed of heterogeneous devices” advocated by Suchman (2002, p.99).

Although textile designers, through their understanding of textile materials and techniques, are well placed to support some smart material development activities, the list also highlights areas that are not routinely part of textile design practice. This section has highlighted what textile designers could do to support the development of new materials, but it has not suggested how these aims might be achieved. Therefore, the next section examines different approaches to design and innovation that could be adopted.

2.6 Orientations in design and innovation

This section discusses several orientations in design and innovation, namely technology push and market pull innovation, HCD, Design Driven Innovation and Material Driven Design. It examines these looking for their strengths and weakness in relation to a purpose-led E-textile design process.

2.6.1 Technology push and market pull innovation

The previous section described the approach to design of the Institute of Making (Miodownik, 2013) and the LTM project (Dell’Era et al., 2016). These examples illustrate the two basic models of innovation: technology push and market pull. The Institute of Making seeks to solve real world problems with the involvement of users (Wilkes and Miodownik, 2018). When the starting point is a need and the solution can be constructed out of whatever material best addresses that need, innovation can be described as market pull (Figure 2-7).

Figure 2-7 Market Pull innovation model (adapted from Rothwell, 1994)

By contrast the LTM project was characterised by a technology push undercurrent, apparent in the project's aim which was to accelerate adoption of the smart material composite being investigated. Technology push innovation, shown in Figure 2-8, is where technological innovation drives the creation of new products. The material in the LTM project came before the problem or need.

Figure 2-8 Technology Push innovation model (adapted from Rothwell, 1994)

Although these models have been used as the starting point for discussion of design strategies for innovation (Giacomin, 2014; Norman and Verganti, 2014; Verganti, 2009), the research collated by Rothwell (1994, p.9) shows empirical studies have found the technology push and market pull models to be "extreme and atypical". Innovation is increasingly not seen as either market pull or technology push, instead the two forces are considered mutually dependent (Di Stefano, Gambardella and Verona, 2012).

In the context of interior spaces, it is hard to think of needs or problems E-textiles address that could not also be constructed from other material configurations, which means working with them is, in some respects, a case of technology push innovation, but as Rothwell asserts reality does not fit neatly into either model. This investigation explored possibilities for an E-textile design process that responds to needs, rather than pushing the technology without a clear purpose, but is caught by the fact that its starting point is a category of technology.

2.6.2 Human-Centred Design

The terms User-Centred Design (UCD) and Human-Centred Design (HCD) are often used interchangeably. HCD is used in this thesis as an umbrella term for a range of design methods that give varying emphasis to the role of users, from subject to partner. Sanders and Stappers (2008) landscape of HCD research illustrates the varied approaches that come under this umbrella and their emphasis with respect to the user (Figure 2-9). In this investigation, designers had to imagine the user, rather than potential users being present in the *Design Situations*. The term user-centred design, as it was first described did not prescribe user involvement in the design process, but prioritised user understanding over the desire to “use a specific technology” (Norman 1986 in Gulliksen *et al.*, 2003, p. 397).

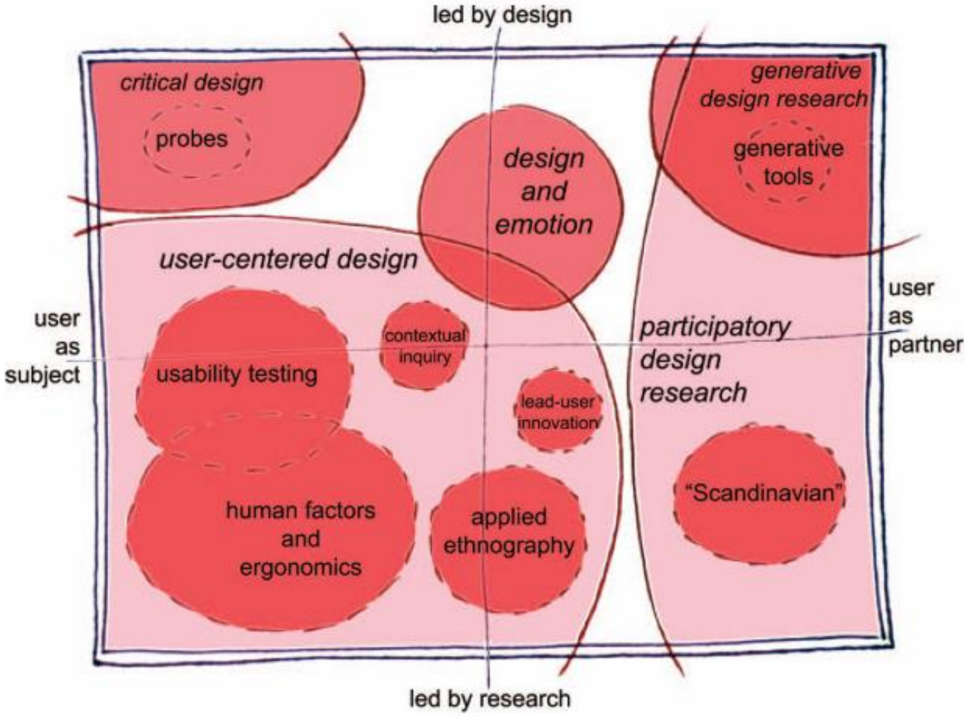

Figure 2-9 Landscape of Human-Centred Design Research (Sanders and Stappers, 2008, p.6)

Norman and Verganti (2014) characterise HCD as market-pull and maintain that it produces incremental rather than radical innovation. Ossevoort (2013) and Verganti (2009) contend that that users can propose improvements to products and services, but struggle to imagine completely new solutions, in particular for latent needs or desires. Yet Giacomin (2014) and van der Bijl-Brouwer and Dorst (2017) present a different reading of HCD. Giacomin (2014) describes the origins of HCD in the fields of ergonomics and computer science where its focus according to Gasson (2003, p.30) was on resolving “predetermined, technical problems”, but moves on to present a model of HCD that is open-minded and challenges constraints. The paradigm of HCD presented by Giacomin (2014) and van der Bijl-Brouwer and Dorst (2017) is based on human behaviours and meanings and uses a broad range of techniques, including ethnography, interviews and role play.

HCD is not without its challenges. To use HCD with an emerging technology, the first step in the process must identify the context and users that the design is intended to benefit. As the role of emerging technologies is yet to be defined, there is often no obvious use case and therefore no apparent users. Moreover, Steen (2011) reminds us of the inherent tension in HCD between the knowledge of the user and that of the designer, and between understanding what exists and envisioning alternatives, new contexts and practices.

When attempting a HCD process to create “smart-textile applications for teenagers”, Ossevoort (2013, p. 411) found that instead of conceiving new ideas, they merely imagined the technologies that the research team had presented to them on a favourite item of clothing. The team’s lack of success does not signify the HCD paradigm cannot produce radical innovation, but that the specific method they used was not suited to the task, highlighting that designers should carefully consider how users are involved in the process. HCD offers designers many tools to examine and understand the context and experience of the people for or with whom they are designing to purposefully conceive design proposals in response.

2.6.3 Design Driven Innovation

Design driven innovation, proposed by Verganti (2009), is a strategy of radical innovation of meaning, which may or may not be accompanied by technological innovation. Examples of this type are the Nintendo Wii, which changed the meaning of gaming into a family orientated exercise activity and the Swatch watch, which changed watches from luxuries akin to jewellery into relatively inexpensive fashion items (Verganti, 2009; Norman and Verganti, 2014).

For Verganti (2009), design driven innovation occurs where a firm works with a network of interpreters able to deliver insights into the world of cultural production and technology outside of the firm. Baha *et al.* (2013) interpret design driven innovation as being guided by the designer’s culture rather than by market and user research or technological invention. It was the approach of choice for both the LTM (Tempelman, 2016) and Solar Design (Adamovic, 2016) projects which investigated smart materials and are discussed in Section 2.5. Textile designers have also cited it as their approach to innovation in industry (Lottersberger, 2012) and to the design of “sustainable smart textile services” (Kuusk, 2016). It is useful when working with emerging technology precisely because in these cases it may not be immediately obvious who the users are to carry out a HCD process.

Norman and Verganti (2014) present design driven innovation as being in opposition to HCD, but closer examination reveals they are not so clearly distinct. Of the extensive list of HCD tools provided by Giacomin (2014, p.616), several have also been used in projects described as design-driven in character. In his book on design-driven innovation, Verganti (2009, pp.36–37) presents the Skyline kitchen designed by the manufacturer Snaidero as an example of design driven innovation. The kitchen was created with wheelchair users in mind (Snaidero, n.d.) and ethnographic research observing user behaviour and collaboration with rehabilitation institutions were part of the design process. If this example is not consider human centred, it would appear that Norman and Verganti (2014) are using a rather limited definition of the field. As this and other examples show, HCD is more capable of producing radical innovation and innovation of meaning than has been argued.

Verganti (2010) also contends that examples of more environmentally sustainable designs, such as electric vehicles, resulted from design driven innovation rather than listening to users. He states that user and market data suggested that "gas-guzzling SUVs" were the vehicle of choice and that users were not interested in low-emission vehicles. However, this is a crude link, as market data and HCD are not synonymous. To suggest users were not interested when these vehicles did not yet exist stretches the point. Yet, the human-centeredness of HCD can be problematic. Focusing on human needs risks compromising the needs of other non-human actors: such as plants, animals and ecosystems, but sustainability and HCD are not necessarily incompatible (Thomas, Remy and Bates, 2017).

2.6.4 Material Driven Design

Materials play a fundamental role in products and architecture, but their inclusion in the design process, partly because of the ease provided by CAD (Oxman, 2010), is often reduced to selection when a design is nearly complete. This has led some to advocate a 'Material(s) Driven' approach (van Bezooyen, 2013; Karana et al., 2015). This thesis uses the term 'material' to refer to the intermediate elements out of which our built environment is created. Tonuk (2016a, p.6) found that what is classified as a material "is contingent upon the stakeholder in the production chain of materials and products". For textile designers, fibres and yarns are their materials, whereas for an interior designer, textiles – the product of the textile designer's process – are the materials with which they create the look and feel of a space.

Karana *et al.* (2015, p.35) developed the Material Driven Design (MDD) method to provide ways "to design for experiences with and for a material at hand" with the aim for the material to "elicit meaningful user experiences". The process consists of four stages: understanding a material through technical and experiential characterisation; creating a materials experience vision; manifesting materials experience patterns; and finally, designing material/product concepts (Karana et al., 2015). It offers an alternative to design processes starting with user needs or requirements.

It supposedly provides a means of designing with materials using questions about what a material "expresses to us" or "elicits from us" as the starting point (Karana *et al.*, 2015, p. 35), but has distinct limitations as a method and for the design of smart materials including E-textiles. The method over simplifies the complex interplay described by science and technology studies between human and non-human actors: manufacturers, designers, consumers and materials (Tonuk, 2016b, 2018; Bijker, 1997). Tonuk (2016b) highlights the fluid nature of what materials are or are viewed as, which rather than a fixed definition depends on their proposed application.

Tonuk (2018, p. 116) examined bioplastics which she calls “materials by design”, borrowing from Küchler’s (2014) description of smart materials. Bioplastics are a diverse and emerging category of materials that are engineered to have specific properties but are at the same time amorphous and able to take multiple forms. We can transform them into a wide range of products, from textiles to tableware. Reflecting on the amorphous nature of materials allows us to see that ‘material characterisation’, the first stage of the MDD process, may be a near futile act because many materials do not have stable characteristics that allow them to be classified (Karana *et al.*, 2015, p. 43). Tandler (2016, p.188) defines conventional textiles as “material systems governed by principles of structural hierarchy”. Depending on the weave, knit, non-woven or braided structure used to assemble fibres into a textile, the same yarn can create distinct sensorial, interpretive (meanings), affective (emotions), and performative (actions) characteristics[7]. The case is even more complex for E-textiles which are multi-material composites, closer to finished products than they are raw materials like cotton.

This instability makes it difficult to create a material characterisation for complex designed materials and systems such as textiles and E-textiles. Where E-textiles are concerned additional components such as batteries and micro-scale devices, not to mention computer programs, work together to form a system. Similarly, the so called ‘material’ investigated during the LTM project consisted of four distinct technological components. During the arc of the project, it became clear that many of what were considered material properties were the result of integrating the four technologies rather than fixed parameters (Tempelman, 2016).

As with E-textiles, many smart materials are still under development which has led them to be described as “underdeveloped smart material composites” (Barati, Giaccardi and Karana, 2018). Karana et al. (2015) recognize that the underdeveloped nature of these material composites also creates challenges for the step of understanding a material described as “tinkering”. The phrase ‘material understanding’ is problematic when, as discussed above, the so-called material is composed of interconnected elements each with its own properties. Direct hands-on exploration of material properties through tinkering with E-textiles is difficult because the elements they are composed of may not be available beyond the laboratory or in sufficient quantities. Textile designers are also unlikely to have a sufficient grasp of electrical properties and programming to explore the possible behaviours of E-textiles fully.

Given the near infinite possible combinations of textiles and electronics and the other challenges I have presented, it is questionable whether material characterisation is possible for smart

[7] The terms: sensorial, interpretive (meanings), affective (emotions), and performative (actions) are taken from the stage of ‘experiential characterization of the material’ of the MDD process (Karana et al., 2015).

materials independent of their use. The components needed to create even a basic E-textile containing LEDs highlights the complexity. To attempt a characterisation, a designer could work with only white LEDs, a 3V coin cell battery, silver-plated nylon and ecru cotton of a specified yarn count to be made by hand weaving, but even then, a wide variety of outcomes would be possible, each with different characteristics.

The material libraries that have popped up around the world are testimony to designers' desire for physical encounters with the vast array of materials now available (Miodownik, 2007). Engagement with materials and processes to understand them can liberate designers, allowing them to think around a problem, but if a textile designer limits the possibilities they envisage for E-textiles to those they can realise, they may not exploit the full potential of the technology.

Alternative methods of material tinkering trialled on the LTM project to increase design understanding of smart materials included referencing other materials, using stand-in materials, augmented video and real-time simulations (Barati, Karana and Foole, 2017). These methods allowed the designers to test ideas while the material was still in development and experiment without support from scientists. However, even if we ignore the problems of characterising complex material hybrids like E-textiles, there remains a gap between understanding their properties, appearance, and behaviour and conceiving the role we wish them to play. Just because a material can, for example, light up in a particular way when pressure is applied does not tell us why that would matter or what purpose we could use it for.

Adopting a material driven strategy with E-textiles risks becoming an exercise in technology push innovation, where any outcomes developed are perceived a success, independent of their purpose. An ethical consideration to using a material-driven design process for E-textiles is that risk causing environmental damage, so we should be cautious in promoting them. Unlike finding uses for waste materials (Karana et al., 2015) they do not reduce resource consumption. Nor do they reduce impact on human health and the environment by providing a substitute for more energy intensive materials. The motivation for developing smart materials, outside of commercial incentives, is unclear and their benefits depend on judicious design. Adopting pervasive computing technologies, which many E-textiles are, is not necessarily benign and can cause harm to people and the environment (Hilty, Som and Köhler, 2004). Karana et al. (2015, p.49) acknowledge the high risk of using a material driven design strategy for smart materials because any transformation of the material that fulfils its "functional affordances" may be considered of worth despite offering little "real value for people and society".

2.7 Directions for a purpose-led E-textile design process

For commercial textile design, and often also textile design education, the human of HCD is present in the design process only in as much as trends, aesthetic preferences and concerns such as sustainability reflect society. The individual that will ultimately encounter the textile, referred to as the ‘user’, is not perceived as an individual but a representative of a market category. This is changing both in education, as shown by *Design Situation 3,* presented in Chapter 6 of this thesis, and across a range of other textile design research projects (McLaren, Stevenson and Valentine, 2017; Hunt, Piper and Worker, 2020), but this change is not without its challenges given the position of textiles as ‘materials’.

If the development of E-textiles is to be more than a technology push endeavour, research into *why* is required - what might be their purpose? The answers to *why* are not found in scientific research to develop new E-textile manufacturing process or materials, but by seeking to uncover meanings, needs and aspirations to conceive their purpose. As will be discussed in Section 3.1, it is only if we understand the purpose for which we are designing that we can weigh the benefits a design brings to individuals and society against drawbacks such as environmental degradation or loss of privacy.

For textiles designers to address the gap between the development of new enabling technologies for E-textiles and the meanings, needs and aspirations, I propose a hybrid approach that sits between design-driven innovation and HCD. The approach is also connected to material driven design, if for no other reason than the origin of textile design as a discipline that creates materials, but does not adopt the thinking of the MDD process proposed by Karana *et al.* (2015).

A similar approach was adopted on the UHCI project where the aim was “towards human-centred design, as well as towards a creative approach to the design process” (Heinzel, 2014, p.8). In this investigation, like the UHCI project, no users were actively involved because in all but *Design Situation 3* the starting point was the extreme of the fuzzy front end, where the user is unidentified. At the fuzzy front end of the design process described by Sanders and Stappers (2008) the nature of the deliverable is unknown and the questions are open ended. The design methods chosen encouraged the textile and other designers that took part to put themselves in the shoes of the user using empathy and reflection. The *Design Situations* interrogated the possibilities that might exist for E-textiles in transport, domestic and non-domestic interiors to envisage a purpose, focused on people and place rather than materials and technology.

3 THEORY AND METHODS

The research described in this thesis had two distinct phases which this chapter will outline. Phase one, while I was employed at Company X, was integrated into the whole as *Design Situation 1* and served as a diagnostic step in the research. It allowed me to identify the question: **How can the textile design process be adapted to create a purpose-led process of designing E-textiles for interior spaces?** This question steered phase two, consisting of *Design Situations 2*, *3* and *4*. Each *Design Situation* is described in a dedicated chapter, starting with *Design Situation 1* in Chapter 4. It is important to note that between the two phases I worked as a research assistant on a project, funded by NTU, that examined E-textiles and sustainability[1] (Wickenden, McLaren and Hardy, 2019; Hardy, Wickenden and McLaren, 2020). This separate project developed in parallel and contributed to the critical perspective on E-textiles of the thesis by highlighting the likely negative environmental consequences of their adoption.

The methodology adopted to integrate the two research phases is a hybrid of action research and case study research. This chapter will explain the rationale for this hybrid. The empirical work consisted of four interconnected *Design Situations* depicted below in Figure 3-1. It focused on the steps by which a textile designer moves a design proposal from not existing to existing, specifically those which in the double diamond model (Design Council, 2019a) occur in the Discover and Define stages. The early stage of the design process is also known as the fuzzy front end. It is a point in the process where the nature of the design outcome is unclear and is an opportunity to ask open-ended questions (Sanders and Stappers, 2008, p.7). For example, in *Design Situation 3* the question was, how might we improve the experience of Micro-Living? This thesis views the design process from within the constructivist paradigm, aligned with Schön's view of design as a "reflective conversation with the situation" (1992, p.4).

[1] The 'E-textiles and sustainability' project was initiated by NTU researchers Dorothy Hardy, who at the time was a research fellow with the ATRG and Angharad McLaren Senior Lecturer in Textile Design and former Research Fellow on the DEFRA funded clothing longevity project. Under their guidance, I conducted a literature review of E-textiles in relation to sustainability, a product review and product teardowns. I presented the research outcomes at PLATE 2019 (Product Lifetimes and the Environment) conference held in Berlin and the team subsequently developed the research into an article published in the Journal of Cleaner Production (JCP).

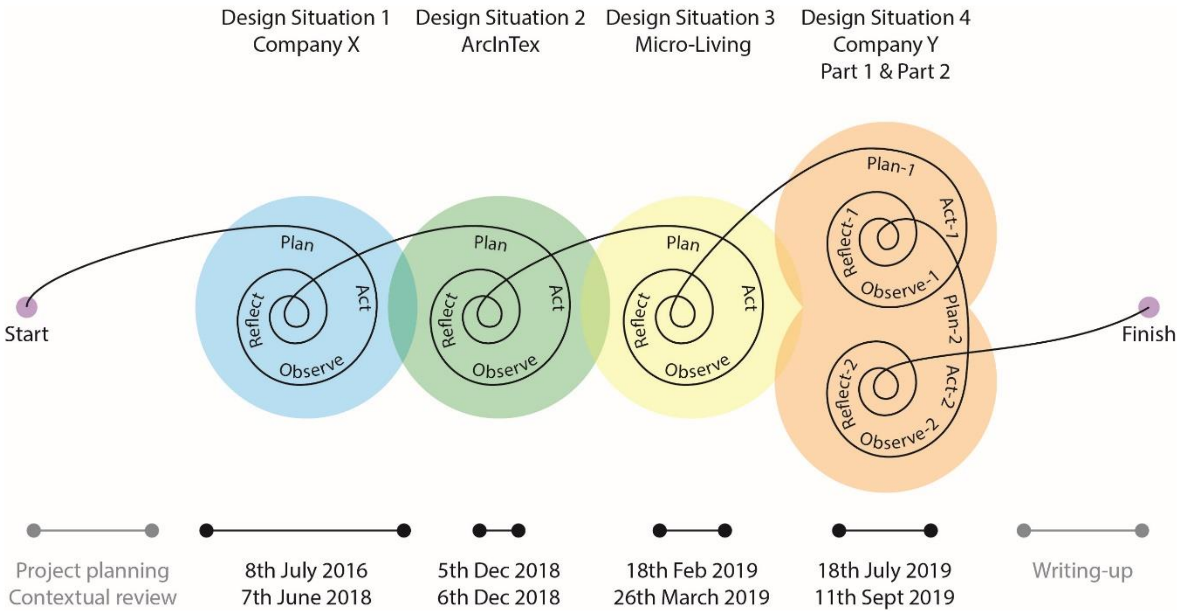

Figure 3-1 Diagram of the hybrid action and case study research methodology

In Figure 3-1, the thread of the investigation is shown starting outside *Design Situation 1* while I reviewed the context and planned phase one of the project. As depicted, each *Design Situation* can be defined as a case with set boundaries in terms of context and participants (Flyvbjerg, 2011), but the cases are connected through cycles of planning, acting, observing and reflecting. The thread of the investigation moves from one *Design Situation* to the next, and in *Design Situation 4* between its two parts, illustrating how reflection on one *Situation* or part informed those that followed. This depiction has parallels with the "generative transformational evolutionary process" spiral presented in McNiff and Whitehead (2001, pp.56–57). The *Design Situation*s are depicted in the style of a Venn diagram to represent the boundaries of the *Situations* which define each as a unit of study, common ground between them and temporal overlap in their planning.

3.1 Inquiry Paradigm

This research adopted a constructivist inquiry paradigm, claiming knowledge built around individual subjective understanding of phenomenon produced by human consciousness in a social context (Lincoln, Lynham and Guba, 2011; Costantino, 2012). It focused on knowledge constructed by the individual, in contrast to what Schön (1995) terms 'technical rationality', the positivist epistemology adopted by science and engineering researchers to develop and perfect the performance and functionality of E-textiles, for example Satharasinghe, Hughes-Riley and Dias (2018) and Ojuroye, Torah and Beeby (2019). The ontology of the constructivist paradigm is relativist, hence this thesis makes its claims not based on an external objective reality, but on one that is local, specific and constructed during the research process (Lincoln, Lynham and Guba, 2011). In using the constructivist paradigm, the criteria by which to evaluate this research are not repeatability or objectivity, but authenticity, credibility and trustworthiness (Costantino, 2012).

The *Design Situations* were 'real world' settings rather than a laboratory environment or randomized control trial (Robson and McCartan, 2002). Although I was the architect of elements in the *Design Situations*, this investigation was nonetheless a naturalistic inquiry consistent with the constructivist paradigm. This research aimed for insights transferable from the *Design Situations* out of which they emerged to other design contexts, as opposed to generalizable findings. Its contributions are both theoretical insights and, of importance to me as a practitioner-researcher, practical strategies that can be used by textile designers when engaging with emerging E-textile technology.

The research design was flexible rather than fixed (Robson and McCartan, 2002, pp.4–5), meaning it was not fully specified prior to starting the empirical work. Flexibility in the research's design meant that I could benefit from opportunities that arose, detailed in Section 3.2.1. I responded to my observations in each *Design Situation* and planned subsequent interventions through reflection on my developing understanding.

Design research has been defined as distinct from that of the sciences or humanities (Archer, 1979), but as a young discipline it is still formulating its methods, borrowing and adapting from others or constructing its own (Gray and Malins, 2004). Sometimes for the task at hand it is necessary to make your own tools. Posch (2018) found that neither the tools used to make and test textiles nor those from the electronics domain were adapted to the particularities of E-textiles. This prompted her to design tailored alternatives, one of which is shown in Figure 3-2.

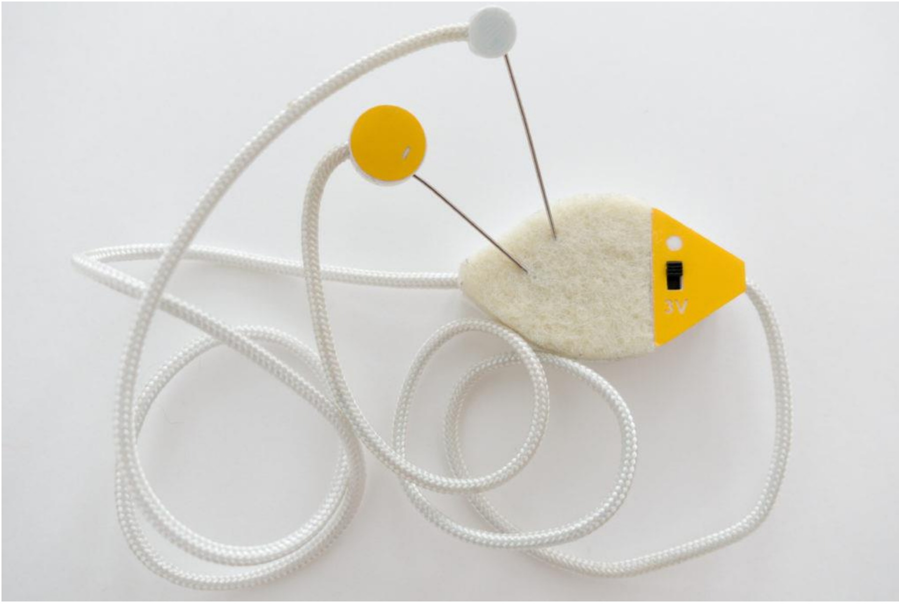

Figure 3-2 E-textile circuit continuity tester (Posch, 2018)

From a research perspective the French word bricolage, which translates as do-it-yourself, is used to denote the adoption of “methodological processes as they are needed in the unfolding context of the research”, rather than adhering to a given structure (Kincheloe, 2001; Kincheloe, McLaren and Steinberg, 2011, p.168). Consistent with the constructivist paradigm, I used bricolage to construct the methodology that best fit my research question and the particularities of studying the design process for emerging E-textile technology. To use Jonas’s (2001, p. 79) term, this thesis is primarily a study “*for* design” to create insights that textile designers might use. It aims to envisage a new form of textile design practice, making an ‘off the peg’ methodology a poor fit.

My role in the investigation was that of practitioner-researcher (Robson and McCartan, 2002, pp.219–220). It was not, as commonly found in design research, a practice-led or practice-based investigation where the role of the researcher coincides with that of practitioner primarily or entirely through the researcher’s own design practice (Gray and Malins, 2004, p.21; Pedgley and Wormald, 2007). Although my practice contributed to the insights developed in this thesis, I have also observed other textile designers as a counterpoint to my subjective and critical view of E-textiles. In *Design Situations 2*, *3* and *4*, my role, besides that of researcher and practitioner, was that of facilitator and educator. In common with other textile design researchers (Igoe, 2013, p. 20; Twigger Holroyd, 2013, p. 36), I locate myself in the research through the use of the first person. Besides my voice, the accounts of the *Design Situations* contain the words and actions of others. This is consistent with Lincoln, Lynham and Guba’s (2011) outline of the use of mixed voices in constructivist research.

As a practitioner-researcher I was both “inquirer and respondent” (Lincoln, Lynham and Guba, 2011, p.124). I had to turn the lens of inquiry not only on my participants but also on myself through reflexivity and introspection, a process of self-examination. Extending the idea of reflection found in action research, Schön (1995, p. 29) argued for an epistemology of practice based on reflection in and on action. He suggested that such an approach was more adapted to situations of “uncertainty, complexity, uniqueness and conflict”, also traits of design problems, than what he termed “technical rationality”. To be reflexive meant questioning my views and the conventions of my practice. I mark the major decision points in the research to explain the path I chose and my account of the process is reflexive and incorporates critique.

My interpretation of data was informed by the hermeneutic circle which expresses the idea that to understand the whole one must understand the parts and vice versa (Schmidt, 2006b; Willig, 2017). The concept of the hermeneutic circle, acknowledges “the impossibility of approaching a phenomenon without adopting a particular perspective in relation to” that phenomenon (Willig, 2017, p.276). This initial perspective is the researcher’s pre-understanding (Alvesson and Sköldberg, 2009). This approach to interpretation and its implications for the research are expanded in Section 3.3.

Part of the pre-understanding I bring to the research is my concern about the “adverse impacts of these emerging technologies [smart textiles] on the environment, human health & safety, and sustainability” (Köhler, 2013a, p.73). These impacts include the creation of large volumes of unrecyclable, unrepairable waste (Hardy, Wickenden and McLaren, 2020), consumption of critical raw materials (Köhler, 2013a) and yet to be fully understood hazards generated by the use of nanoparticles (Bundschuh et al., 2018). Designers cannot escape that the decisions they make regarding what constitutes good or bad design can also be ethical choices (Manzini and Vezzoli, 2008). I cannot therefore take a dispassionate view that would allow me to explore processes and techniques to create E-textiles without trying to understand why and how they might be used, and their impact at end of life.

In Hardy, Wickenden and McLaren (2020), we recommend considering the notion of ‘value verses impact’, where ‘value’ is an ethical question about what is good and ‘impact’ refers to the negative environmental consequences of a design. The thesis adopts a pluralist perspective of value, where value is not reducible to a single notion, and well-being, happiness and liberty can all be considered (Mason, 2018). This is consistent with the different values addressed in the Handbook of Ethics, Values and Technological Design (van den Hoven, Vermaas and van de Poel, 2015) and fits Dilnot’s (2019) assessment in Tricky Design: The Ethics of Things, of the complexity, contradictions, tensions and uncertainties designers face. The point made by the relational model, shown in Figure 3-3, is that *if* the purpose of an E-textile is unknown, we have no basis to reflect on either its value or its environmental impact.

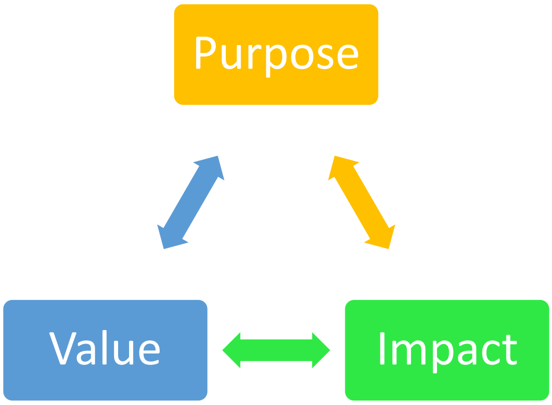

Figure 3-3 Purpose - value - impact relational model

This model is linked to the consequentialist view that “what is best or right is whatever makes the world best in the future” (Sinnott-Armstrong, 2019). Economic welfare is arguably the predominant ‘value’ driving national and multinational innovation policies (Bryden and Gezelius, 2017), as implicitly expressed in Schwarz *et al.’s* (2010) roadmap on smart textiles, but focus on measures of economic welfare, such as GDP, cannot resolve the current state of unsustainability that is bringing about climate change and the collapse in biodiversity.

Let me provide an example of how the model might aid reflection from outside the field of textile design. Helium is an essential element for medical Magnetic Resonance Imaging (MRI) scanners and other lifesaving medical purposes (Berganza and Zhang, 2013) but the supply of helium is at high risk[2] (Royal Society of Chemistry, 2020). Given the status of helium as a critical raw material, it is easy to argue that its use for the non-essential purpose of entertainment, in balloons and other novelty items, will not improve well-being in the future, given its use in these items could threaten the availability of MRI. If we apply the United Nations’ definition of sustainable development, which is to meet “the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987), helium should be used responsibly to conserve its supply for the well-being of future generations.

E-textiles can also contain critical raw materials (Köhler, 2013b), the irresponsible use of which could compromise the ability of future generations to meet their needs. Some uses of E-textiles arguably fall into the same category as helium-filled balloons. For example, Christmas jumpers, which have already been linked to plastic pollution (Smithers, 2019), can contain electronic components (Hardy, Wickenden and McLaren, 2020) and offer little more than novelty. If used for

[2] Finite reserves of natural gas, comprised of up to 7% Helium, are its primary source. Although Helium is found in our atmosphere, its extraction from the air is uneconomical, leading to its supply being classified as critical (Royal Society of Chemistry, 2020).

fleeting novelty, surely their impact outweighs their value. In contrast, the use of E-textiles in large area sensing systems that detect falls and safe lives (Köhler et al., 2012), has a much stronger claim to value in terms of well-being so a different overall assessment might be made.

The model serves not as a resolution of the relationship between purpose, value and impact but a starting point and a prompt to consider the value of a purpose and how the impact of a design created to serve that purpose might be mitigated. The discussion of the ethics of innovation, taken up by Bryden and Gezelius (2017), is outside the scope of this research, but their work highlights that reflection on the model is not the responsibility solely of designers. The aim of this thesis is to demonstrate how purpose – in this context, the role an E-textile aims to fulfil – could become a leading force in the E-textile design process, thereby expanding the focus of designers beyond materials and technology.

This thesis identifies purpose as a missing or overlooked element in the conventional textile design process and indicates the need for its integration where emerging hybrid technologies of textiles and electronics are concerned. It examines the strategies and roles available to textile designers so that purpose can become an integral part of their design process.

I have presented the constructivist epistemology and relativist ontology of this thesis, my position as a practitioner-researcher, the framework used to interpret the research and clarified its criticality so my reader may appreciate the vantage point on which it stands. The next section details how the research was constructed and carried out.

3.2 Research design

As laid out at the beginning of this chapter, the research had two phases. In phase one, the research was bound to my employment at the automotive textile manufacturer that I refer to as Company X[3]. The condition which made it possible for me to undertake part-time study was that the research was relevant to the company. I intended to complete the investigation as an MPhil, the title of which was, ‘A design investigation of E-textiles for automotive interiors’. As will be expanded in Section 3.2.2, in this phase the research was intended as a practice-led investigation of E-textiles that examined their performance, manufacturing, functionality and aesthetics. The configuration of my supervision team was also different, with greater emphasis on the fields of textile and electronic engineering. Phase one ended when I left Company X. I had obtained a scholarship from the Midlands Four Cities (M4C) doctoral training partnership funded by the Arts and Humanities Research Council (AHRC) and I no longer had an obligation to Company X. When I applied for funding, a new multidisciplinary supervision team was formed, with expertise in

[3] Due to confidentiality.

product, fashion, and textile design as well as E-textile engineering. This marked the start of phase two and shifted the emphasis from an engineering informed study to one focused on design. The next section describes action and case study research in relation to design and then details the hybrid approach of this investigation and the role of design practice within it.

The basic principle of action research is that it consists of iterative cycles of planning, action, observation, and reflection to bring about change. It has a long history outside the field of design (Adelman, 1993) and is widely used “in the fields of education, social care, health services and community development” because it is “uniquely suited to researching and supporting change” (Given, 2012, p. 5). In practical disciplines, including design, it is attractive for its ability to bridge the gap between theory and practice. It is also a flexible methodology that accommodates qualitative and quantitative data, which made it appropriate for both the engineering orientated and design aspects of phase one.

Change and iteration are also characteristics of the design process, which has been likened to that of action research (Swann, 2002). Phase one was planned as a practice-led investigation, meaning that its aim was to create knowledge through the study of design practice (Pedgley, 2007). A format termed “research *through* art and design” by Frayling (1993, p. 5). Frayling (ibid.) identified three ways that research *through* art and design can be conducted and one of these is action research. Action research is conducted “through the medium of practitioner activity” (Archer, 1995, p.10), which allows designers to use it to research their own practice, as exemplified by textile designers Lottersberger (2012), Veja (2014) and Ballie (2014).

Had I stayed at Company X, where *Design Situation 1* took place, and aimed to advance E-textile design practice within the company, the investigation would have sat squarely in the camp of action research[4]. However, in researching four different cases of action, it was not possible to evaluate and refine interventions in their original context. Instead, each *Situation* described in this thesis can be viewed as a unit of study, a case with set boundaries (Flyvbjerg, 2011). The emphasis on change and the use of reflection on the previous *Situations* to plan those that followed provided an action orientation. It is this orientation that informs my labelling of each of the interventions a ‘*Design Situation*’ rather than a case.

Case study research, according to Flyvbjerg (2011), is less a decision about methodology than a definition of the object of study. Flyvbjerg advocates the Merriam-Webster dictionary (2020)

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[4] Ballie (2014) also carried out four types of interventions with different participants and in different contexts, but each intervention was trialled through multiple iterations in keeping with action research methodology. Her investigation combined textile design practice with social media in interventions with the aim of supporting sustainable fashion practices.

definition of a case study as, “an intensive analysis of an individual unit (as a person or community) stressing the developmental factors in relation to environment”. Case studies can be carried out using quantitative, qualitative, or mixed methods. Flyvbjerg (2011) and Yin (2012) argue in favour of case study research, challenging the perception that it is “a method of last resort” (Yin, 2012, p.5). Valentine, Bletcher and Coulson (2014) point out that disputes concerning the status of case study research outlined by Flyvbjerg (2011) and Yin (2012) are heavily tied to broader debates regarding the legitimacy of different research paradigms[5]. That is between the objectivity of technical rationality and subjectivity of constructivism.

Parrillo-Chapman (2008) used case studies in combination with the Delphi method to create a process model aimed at improving design and development of textile design engineering within the shape of a product[6]. Two of her case studies were of E-textile products. One was a seamlessly knitted heated garment produced for the brand WarmX and another, a woven cut and sew garment for the military. As a result of her investigation, and in addition to her design process model, Parrillo-Chapman provided some recommendations for practice, such as “refinement of design software” (2008, p.196), but the Delphi method and conventional case study research are suited to understanding an existing process. They analyse the state-of-the-art, but they do not create and test something new, such as a purpose-led E-textile design process. Nor are they directly connected to the practice of the participant(s). These methods can serve as the basis for recommendations, but do not explore their implementation through action.

As an alternative to either case study or action research, Nilsson (2015), Persson (2013) and Bang (2011) defined their doctoral investigations as ‘programmatic design research’ (Bang and Eriksen, 2014; Binder and Redström, 2006). In this style of research multiple design ‘experiments’ are grouped around the core idea of the ‘program’. It offers an alternative way to acknowledge and elevate the projective and interventionist nature of design for the purpose of research. My research had parallels with programmatic design research. For example, it used multiple *Design Situations*, which could be viewed as experiments, to answer its research question. However, programmatic design research was developed as a framing of research *through* design (Frayling, 1993; Bang and Eriksen, 2014). Programmatic design research accounts less well, compared to the hybrid methodology described, for the critical stance of this investigation and its oscillation between examining my practice and observing that of other designers.

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[5] For further insight into these debates see (Lincoln, Lynham and Guba, 2011).

[6] The Delphi method involves interviewing subject experts and has been described as a useful tool where there “is incomplete knowledge about a problem” (Skulmoski, Hartman and Krahn, 2007, p.1).

In her research ‘program’ investigating the relationship between the product design and textile design process, Nilsson (2015) supplemented her practice-based research with a qualitative investigation of a semester long product design masters course in which she was an "observer-as-participant” (Baker, 2006, pp. 175–176). As in my investigation, Nilsson (2015) assumed that the foundations for professional practice are laid during a designer’s education. The students from a variety of undergraduate design disciplines, most who had no prior experience working with textiles, were tasked with designing a textile product. The data from the project took the form of field notes, recordings, photographs and the students’ reports and was analysed using the phenomenographic method described by Marton and Booth (2009, pp.110–136). Nilsson’s (2015) diverse research, in which she also designed smart and 3D printed textiles, was held together by the program which was the frame of her investigation. In this way she developed two practice related outcomes, in the form of designed textiles, and a theoretical framework to illustrate the intersections between textile design and product design.

Nilsson’s (2015) investigation provides an example of how a researcher’s design practice can be combined with observation of other designers to answer a research question. Similarly, this investigation is bookended by my practice, but observing other designers has played a vital role in its development. The workshop that I created for part one of *Design Situation 4*, was a result, as illustrated by Figure 3-1, of my reflection on the preceding *Situations*. I had observed other designers working with a range of strategies, outlined in Chapters 5 and 6, which I then put into practice.

Nilsson (2015, pp.16–17) shows her awareness of sustainability issues by suggesting, in her introduction, that a better understanding of the process by which textiles become products could lead to textiles being used more appropriately, thus generating longer lasting products. However, following her introductory statement, she does not develop her position in relation to the environmental issues she presents. My concern about these issues is the reason the focus of this research is not on the physical process of making E-textiles, but on how textile designers might lead their process by purpose to rationalise *why* an E-textile should be created.

Like action research, case studies are a mode of inquiry that can explore “the space between the world of theory and the experience of practice” (Breslin and Buchanan, 2008, p. 36). For this reason, Breslin and Buchanan (ibid.) argue that case studies should play a greater role in design research and education while warning that they risk becoming “self-promotion articles” (ibid. p. 37). The critical position of this thesis guards against this tendency, but case study methodology alone struggles as a container for the projective and future orientated nature of design (Valentine, Bletcher and Coulson, 2014; Chow, 2008). Unlike action research, case studies examine that which already exists rather than explore its alternatives. Therefore they do not traditionally contemplate action by the researcher directed at change. Therefore, this thesis proposes a hybrid of action and case study research that accounts for the bounded nature of each *Design Situation* and their projective action orientation.

The various stages of this investigation are referred to as *Design Situations* to capture what Kimbell describes as the "messy contingent combination of minds, things, bodies, structures, processes and agencies" involved in design (2012, p.141). Following the distinction drawn by Baskerville (1997), the *Design Situations* were not impartial case studies which I observed as a 'fly on the wall'. Instead, in the hybrid of action and case study research used, I actively planned and introduced change into the research context. The choice of the term *Design Situation* also draws on the work of Schön (1983, 1992) who described the act of design as a "reflective conversation with the situation". Each *Design Situation* comprised a distinct context, actors, and duration and has a dedicated chapter in this thesis[7]. Reflection on what had occurred was significant in planning subsequent phases of action, as illustrated by Figure 3-1. In *Design Situation 4,* I returned to a context selected for its similarity to *Design Situation 1.* Here I assessed an adapted combination of the strategies previously used. This investigation did not stay with one context developing ever greater understanding, rather the research was constructed to develop and test insights across the boundaries of each of its four *Design Situations*.

3.2.1 Selection of the *Design Situations*

Selection of the bounded unit of study or case is an important step in case study research. The selection of the four *Design Situations* has parallels with purposive or judgement sampling combined with heterogeneous or maximum variation sampling (Etikan, Musa and Alkassim, 2015; Marshall, 1996). Purposive or judgement sampling is where the researcher uses their knowledge of their subject and judgment to select which cases to include. Heterogeneous or maximum variation sampling involves selecting cases *because* they are different in some dimension (Etikan, Musa and Alkassim, 2015; Flyvbjerg, 2011, p.307). In this research the participants belonged to different groups: industry, academics, and students, which allowed the research question to be examined from different angles. In practical terms, each *Situation* was chosen because it consisted of textile designers envisioning and producing E-textiles for interior spaces[8]. *Design Situation 1* was the given starting point of the research, but also fitted the selection criteria. By

[7] I use the term actors, not in the manner of Actor Network Theory (ANT) to denote the human and non-human elements in a network (Latour, 2005; Ingold, 2008), but to refer to the people whose actions contributed to each of the *Situations*.

[8] During phase two of this investigation, I facilitated other workshops involving textiles designers at MA and BA level working with E-textiles, but as these did not fully meet the criteria outlined, they were not included in the thesis.

investigating *Design Situations* in academia and industry, the transferability of the insights developed was tested during the research process.

The research, as recognised in Section 3.1, was also flexible in its design and responsive to opportunities. I was invited to run a workshop at the three-day event "Knitting the Gap: Textiles meets Architecture meets Textiles" held at NTU in December 2018 (Nottingham Trent University, 2018). The event, which became *Design Situation 2*, was the perfect forum for my research and allowed me to plan a workshop that met all the selection criteria. The workshop fused the design of textiles, interior spaces and future interactions involving electronic and computational technology.

Design Situation 3, detailed in Chapter 6, was also a result of an opportunity. In 2019 NTU were piloting collaborative cross-disciplinary projects and the BA Textile Design Principal Lecturer instigated one such collaboration. The project was a six-week elective for 2nd year product and textile design students that took place in Spring 2019. The textile and product design team set the project topic 'E-textiles for Micro-Living' prior to my involvement as its facilitator. My influence over the project's structure was restricted to seven dedicated sessions for the students that chose the elective. As with *Design Situation 2*, *Design Situation 3* – the Micro-Living project – met my selection criteria for the investigation. My role was part observer of an education case study and part that of a participant in an action research intervention, in which I learnt as much about my textile design practice as the students that took part.

Planning of *Design Situation 4*, which took place in July 2019, started in late 2017 during the transition from MPhil to PhD. The exact format of the intervention and legal agreements to allow the collaboration to take place were negotiated between NTU's legal department, myself, and Company Y over a period of approximately one-year. The form *Design Situation 4* ultimately took was built from observation and reflection on the previous *Design Situations*. It met the selection criteria previously described and permitted me to bookend the investigation by revisiting a similar context to *Design Situation 1*. It brought my textile design practice back into focus and tested the insights advanced by this thesis.

The next section outlines the strategies chosen for data collection and interpretation that led to the insights into a purpose-led process of designing E-textiles that are the findings of the thesis.

3.2.2 Phase One

During the two-years of phase one, ultimately integrated into the investigation as *Design Situation 1*, I was a part-time researcher and full-time employee, initially intending to complete an MPhil. The initial 'research *through* design' project aimed to investigate the possibilities for E-textile illumination in vehicle interiors along four interrelated strands: performance, manufacturing, function and aesthetics. ‘Performance’ related to the evaluation of physical durability and electrical and light emission properties. I planned to measure the abrasion resistance and tensile strength of any E-textiles produced, as well as their conductivity, brightness and other properties relevant to their intended design. An additional challenge for those designing E-textiles is the incompatibility of the manufacturing processes of textiles and electronics, explained in Section 1.8. The aim of the ‘manufacturing’ research strand was to evaluate the extent to which E-textiles for automotive interiors could be produced using industrial machinery. These first two strands are evidence of the influence of technical rationality on the first phase of the research and relate to problems that can be clearly defined and measured quantitatively.

Tandler (2016, pp.7–17) draws a dividing line between textile design and textile related science, technology and engineering (S-T-E). She suggests that textile design relies on qualitative evaluation, while S-T-E make use of quantitative data. Tandler’s (ibid.) view that textile design is separate from textile engineering may be a fitting description for some forms of textile design practice, such as Kettley’s (2016a) description of ‘studio textile practice’ closely connected to art and craft. It does not, however, fit my professional practice nor the process of designing interior textile products reported by Calamari and Hyllegard (2015). In the design process examined by Calamari and Hyllegard (ibid.) and that of automotive textiles covered in *Design Situation 1*, qualitative and quantitative data both play a role, making quantitative analysis part of the initial research construct.

My first qualification is a Bachelor of Science degree (BSc.), but not in textile engineering, in textile *design*. In contrast with Tandler’s (2016) separation of design and engineering and aligned with my academic and professional experience, as argued in Section 1.6, textile design is multidisciplinary (Moxey, 1999; Glazzard, 2014; Kettley, 2016b; Gale and Kaur, 2002, p.37). It is more accurate to say that there is a continuum between textile design and engineering. In phase one, my supervision team was aligned with what Schön (1995) terms technical rationality. The researchers of the ATRG use rigorous controlled experimentation to develop the technical possibilities of E-textiles. However, accepting the idea of a continuum from design to engineering, my practice sits between the two extremes.

An area of E-textiles in which the automotive industry and its textile suppliers have shown interest is capacitive electrocardiogram (ECG) measuring to monitor vehicle drivers (Wagner, 2013; Eilebrecht et al., 2011). The ATRG have conducted research to develop “design rules for a nonintrusive, textile, heart rate monitoring system” (Hughes-Riley et al., 2020), but the technical competencies for this type of research lie beyond my technical capabilities and knowledge of electronics. In phase one, I examined a combination of defined properties of E-textiles relating to manufacturing and performance and the unquantifiable qualities of aesthetics and function. In structuring phase one I did not completely ignore the unknown quality of E-textiles as an emerging technology, discussed in Section 1.3. The Inclusion of ‘function’ in the initial research design reveals my implicit awareness, to use Suchman’s term, that E-textiles have yet to ‘stabilise’ (2002). The investigation did not explore a pre-determined use case and therefore why E-textiles might be desirable became an important question. I did not, however, appreciate at the start of *Design Situation 1* the centrality the question *“why’?”* would gain.

The inclusion of a strand relating to function was also a recognition that to be adopted in the automotive industry, an E-textile for illumination would have to be in some way superior to existing interior lighting components. This might be a lower price or longer lasting product, but it could also be new functional possibilities, giving lighting a reimagined role in vehicle interiors. Finally, the strand relating to ‘aesthetics’ was to explore the possibilities of light as an element in textile design and the visual and tactile possibilities of its combination with textile fibres.

In phase one, I engaged in E-textile design activities which included weaving textile samples on industrial machinery using LED E-yarns produced by NTU’s ATRG and conductive yarns. I connected these samples to different microcontrollers to explore the samples’ functionality. The outcomes of these experiments were subjected to various types of testing under the performance strand of the research. The testing included standard automotive procedures and light measurements using a purpose-built rig for the LED E-yarns. Alongside these quantitative assessments, I documented the experiments in a research diary, excerpts from which are found in Appendix A1. I recorded design ideas, steps I took when designing, difficulties I faced and how I overcame those difficulties and theoretical development.

Pedgley (2007) or Veja’s (2014) interpretation of action research focused on their design practice rather than being an account of a designer embedded in a particular context. In contrast, my action in phase one was bound in the web of relationships and events at Company X and NTU that surrounded my practice. Therefore, the research diary and notes also recorded conversations and meetings with colleagues and customers and my reflections on those interactions.

Traditionally, in the process of action research, “the researcher enters a real-world situation and aims both to improve it and to acquire knowledge” (Checkland and Holwell, 1998, p.9). The word improve is challenging in any research context because it raises the question of who decides what constitutes improvement. From the perspective of Company X in *Design Situation 1*, it may have meant gaining the capabilities to produce an E-textile desirable to their customers. By contrast, improvement, where the adoption of an E-textile would generate large amounts of unrecyclable waste, could mean deciding *not* to commercialise an E-textile product, if its negative impact could not be reduced and these impacts were deemed to outweigh its value. My concern about the environmental impact of E-textiles is therefore potentially at odds with that of Company X. The research design in phase one offered little scope to explore the tension between the forces of technological change and the negative environmental and social impacts that might result from the adoption of E-textiles, outlined in Sections 1.9 and 3.1.

The problem of finding use-cases is experienced across the spectrum of research into E-textiles, from design to engineering, and was discussed by Dr Jacob Skinner (2020) and Dr Jesse Jur (2020) at E-textiles 2020[9]. I was aiming to create an overview of the performance, manufacturing, functionality, and aesthetics of E-textile illumination for the automotive industry, which I did to some extent achieve. However, the major problem I diagnosed was that textile designers and manufacturers have little or no experience designing that which the textile will become. They therefore know few strategies to explore and envisage the purpose of emerging E-textile technology. If you cannot answer *why* to design an E-textile, other questions regarding how an E-textile might be made or perform, what it might do or how it might look become either marginal or impossible to answer.

Moving into phase two, the research evolved into an investigation of how textile designers can envision *why* to design an E-textile. Due to the critical stance underpinning the research, the question was reformulated around the idea of a purpose-led textile process to design E-textiles for interior spaces. Understanding whether an E-textile element can be made on industrial machinery does not give that element a purpose and without a purpose it is difficult to evaluate its appearance or function. The results of phase one relating to the manufacturing or performance of E-textiles could not answer the redefined question, how can the textile design process be adapted to create a purpose-led process of designing E-textiles for interior spaces?

3.2.3 Phase Two

The aim of phase two, with its newly formulated research question and shift in methodology, was to deliver practical strategies and insights for textile designers working with emerging E-textile technology. The methods used in phase two to achieve this were workshops and associated design projects, whereby I could construct situations in which textile designers, including myself, could trial new approaches aimed at envisaging a purpose for E-textiles in interior spaces.

The term workshop has come to mean an arrangement where people are brought together to learn and creatively problem solve (Ørngreen and Levinsen, 2017) and they have been used in other textile and fashion design research (Ballie, 2014; Twigger Holroyd, 2013). The structure of

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[9] E-textiles 2020 was the 2nd International Conference on the Challenges, Opportunities, Innovations and Applications in Electronic Textiles, held online 3rd-4th November 2020 and organised by the E-textiles Network (E-textiles Network, 2020) which is funded by the British Engineering and Physical Sciences Research Council (EPSRC).

the workshops differed across *Design Situations 2-4,* but they shared the aim of trialling strategies for textile designers to envisage a purpose for E-textiles. Each was adapted to the specific context and participants and were developed iteratively through reflection on the previous *Design Situations*.

My role was that of facilitator and the structure and content of each workshop was prepared in advance. As facilitator, I did not adhere rigidly to my plan, presented in the relevant chapter for each *Design Situation*. Instead, I responded to the situation as it unfolded. For example, in cases where participants took an activity in a different direction from that which I had envisaged, I did not necessarily bring them back to the planned structure. When I felt what I had planned was unsuitable for the situation as it was unfolding, I changed its sequence, timing or adapted an activity.

In addition to the workshops, in the student project that was *Design Situation 3* the participants worked outside the allotted sessions and, in *Design Situation 4,* the workshop was only the starting point the phase of design research I carried out independently. Constructing workshops and design projects within a hybrid action research case study methodology meant I could tailor their structure to my research question. I challenged my subjective point of view by involving other designers and observed how they responded when attempting to design E-textiles for interior spaces.

As an alternative to the hybrid methodology used to research the design process in this investigation, Studd (2002) used semi-structured interviews of a number of practitioners in different contexts to understand textile design practice in industry and produce a generically applicable sequential process model. Similarly, I could have interviewed some of the few textile designers who have worked with E-textiles for interior spaces (Persson and Worbin, 2010; Nilsson et al., 2011; Heinzel, 2014; Orth, 2001; Robertson, 2011). Informed by the work of Studd (2002), Calamari and Hyllegard (2015) interviewed professional interior textile designers to better understand their process and the influence of Design for the Environment (DfE) on that process[10]. Rather than develop a model, Calamari and Hyllegard (ibid.) used the interview data they collected to define six themes and provide descriptive insights. The difference they found between designers using DfE practices and those who were not, was not their process, but an expansion of their practice to include consideration of human health and environmental factors.

[10] DfE, also referred to eco design, is the “systematic consideration of design performance with respect to environmental, health, safety and sustainability objectives over the full product and process life cycle” (Fiksel, 2009, p.6). The definition of eco design in relation to E-textiles is elaborated by Köhler (2013a, pp.18–23)

Although interviews provide insights regarding current practice, the fact remains that they say little about how practice can evolve and are not a way to trial alternatives which was the aim of this research.

The idea of an expanded practice applies to the design process investigated in this study. To create E-textiles requires designers to accommodate new variables in their process, such as interactivity and temporality (Section 2.3). Descriptive accounts of design practice, such as those collected by Calamari and Hyllegard (2015) or Parrillo-Chapman (2008) using the Delphi method and case studies, can provide insights into the ways new variables, such as DfE, are already being incorporated into practice. However, where the expansion goes beyond the boundaries of existing practice, an alternative approach is required.

To expand the boundaries of design practice, engaging in design activity is the way to research and test new methods, processes and materials and was achieved in this research using workshops and design projects. The new elements that integrating electronics bring to textile design were also explored through practice by Worbin (2010), Robertson (2011) and Persson (2013). Worbin (2010) and Robertson (2011) both investigated the dynamic patterning possibilities offered by electrical heating elements combined with heat reactive thermochromic colourants. While Persson (2013) examined more broadly the interactive possibilities created by combining a range of smart materials and electronic elements with textiles in a practice that bridged textile and interaction design. The conclusion from the design activity of this thesis is to advocate an expansion of textile design practice into the realm of product design, where inspiration is more often drawn from people and place.

Textile design researchers (Veja, 2014; Glazzard, 2014; Bang, 2011; Ballie, 2014; Lottersberger, 2012) often cite action research as informing their methodology because of its compatibility with the study of practice (Bye, 2010) and change (Given, 2012). It can also be used to study collaborative design practices. For example, Ballie (2014) involved other designers and members of the public in her research into sustainable fashion practices. Lottersberger (2012) used action research to investigate how design driven innovation (Verganti, 2009), discussed in Section 2.6.3, could be adopted in the textile industry during a placement with an Italian manufacturer. Lottersberger's (2012) investigation involved the company's employees, and external 'interpreters', including artists and technical experts. In true participatory action research (McIntyre, 2007) there is no clear line between researcher and researched, instead participants become co-investigators planning, acting, observing and reflecting. By contrast, the participants in my investigation were not aware that my primary interest was in how they arrived at a purpose for their E-textile design proposals and did not knowingly contribute to planning the *Design*

Situations. So, although others took part in the *Design Situations* that make up this investigation, the research cannot be defined as participatory.

Veja (2014) used research through design, described by Frayling (1993), to investigate the process of designing woven E-textiles. Her aim was to find novel ways that electronics could be integrated into textiles during weaving and to describe how the process of creating them differed from that of conventional textiles. Veja's (2014) research was practice-based, a research paradigm where new knowledge generated through practice is embodied in the outcomes of the design process (Candy and Edmonds, 2018). Veja's (2014) contribution lay in the novel E-textile samples she generated, together with a design repository documenting the weaving process and rendering the knowledge contained in the samples accessible. It also lay in the design process model she formulated by reflecting on and documenting the process she used to generate the samples (ibid. p. 252). Her investigation did not explore possible uses of the samples. Instead, it was an exercise in combining material and process. Veja (ibid.) appears to adopt a neutral stance towards E-textiles. However, reflecting my own concerns (Wickenden, McLaren and Hardy, 2019; Hardy, Wickenden and McLaren, 2020), when she sought expert feedback, several interviewees commented negatively on the recyclability of the samples she had created because of the electronics and conductive materials they contained.

The *Design Situations* in which other textile designers participated acted as a counterpoint to my concerns about E-textiles, allowing me to compare and contrast my perspective and practice with that of others. While planning, acting, observing and reflecting on the *Situations*, I was looking for strategies I could use to answer the question of *why* to design an E-textile - what would be its purpose. By observing other textile designers, I was increasing the probability that the insights emerging from the research might be relevant and useful beyond my own practice.

3.3 Data collection and interpretation

Neither case study research nor action research are connected to a specific data collection method, analytical or interpretative approach. Both quantitative and qualitative data may illuminate the questions case study research can be used to answer (Flyvbjerg, 2011) and Wicks, Reason and Bradbury (2008) trace the many theoretical orientations that coexist in the action research community. A study by Chen, Huang and Zeng (2017) of action research published between 2000 and 2014 found that 75% of articles did not explicitly state the analytical strategy used. This is also true of textile design research using an action research methodology (Ballie, 2014; Veja, 2014). To provide clarity as to how conclusions were drawn, any researcher using a methodology linked to action research or case study research needs to provide additional explanation of their data collection and analytical or interpretive approach.

My approach to the data – in the form of actions, text and designs – generated through this investigation was interpretive, informed by philosophical hermeneutics (Ricœur, 1973; Gadamer, 2013; Butler, 1998; Schmidt, 2006b; Grondin, 1994). Hermeneutics is consistent with Lincoln, Lynham and Guba's (2011) delineation of the constructivist paradigm, the interpretation of case studies (Flyvbjerg, 2011) and of action research (Wicks, Reason and Bradbury, 2008; Friedman and Rogers, 2009). Design researcher Bletcher (2016) explicitly used hermeneutics in her doctoral investigation of innovation in exhibition design. The word hermeneutics refers to the "science or art of interpretation" and is historically associated with the interpretation of biblical and legal texts (Grondin, 1994, p.1). From its original use for interpreting texts, Dilthey initiated a relocation that allowed hermeneutics to be applied to the human sciences (Grondin, 1994; Schmidt, 2006a), meaning human social and cultural life. A position that was later developed by Gadamer (2013) and Ricoeur (1973).

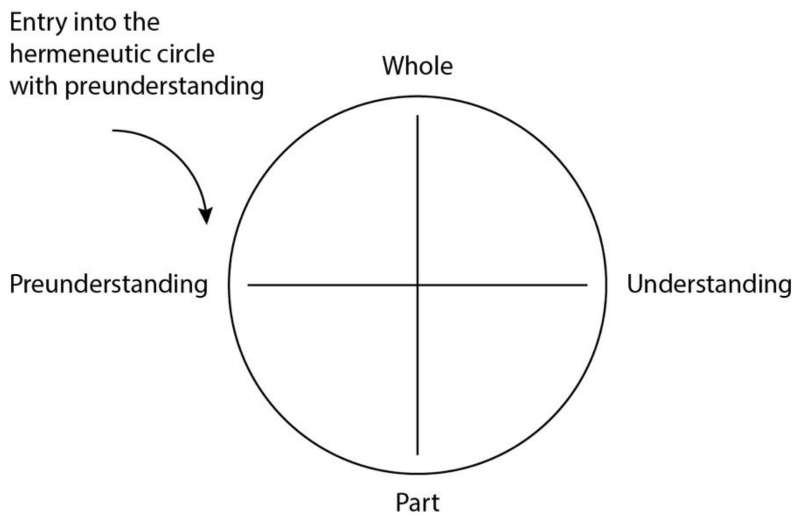

Figure 3-4 The hermeneutic circle, adapted from (Alvesson and Sköldberg, 2009, p.104)

To paraphrase (Willig, 2017, pp.276–277), a core concept of hermeneutic interpretation is the hermeneutic circle depicted in Figure 3-4. The circle depicts the interdependency between the parts and the whole of that which is being interpreted. It also shows that when entering the circle as interpreters we necessarily bring our pre-understanding and through interpreting that which we encounter we develop understanding.

> *We do not simply project our expectations onto a blank screen in the outside world and then find what we are looking for. We do encounter something which we then make sense of with the help of the ideas and assumptions we brought to the task. In the process of the encounter between our ideas and the world, our ideas about the world are modified in order to accommodate what we have encountered.*
>
> (Willig, 2017, pp.276–277)

Although not the most elegant, an additional explanation I find helpful is Robson and McCartan's description of hermeneutic interpretation as a process of, "trying to understand what *it* means to those who created *it* and to integrate that meaning with *its* meaning to *us*" (2002, pp.196–198). *It* can refer to situated human communication and action, designed objects and design practice (Jahnke, 2012), while *us* refers to the researcher(s).

In juridical hermeneutics, the art of interpreting legal texts, the interpretive task could relate, for example, to the American Constitution. To understand how the constitution applies to a legal case today requires that words and sentences be understood in relation to the complete text, as well as the meaning the parts and the whole had in 1787, the historical moment in which the text was written. The text must also be interpreted and meaning developed for the current moment and for the case in question (Schmidt, 2006b, pp.108–109). I argue that my interpretation of the *Design Situations* follows the hermeneutic circle whereby the parts – actions, designs and words, and the individual *Situations* – must be understood in relation to the contextualised whole of the investigation and vice versa. The *Situations* are framed by the account in Section 1.7 of the development of E-textiles in relation to interior spaces.

Willig (2017, p. 276) employs Ricoeur's hermeneutics of empathy and suspicion to categorise a range of research methods. The hermeneutics of empathy is a "bottom up" approach, focused on meaning within the data, while the hermeneutics of suspicion is "top down", using a theoretical frame to interpret its meaning. The categories of empathetic and suspicious interpretation are not discrete, neither is one preferable, despite the negative connotations of the word suspicious in everyday use. Rather, different qualitative methods can be placed on a continuum. Willig (2017, p.277) places thematic analysis (Braun and Clarke, 2006) and phenomenological methods (Moustakas, 1994) at the empathetic end of the spectrum. Both these methods develop their analysis through induction, staying close to the meaning of an experience for the person to whom it belongs, an approach not adopted by this thesis.

I have empathetically considered the meaning that participants attributed within the *Situations*, but my research question does not centre on that meaning. Although in action research interpretations are developed inductively, it is an approach that carries with it the values of its participant-researcher(s). Willig (2017) considers these values, such as the critical stance of this thesis reflected in its research question, to constitute a theoretical frame. Thus, Willig places action research, one methodology upon which this thesis draws, towards the centre area of the continuum. It uses both empathetic and suspicious interpretation, but because of the value stance of its participant-researchers errs towards suspicion, a view which fits the interpretive location of this thesis.

An additional characteristic of the chapters dedicated to each of the *Design Situations* is that they are a narrative account. They rely on the sequence of events to develop and recount the interpretation. My aim, unlike that of Studd (2002), was not to create an abstracted process model by extracting themes from interview data. Had I attempted to code the data by extracting themes and breaking the account into codes, the structure and flow of the material would have been lost, making it impossible to analyse the narrative dimension (Willig, 2017, p.274).

Gadamer (2013, pp.369–372) stresses the importance for interpretation of openness both in the nature of the question and as an attitude verses the 'other', meaning that which is being interpreted. Because coding imposes a structure on the data, it becomes difficult to remain open to alternative interpretations. I have endeavoured to remain open throughout the action of the *Design Situations* and their subsequent interpretation. Sometimes when reviewing the data I realised that during action I had misunderstood what a participant had said or done. Entering the hermeneutic circle and immersing myself in the data allowed me to challenge my initial interpretations. In the movement between the parts and the whole, I continually revised the narrative presented in this thesis. The whole was changed through a better understanding of its parts and I reviewed my understanding of the parts in light of the emerging whole.

Having described hermeneutic interpretation at the conceptual level and argued for its alignment with this investigation, I will now provide a practical account of the interpretive process used to develop this thesis. In Section 3.2.2, I explained the original research plan and how this initial phase, an important diagnostic step, was integrated into the research as *Design Situation 1*. At the end of phase one I had over a hundred of pages of notes written in a research diary and the notebooks I used professionally, a selection of designed artefacts including E-textile samples, prototypes and my recollections of the lived experience. *Design Situation 1* is a case of action. It is a first-person account which reports on my experience over two years as a practitioner-researcher in industry, in line with the action research framework (Coleman, 2015). I lacked a third person perspective in the data, as it was not possible because of confidentiality to record conversation or meetings with colleagues and customers, instead I relied upon the notes I had taken during and after these events.

The aim in phase one had been to examine E-textile illumination in terms of performance, manufacturing, function, and aesthetics to create a better understanding of the technology, its potential and limitations for the automotive industry. As in phase two this was no longer the aim I had to re-examine the material. To answer questions about craft thinking, Kettley (2016c) used heuristic inquiry (Moustakas, 1990) to examine and draw answers from notebooks recording a decade of her practice and theoretical reflections. Moustakas (1990, 1994, pp.16–21) describes heuristic inquiry as a process whereby the researcher starts with a question that has been "a personal challenge or puzzlement". While this description fits the question posed by this research, heuristic inquiry does not contemplate how history, politics, or anything outside the experience of the researcher(s) accounts for meaning. By contrast, this thesis looks both inward and outward for answers to its question.

Hermeneutic interpretation is not a process governed by rules (Alvesson and Sköldberg, 2009, p.97), therefore I will explain my approach at a practical level. To build the account of *Design Situation 1,* I first reacquainted myself with the whole of the *Situation* by reviewing all the available material. I reviewed the parts by using NVivo to sort excerpts into categories, such as whether they were about a meeting with a customer or my emerging E-textile design practice and then examined the details within each category. Using NVivo allowed me to locate individual elements easily. Throughout this process I made notes and developed my interpretation dialogically as a conversation between the parts and the whole of the material, my pre-understanding, including my memory of events, and new understanding of the material.

In *Design Situation 1,* I experienced the limitations of the conventional textile design process when designing emerging E-textile technology, while in phase two, I sought approaches to negotiate these limitations. To challenge my subjective view of E-textiles, in *Design Situations 2*, *3* and *4* I enlisted participants, which allowed me to step into the role of participant-observer. I was still actively involved, as facilitator or educator, but until part two of *Design Situation 4* my design practice was no longer the focus.

In phase two, I maintained the research diary, but it and my experience were no longer the primary sources of data. With the participants' permission, I could audio and video record subsequent *Situations*. When planning each *Situation,* I selected appropriate phases of the workshops and projects to record. In addition, I collected the participants' design outcomes, survey responses, and recorded group interviews to gather their reflections on action. My practical approach to the data was the same as that which I had adopted to decipher *Design Situation 1*, but now I was interpreting the actions, words, and reflections of others, besides my own.

In the second phase of the research, I was looking for how textile designers might adapt their process to be better equipped to explore the potential of emerging E-textile technologies, designing in a manner led by purpose. That is to say, led by the reason these technologies should be brought into existence, rather than the emphasis being on the possibilities they offer. In her presentation at *Tricky Design*, a symposium held at the London Design Museum in June 2019, Stefanie Hankey of Tactical Tech discussed the Information and Communication Technology (ICT) industry's tendency towards an approach she summed up as "we can so we will"[11]. This phrase highlights the absence of the question "we can, but should we?". In this investigation, I explored part of this missing question in relation to E-textiles by changing the position of purpose in the textile design process, placing it as a leading force.

3.4 Summary

The cases, or as I have named them *Design Situations*, of E-textile design explored in this thesis are not an abstract study of the design process, nor was the investigation based on a single material, manufacturing technique, a protocol or rooted on a single design problem encountered by a group of people. Rather, it was a confrontation with the opportunities, trade-offs and challenges faced by professionals, academics and students when designing with emerging E-textile technology. This family of technology has the potential to enhance the interior spaces in which we live, work and travel, but also to exacerbate existing sustainability challenges (Hardy, Wickenden and McLaren, 2020; Köhler, 2013a). It also raises new ethical questions for the textile industry regarding data and privacy (Sametinger et al., 2019). The investigation focused on the fuzzy front end of the design process before the nature of what is to be designed is known. It sought, through action, to find ways that textile designers could better link the materials they design with the contexts and people they are designing for. The thesis encourages textile designers to move beyond visual trends, market demographics and generic categories of use and be led by purpose, taking their starting inspiration from imagined lives, places, and the systems in which we are all embedded.

The next chapter is an account of *Design Situation 1*, the starting point of the empirical research. It documents my growing awareness of the need to understand the purpose of any E-textile I was to create and ways gathering inspiration from those individuals that might become the users of a product my textiles could become part of my design process. The challenges I encountered in phase one led me in search of an alternative process, which I termed a 'purpose-led' design process for E-textiles.

[11] Tactical Tech (Tactical Tech, 2019) is an NGO set up to 'investigate and mitigate the evolving impact of technologies on society'.

4 *Design Situation 1*: Company X

The particularities of *Design Situation 1* have strongly influenced the direction of this investigation. What follows is a first-person account of the research conducted while I was a part-time researcher working full-time for Company X, an automotive textile manufacturer and a small segment of a larger organisation I refer to as Corporation X[1]. The chapter recounts the action research design ‘experiments’ to make E-textile samples and prototypes and my interaction with colleagues and customers between July 2016 and May 2018[2].

The research described in this chapter should be seen as diagnostic, directing me to the search for a purpose-led process to design E-textiles. As outlined in Chapter 3, this *Situation* was conducted as practice-led action research to examine the performance, manufacturing, functionality and aesthetics of E-textiles for automotive interiors. It was then integrated into the hybrid action research case study methodology. My primary conclusion from *Design Situation 1* was that the design process used in the automotive textile industry was ill-equipped to manage the fuzzy front end of E-textile innovation. That is, the uncertain initial stages of design before the nature of the outcome is known. I found the lack of connection between textile designers and users, the individuals who will ultimately encounter the textile as part of a vehicle, a barrier to invention. This is a particular problem for E-textiles because, as an emerging technology, their purpose has not yet been defined. The textile design process I had been introduced to during my undergraduate education and developed over a decade of professional practice was not suitable to handle the variables I now needed to consider to design E-textiles.

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[1] Both are anonymised for confidentiality.

[2] When the research that has become this PhD started in October 2015, I had been working at Company X for three and a half months, having previously worked for a competitor. At the end of May 2018, I left the company and from October 2018 became a full-time PhD candidate.

4.1 Contextualising *Design Situation 1*

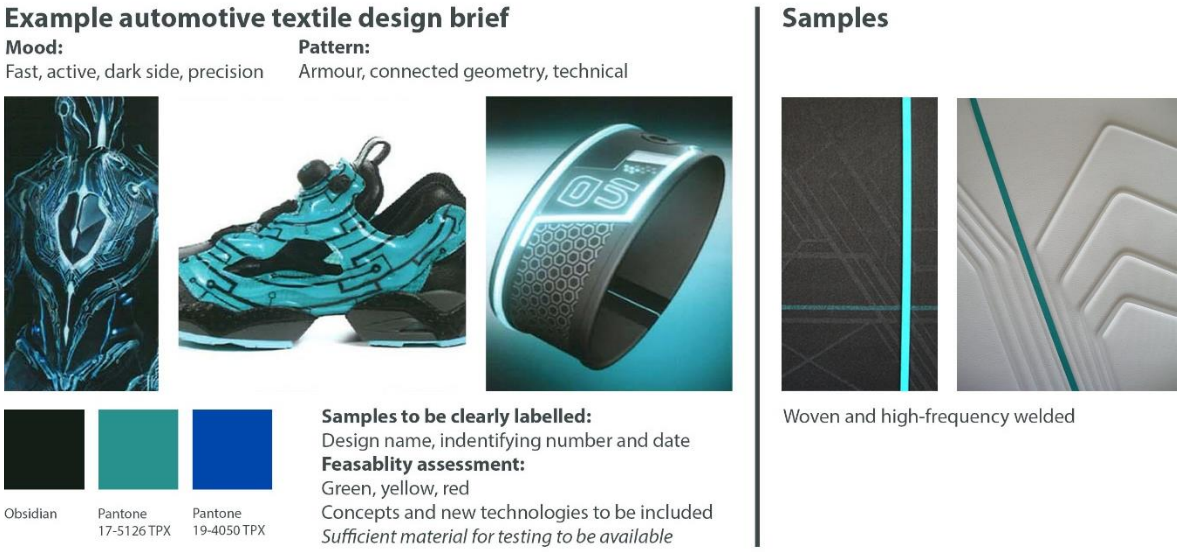


Figure 4-1 Example automotive textile design brief and associated textile samples

To be inspired and innovate automotive textile designers focus on appearance, haptics and the possibilities that new manufacturing processes and materials offer. The left of Figure 4-1 shows an illustration of a typical automotive textile brief created using images from my archive. The brief gives the designer a selection of visual references, guiding words for mood and pattern and colour indications, including the automotive manufacturer's very own nuance of black[3]. They all have them, and they are *not* the same. The brief asks the textile designer to innovate by using new technologies, indicating their feasibility using a traffic light labelling system where green indicates 'good to go', yellow 'some work necessary' and red 'still in the experimental phase'. Shown on the right of Figure 4-1 are samples that were produced in response to a similar brief[4]. Both parties take the textile's application for granted because they know it will be used as automotive upholstery. There is no reference to a user or notion of the people that will encounter the textiles, as driver or passenger, once it is part of the vehicle interior. The exception is when, usually for a new model, design briefs include a customer profile in the form of demographic data which approaches a loosely defined user group.

[3] The visual inspiration for the brief relates to *Tron Legacy*, a movie release by Disney in 2010, that was a popular inspiration for automotive manufacturers and appeared frequently in automotive textile design briefs. I have deliberately used this older theme due to the commercial sensitivity of more recent projects. Briefs are often multi-page documents with a variety of themes that cover different vehicle levels, such as Base, Sport and Premium.

[4] These are woven jacquard fabrics with high frequency welded details which to give a sense of scale were size A3.

To understand *Design Situation 1* requires an outline of its context and the design process used in automotive textile design. Company X employed me as their 'Advanced Textile Designer', a role bridging the engineering and design departments. My job was to develop new or improved automotive interior textiles and related textile products, both proactively and in response to customer requests. As the brief in Figure 4-1 illustrates, customers provide automotive textile designers with visual references which provide the starting point for the design process. I would also research and trial new fibres, yarns and manufacturing processes to create textiles with a novel appearance, feel or performance properties. Figure 4-2 is a representation of the design process for transport and contract textiles I have practiced and observed others using in my time in industry, and broadly corresponds with process sketch of the textile designer in *Design Situation 4* (Section 7.2.3).

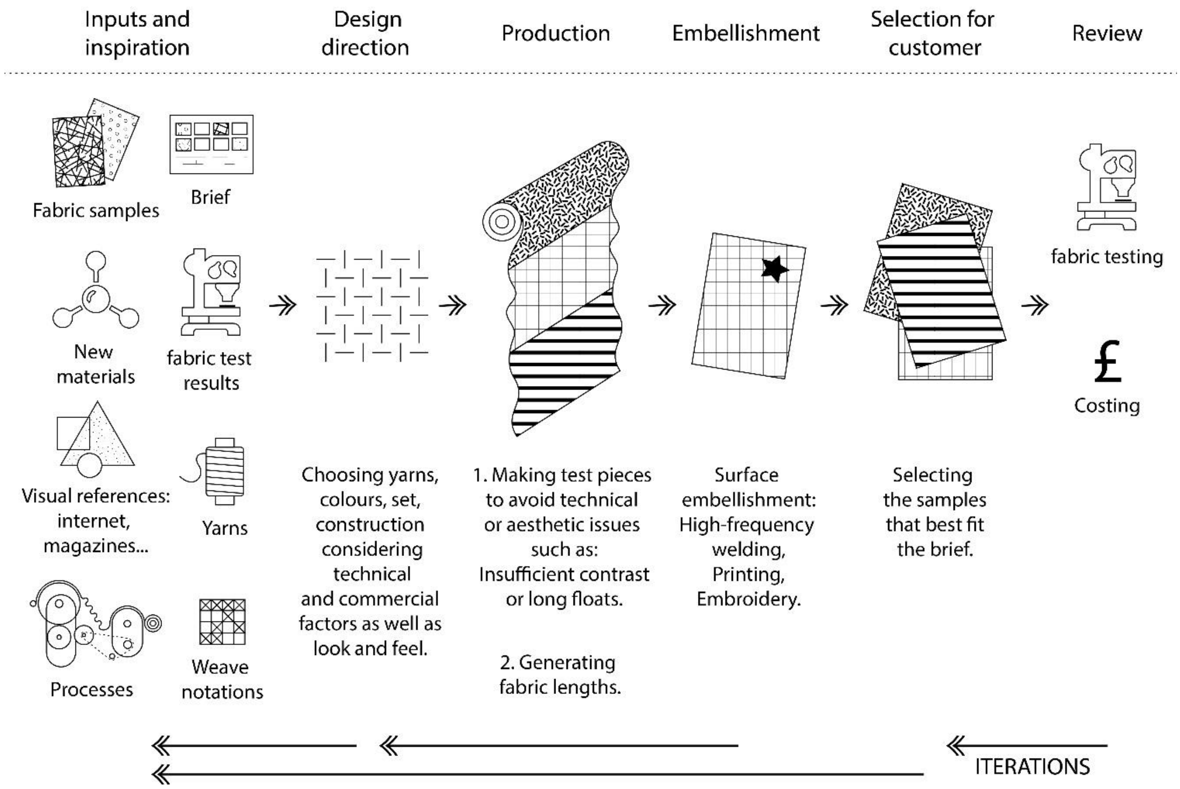


Figure 4-2 Automotive textile design process

As Figure 4-2 shows, the inputs used to formulate a design in the standard automotive textile design process are the customer's brief, the designer's visual research and their knowledge of and experience with yarns and manufacturing processes. The designer synthesises these inputs to create woven or knitted textiles, sometimes with additional surface embellishments such as print, embroidery or high-frequency welding. Initially short lengths are made to check and improve each design, including changing a yarn colour or correcting aspects of the fabric's construction. Once washed and laminated with a foam backing, the textile samples that are deemed most aesthetically, technically, and commercially appropriate are shown to the customer.

For an automotive textile designer, their customers are the CMF designers who work for vehicle manufacturers, known in industry as OEMs, an abbreviation of Original Equipment Manufacturer[5]. It is the job of the CMF designer to coordinate the choice of textiles and plastics found in the vehicle interior. Just a small percentage of the fabrics presented by textile suppliers are ever selected. Suppliers are in fierce competition to be awarded business to manufacture each square centimetre of a vehicle's interior textiles. CMF designers may request adjustments to a design, which over the course of one to two years is refined both aesthetically and technically. The selection of fabrics is whittled down by the CMF designers until just one fabric per level is chosen by the OEM's management team to go into production.

In her examination of the relationship between the design of textiles and products, Nilsson (2015, p.27) describes automotive textiles as "details" with little influence over the form of the seat and other interior parts. Their relationship to the product fits Nilsson's category of "specification" (2015, p.13). This means that the design process of the textile and that of the vehicle run on parallel tracks with minimal intersection. Secrecy around new vehicles means although automotive textile designers usually know the model for which they are designing, they rarely see an image of the vehicle or its interior until late in the design process, if at all.

Automotive textile designers rarely consider the opinion of the user, that is the individuals who will buy and use the vehicle. What little information arrives is filtered through the OEM's CMF designers or trade and special interest publications, such as "Interior Motives", a publication by Car Design News (2019). In the design process I had used up to this point, shown in Figure 4-2, my skill lay in combining visual references and knowledge of manufacturing processes and yarns to achieve the CMF designer's intent. I translated design ideas into fabrics that had to perform to the OEM's specification and adhere to their target price. The OEM determined the final 3D form of my textiles and how they would be perceived by the vehicle's users was not a consideration in my design process.

OEMs and their CMF designers are increasingly requesting 'smart' or 'functional' textiles, as well as more sustainable alternatives to the laminated composite most frequently used in vehicle interiors (Powell, 2008; Eason, 2012). Changes in the automotive industry, including an increase in car sharing services, the possibilities of autonomous driving and the switch to electric vehicles (Bertoncello and Wee, 2015; Ernst & Young LLP, 2013; SMMT, 2018) alter the requirements for vehicle interiors. For example, BMW's 'Vision' concept vehicles embody an imagined future for the group's brands: BMW, Mini, Rolls Royce and Motorrad, and illustrate possible design

[5] There is more than one definition of the term OEM. As it is used in the automotive industry, it refers to the vehicle manufacturer who constructs their product from component bought from other companies.

directions (BMW, n.d.). Design agency IDEO have likewise created their own visions of future mobility, one example of which is an itinerant office space (IDEO, n.d.). The increased demand for 'functional' properties reflects a general textile industry trend, which Colchester (2007) describes as the NASA effect (Shishoo, 2012). BMW's (2020) Vision iNext concept car includes an E-textile which they refer to as an 'intelligent material', a jacquard fabric that functions as a touch interface, but the fabric remains a one-off for display at motor shows.

During *Design Situation* 1 the term 'smart textiles', defined in Section 1.3, was used interchangeably with electronic and functional textiles by colleagues and OEM designers. Such is the confusion around the term and its previous classifications that to study smart textiles Tandler (2016, pp.19–38) created her own definition. The focus of this investigation, however, was the combination of textiles and electronics with or without 'smart' capabilities, hence I do not extend the discussion. Sometimes what CMF designers were looking for was textiles with antibacterial or waterproof properties which would make them easier to clean, but the term 'smart textile' was frequently not qualified. Most likely because OEM CMF and vehicle designers were unsure what role they wanted them to play. In an industry where the OEM directs the design process and the textile designer takes the application of their fabric for granted, this lack of direction presents a challenge.

As I have experienced it, the automotive industry's attitude towards E-textiles has followed a hype cycle (Blosch and Fenn, 2018). Initial enthusiasm in the mid-2000s became disillusionment as the technology failed to meet industry expectations. At international conference E-textiles 2020 Dr Jacob Skinner, CEO of Thrive Wearables, placed electronic or smart textiles as languishing in the trough of disillusionment (Skinner, 2020). Around 2008, Company X collaborated with the University of Manchester on an innovation project dedicated to E-textiles. Together they produced a range of demonstrators, including a door panel upholstered with an E-textile that used the conductivity of human skin to close a circuit, so acting as a switch to raise and lower the window. An OEM was interested in the technology, but the company did not ultimately continue the development due to its lack of reliability and the absence of a partner with whom to commercialise the product. Another of the company's requests was an illuminating yarn, documented in Dias and Monaragala (2012). Company X's prior foray into E-textiles had left employees sceptical towards their development for the automotive industry.

In my role at Company X, I was encouraged to look for what management referred to as 'low-hanging fruit': the most technically and financially achievable innovations. E-textiles presents many challenges, whether or not they would be a superior product, they are not 'low-hanging fruit'. Although Copper (1999, p.117) warns that "the preoccupation with cycle time reduction and the tendency to favour simple, inexpensive projects actually penalizes projects that lead to product superiority", I argue it is currently unclear for what purpose E-textile would be superior. To be put into production, an E-textile would not only have to work and be manufacturable, it would also need to offer an advantage. That advantage might be practical, such as a lower price, lighter weight, or better energy efficiency or it could be a unique function or aesthetic that could not be achieved by other means.

Researching E-textiles from within industry had a two-fold negative effect on me. I felt uncomfortable that I could be implicated in commercial outcomes of the research that could increase the negative environmental impact of automotive textiles. The prevailing vision of seamlessly integrated E-textiles is in opposition with eco-design. Seamless integration runs directly counter to the principle of "reducing the diversity of materials" (Köhler, 2013b, p.56). Seamlessly integrated E-textiles also go against an undercurrent in the automotive industry which is investigating moving from the current unrecyclable textile composite to recyclable mono-material alternatives. At the same time, I was up against the scepticism of colleagues and Company X's OEM customers, making me highly aware of the challenges, both technical and commercial, to developing a viable E-textile for the automotive industry.

The automotive industry's move towards autonomous vehicles (Bertoncello and Wee, 2015), powered by more environmentally sustainable power sources (SMMT, 2018), offers great scope for the automotive design and engineering community to redefine the vehicle interior (Stuart, 2015; Damiani, Deregibus and Andreone, 2009). E-textiles may be an enabling technology for novel design solutions, but interest in them is also motivated by a desire from automotive textile manufacturers to compete on grounds other than price, using innovation as a market differentiator. Automotive textile manufacturing is highly competitive and heavily price driven. The ability to offer E-textiles as part of a product portfolio could offer its manufacturer a market advantage. In the presence of these forces, interest in E-textiles from the automotive industry and its suppliers has never fully disappeared, but their purpose has yet to be clarified.

4.2 Initial research structure

My initial research proposal in June 2016 was to investigate four areas in relation to E-textile illumination for automotive interiors: aesthetics, functionality, manufacturing and performance, as shown in Figure 4-3. Light is being used in increasingly sophisticated ways in vehicle interiors and has been found to have a positive effect on perceived quality, safety and comfort (Caberletti et al*.,* 2010). Fibre optics are already being combined with leather in ultra-high end vehicle interiors to create the effect of a starry night (Rolls Royce, n.d.). Investigating the integration of light into textiles also allowed plenty of scope for the aesthetic driven textile design practice to which I was accustomed. However, the events that will be described in Section 4.3 led me to abandon my focus on illumination. I adjusted the research, removing references to light shown in brackets in Figure 4-3. While maintaining the four areas of the investigation, I looked instead at E-textiles more broadly.

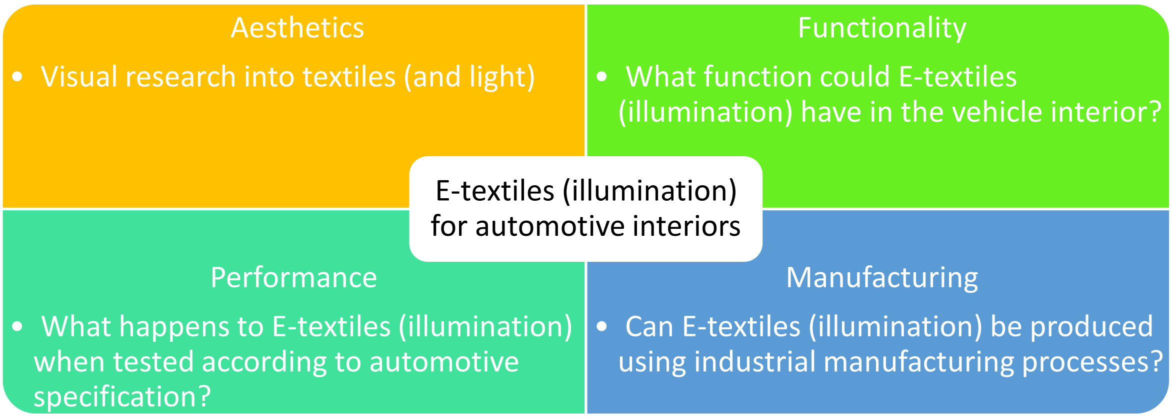


Figure 4-3 Initial research design

My choice to examine aesthetics, functionality, manufacturing and performance reflects the role of the automotive textile designer in ensuring textiles proposed to customers can be industrially manufactured to a consistent standard, meet the customer's performance parameters and appeal aesthetically. The 'manufacturing' branch of the investigation was to trial ways E-textiles could be made in industry. The testing standards to assess E-textiles are yet to be defined by the relevant agencies (European Commission, 2017) or OEM's. Therefore, to measure 'performance' I planned to use a combination of standard automotive textile testing methods, including those for abrasion resistance and tensile strength, and adapt or create test procedures for factors where no tests procedure exists, including for electrical performance properties such as conductivity.

For E-textiles to be of interest as a replacement or addition to existing interior lighting systems, I assumed they would have to outperform incumbent technology by some measure, including an exciting new function or aesthetic. The area of 'functionality' related to the question, what do we want E-textiles to do and why do we want them to do it? I was hoping to gain insight from customers as to what they wished E-textile illumination to offer that current automotive interior lighting does not. Finally, my intention to investigate aesthetics was to explore the visual possibilities of E-textile illumination and a question as to the automotive industry's wishes concerning their appearance.

Like previous investigations of E-textiles discussed in Chapter 2 (Orth, 2001; Berglin, 2008; Veja, 2014; Robertson, 2011), I combined textile engineering and design techniques, measuring properties and performance, and designing E-textile artefacts. Designing automotive interior textiles sits between aesthetically driven textile design and performance driven textile engineering. My rationale for covering the areas of aesthetics, functionality, manufacturing, and performance was that I could provide an overview for industry and academia of the challenges and opportunities for E-textile illumination in vehicle interiors.

Figure 4-4 shows a summary timeline of *Design Situation 1.* Several events or activities, including 'Designing Theorem exhibit' and 'Heat sensor fabric design', took place over a period of weeks but are depicted with a dot on their start date for visual simplicity. The timeline includes meetings with OEM customers, the production of samples and prototyping. In the later stages, I created a touch responsive E-textile demonstrator, exhibited at Theorem art and design symposium in July 2017[6]. In March 2018, I completed a temperature sensing textile that Corporation X was considering as a component in a zonal seat heating system and that contained thermistor E-yarns developed at NTU (Lugoda, Dias and Morris, 2015).

During *Design Situation 1,* I was a participant in events and embedded in the textile design culture of the automotive industry and Company X. The timeline in Figure 4-4 cannot illustrate the detail of day-to-day interactions, instead it serves to place key episodes over the period. My conclusion as to the shortcomings of this culture and its practices for the design of E-textiles grew from the experiences documented in my professional notebooks and research diary. I had initially planned to audio and video record meetings with customers and colleagues, but it was not possible to put the necessary legal agreements in place. Instead, my research diary (Appendix A1) and professional notes from the period helped me recall episodes and my reflections on them at the time they occurred. This chapter is presented as a first-person narrative, in line with other accounts of action research (Lottersberger, 2012; Coleman, 2015).

[6] Theorem is a UK PhD research conference for the visual arts and design that includes an exhibition of practice-based research in conjunction with a one-day symposium (Theorem, n.d.) and book of essays by the participants to which I contributed (Wickenden, 2018).

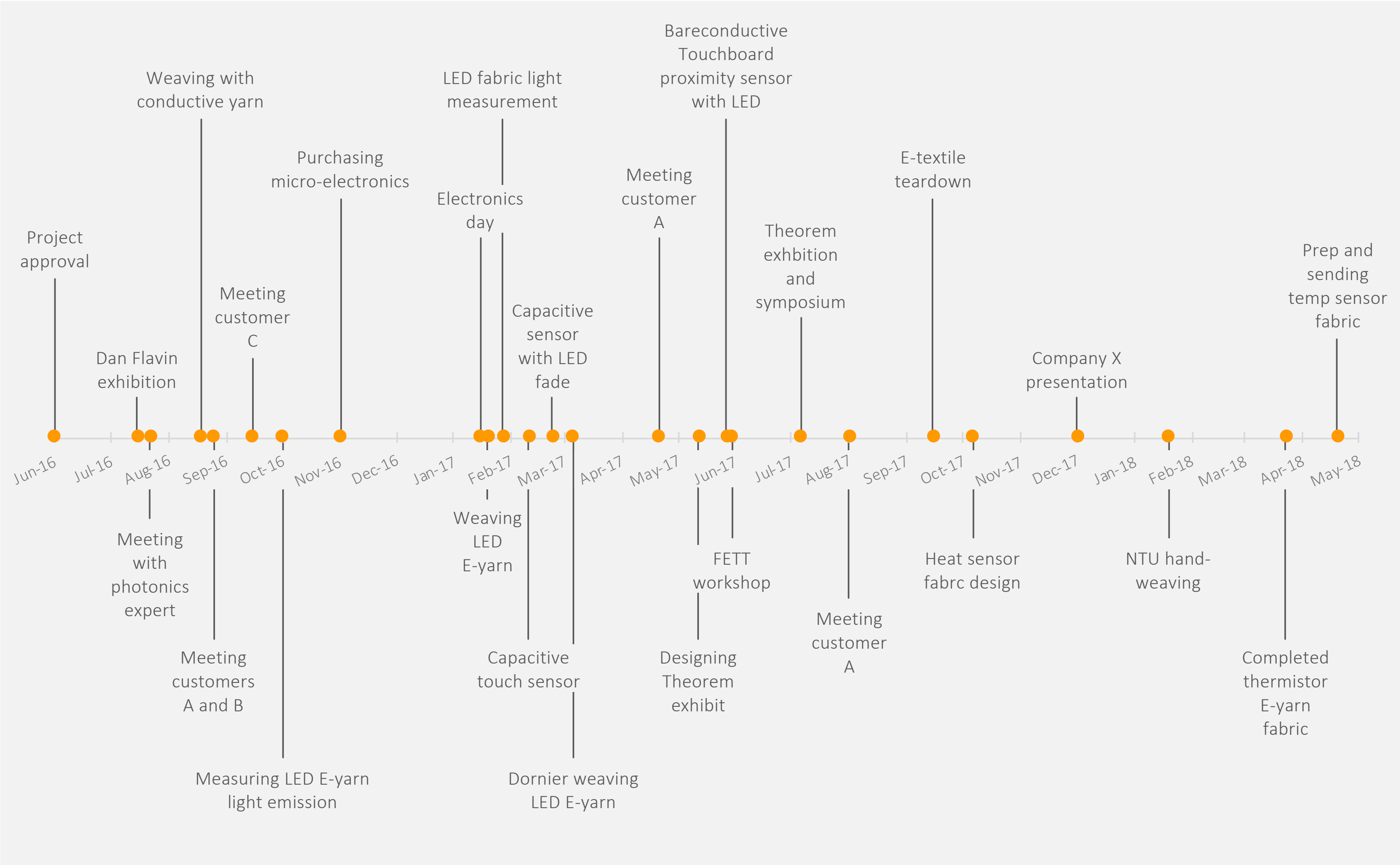


Figure 4-4 Timeline of Design Situation 1

Figure 4-5 visualises the web of connections in which I was embedded. Over the period, I reported to Company X's management team and interacted with colleagues, primarily from the design and engineering departments in the UK and abroad, and our OEM customers. I also interacted with other groups from Corporation X, namely the electrical group and a multidisciplinary group tasked with developing interior styling innovations for premium vehicles that I have referred to as 'Corporation X Premium'. Corporation X's electrical group produced components and the wiring harnesses that connect a vehicle's various electrical systems. Initially unrelated to the investigation, I met a member of the electrical group who was interested in a range of synergies with the textile division. Their primary interest was for Company X to manufacture the textiles used to protect and secure the wire harness. This led to discussions about E-textiles and we set-up a biweekly conference call, also involving members of the premium group, to discuss possibilities. Company X's management team were interested in the outcomes of this collaboration but were not directly in contact with the electrical division themselves.

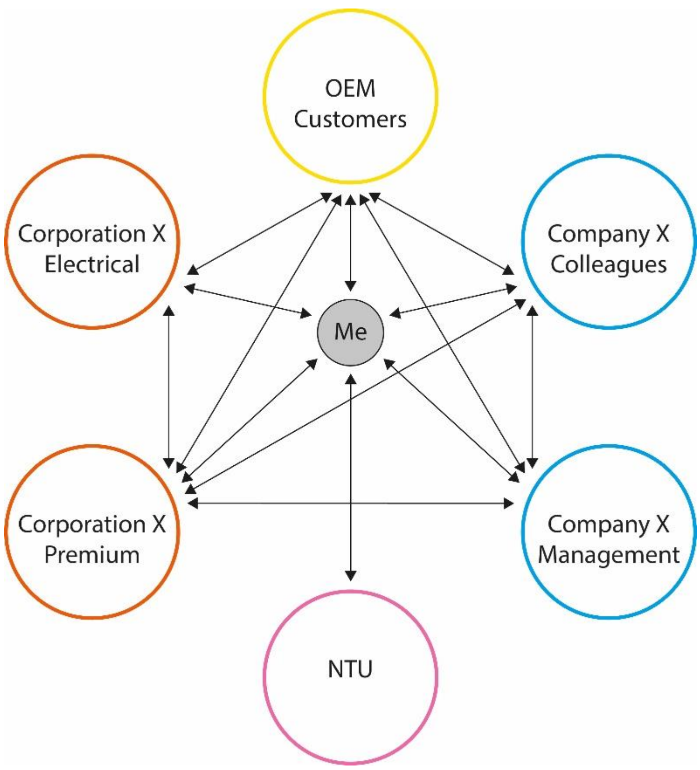


Figure 4-5 Design Situation 1: Lines of communication

Unlike other textile designers at Company X, as the company's advanced designer I did not work for a specific customer. Instead, my role was transversal across customers and bridging between the design and engineering departments. I worked on specific customer requests that called for research to develop new textile offerings or proactively on projects to expand the company's portfolio. My contact with customers often came via other members of Company X or

Corporation X, and related to non-standard requests, including ‘smart’ textiles and textiles with reduced environmental impact.

The members of both the electrical and premium groups were primarily located outside the UK so communication was via email or video conferencing. Some groups in the web interacted with each other independently. For example, Corporation X’s electrical and premium groups worked together on projects with which I was not involved. In other cases, such as between Corporation X’s electrical group and Company X, I was the only connection. The connections between the employees of Company X, Corporation X, OEM customers and I in this *Situation* existed independently of the research, but as Section 4.3 exposes, this network of actors influenced its direction. The web of connections means the requests of others partly governed the research activities I will describe. Now I have introduced the backdrop to this *Design Situation*, I will provide my interpretation of *Design Situation 1*.

4.3 Action in *Design Situation 1*

> *Light is fluid, can travel, be layered but also broken, covered and cut through. It reflects off and creates spaces.*
>
> *(Research diary P3, 18th June 2016)*

I wrote this excerpt in June 2016, I had just visited an exhibition of artist Dan Flavin’s work with industrial fluorescent lighting at Ikon Gallery in Birmingham. From observing design ‘experiments’ and listening to conversations between practitioners, Schön (1992) believed designers construct “design worlds”. These are created by engaging with a design task and its available materials through sketches and prototypes. Having chosen E-textile illumination as the topic, light was one of the new “materials of the situation” (ibid.), alongside electronics, that I wanted to understand to build my design world.

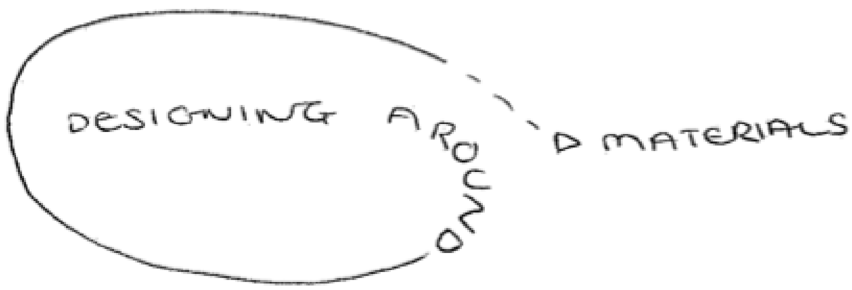


Figure 4-6 Research diary, p. 6: Reflection on materials in the textile design process

Designing automotive textiles requires creativity within constraints formed by stringent technical requirements and cost limitations. Using my knowledge of materials and processes as a source of inspiration was familiar. In the diary excerpt shown in Figure 4-6, I described this as “designing around materials”. However, a major challenge for designers is that the increasing complexity of materials has led to a loss of their recognisability (Manzini, 1989), making it difficult for them to gain knowledge of their behaviour, properties and functionality. The close relationship industrial textile design has to craft (Dormer, 1997), whereby the designer’s knowledge of materials informs the creative process (Gale and Kaur, 2002 p. 31), can prove a limitation for the development of E-textiles. For the properties that E-textiles possess, such as conductivity, cannot be perceived or quantified using our senses alone or tested by standard textile methods. However, at this point in the investigation I still assumed I could learn enough and follow an approach centred on E-textile ‘materials’. I wanted to know more about the technologies that product artificial light and explore how they could be combined with textiles.

Pointing to the work of Orth (2001) and Berzina (n.d.) amongst others, Tandler (2016, p.20) suggest that designers working with E-textiles mainly use LEDs creating “prototypes open to criticism for their limited use, gimmicky appeal and specific suitability – mostly for younger markets”. At NTU I had access to E-yarn technology which has been used to create ‘yarns’ with LEDs soldered along the length which are then covered with a fabric sheath (Hardy et al., 2019; Dias and Ratnayake, 2015). I was, however, hoping to find alternatives to broaden the range of materials with which I could experiment. I organised a meeting with an expert in photonic technologies at NTU. The resulting discussion covered the properties and performance of different lighting technologies, including their luminosity, lifespan, and flexibility. He suggested a range of options for me to consider, but also highlighted many limitations and challenges to combining these technologies with textiles. Companies such as Philips have conducted research into E-textiles and lighting (Günther, 2013) and so after the meeting, I contacted various manufacturers that supply the automotive industry. These inquiries did not, however, provide me access to alternatives to the E-yarn.

In these early stages I was, as per the approach I had laid out, looking at four areas of the design problem of E-textiles as I perceived it. On the basis that E-textile illumination would require reliable conductive tracks to deliver power to the light source, I tested the manufacturability of a range of conductive yarn types. In August 2016, I wove and then ‘finished’ a fabric following the standard processing steps for an automotive textile shown in Figure 4-7[7]. Yarn is woven into fabric then washed, heat set on a stenter and glue or flame laminated to a layer of foam and a thin knitted backing fabric called a scrim. My intention was to test the conductivity and abrasion resistance of the samples and share them with customers and colleagues to generate discussion.

[7] Finishing refers to steps the preparation of a fabric for sale. As a minimum, fabrics are generally washed and dried, but they may also be treated with chemicals, for example, to make them stain resistant.

To explore their aesthetics, I created these textiles using a hexagon design, a motif popular for automotive interior textiles.

Figure 4-7 Research diary, p15: Automotive textile processing route

On 25th August 2016, I met with Customer A to discuss textile innovation, including E-textiles, and among the samples I had with me were those I had woven using conductive yarn in the weft. The CMF designer liked these samples, not because they offered potential functionality but because she was attracted to their appearance. When discussing possible functions, the designer did not have a fixed idea of the role E-textiles might play in a vehicle interior. Despite this, she felt that making functional features visible through the textile’s appearance would help “sell the idea” (Research diary, p. 18), whatever that idea might prove to be. Textile designers have explored the ability of textiles (Bang, 2011) and E-textiles (Uğur, 2013; Davis, 2017) to express or embody emotions. Yet for an E-textile to communicate its function through its appearance requires first a clear understanding of what its function is, clarity that neither my customer nor I had.

Figure 4-8 is an example from my research diary of reflections on how an E-textile might serve as a luxury textile alternative to leather. I was also pondering the manufacturing process by which such an E-textile could become part of a vehicle interior. Vegan alternatives to leather, such as embossed sueded textiles, were an area of customer interest that in my role as advanced designer I was developing in parallel to E-textiles. Textiles in the automotive industry are generally perceived as inferior to leather, but E-textiles might change this perception. E-textiles are currently a challenge for automated manufacturing. By offering them as a premium option craft processes could be adopted, such as hand-wrapping, an upholstery process where a part is covered by hand rather than using an automated moulding press (Rolls Royce, n.d.).

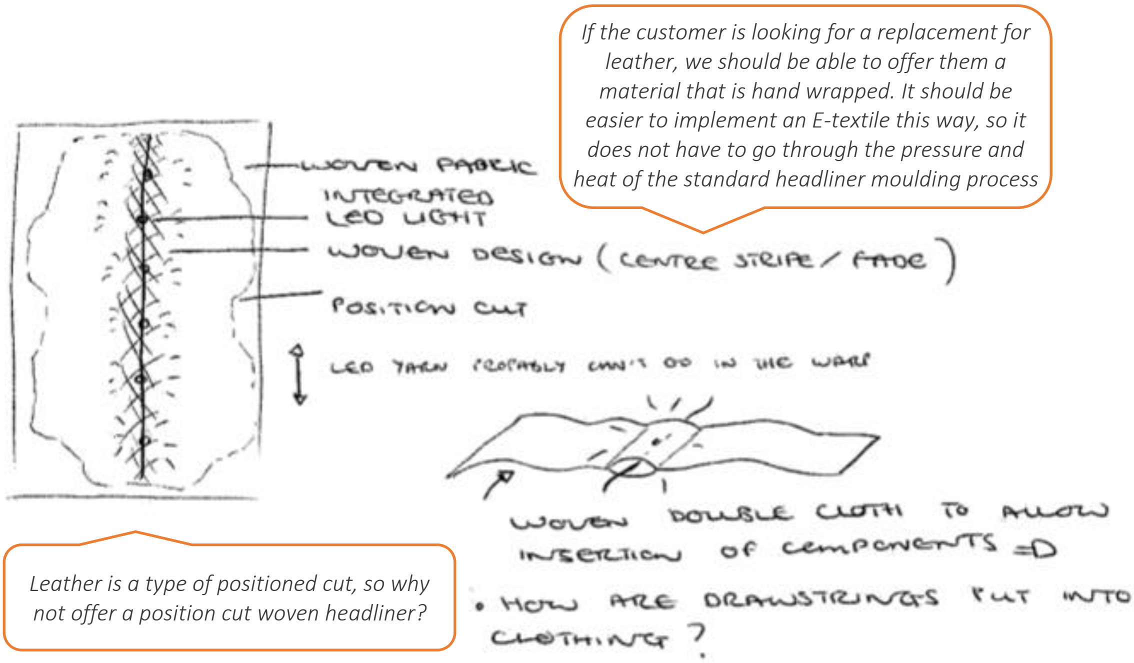


Figure 4-8 Research diary, p. 12: Thoughts on weaving and integrating lighting into a vehicle headliner

On 29th August 2016, I got the opportunity to discuss E-textile lighting at the supplier innovation event organised yearly by Customer B. On presenting my research to the panel, they informed us they were already researching new functions for lighting in the vehicle interiors. However, the outcomes of this research were only going to be shared with specific suppliers. I could sense their scepticism towards E-textiles as a viable alternative form of automotive interior illumination. Balancing my dual role of employee and researcher, I was wary of "forcing the idea onto customers" (Research diary, p. 18) and I was becoming unsure of my focus.

Another opportunity arose to discuss my research in a professional capacity on 15 September 2016. The meeting was attended by a multidisciplinary team from Customer C which included a textile designer and an interaction designer. They outlined their research as "a new concept of interaction". They were interested in E-textiles playing a role in their concept, but did not have a defined idea of what their purpose should be. E-textile illumination, however, was not something they appeared interested in pursuing. Unable to find a partner with whom to collaborate and lacking customer interest in the area, at this point I abandoned the focus on E-textile illumination. The discussions with Customers A, B and C led me to open my project to a broader range of E-textile possibilities. Shown in Figure 4-9, I started to explore the role E-textiles could play in Human-Computer-Interaction (HCI) in vehicles.

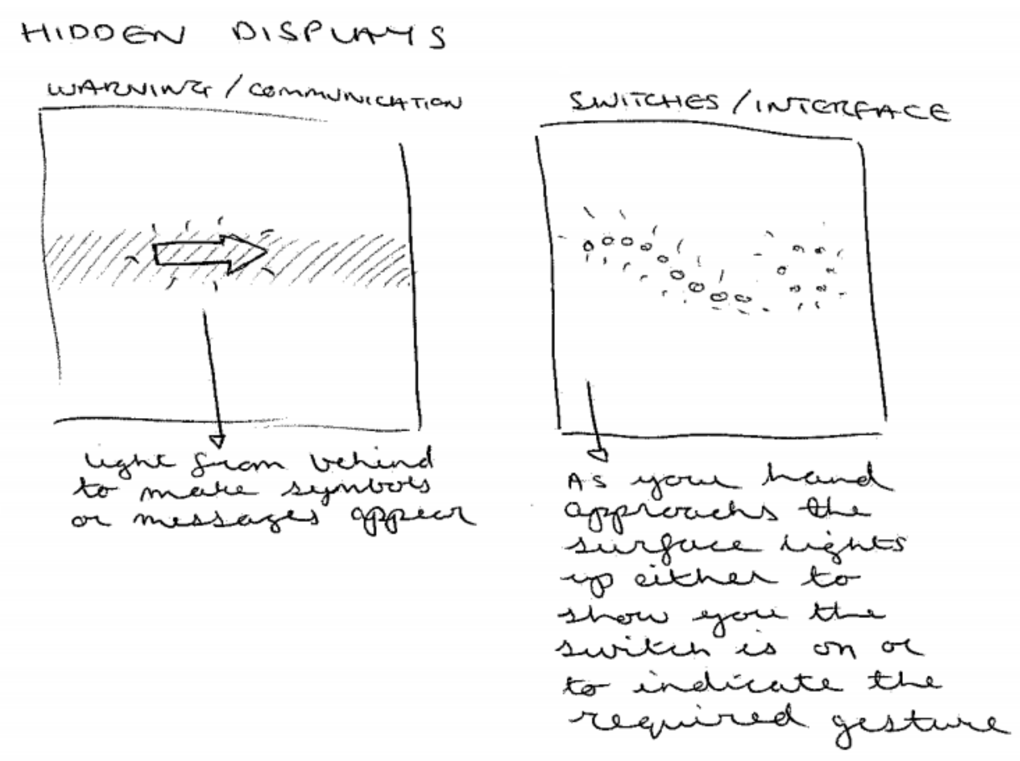


Figure 4-9 Research diary, p. 35: Exploration of the role of E-textiles in vehicle HCI.

The meetings with customers I have described and the research I was conducting as part of the MPhil were leading me into unfamiliar territory. I could no longer take the use of the textiles I created for granted and customers were providing only vague direction. In search of new approaches I was reading Moggridge's "Designing Interactions" (2007a) and Laurel's "Design Research: Methods and Perspectives" (2003) and encountering the concept of the 'user'. Page 19 of my research diary, found in Appendix A1, shows me trying to understand what purpose E-textiles might serve through brainstorming the 'needs' of drivers and passenger and I was researching the causes of vehicle accidents (Institute of Advanced Motorists, 2009). I reflected on why conventional textiles are used in vehicle interiors, such as their warmth, acoustic properties, and homeliness, to imagine how this might complement electronic functionality (Research diary, p. 26).

At this stage I still relied on the framework of my prior design process reflected by the research structure shown in Figure 4-3. I was using familiar techniques, including brainstorming, visual research, testing material properties and experimenting with manufacturing processes. Garlinska and Röpert (2013) suggest that brainstorming is overused and advocate techniques which create deep understanding of customers – meaning users rather than other businesses – to design smart textile products. The problem with this suggestion is that both the industry in which I was embedded and I were unfamiliar with techniques which can generate this deep understanding. Instead, based on Company C's interest in "a new concept of interaction", I made the simple step to exploring capacitive sensors, one of the technologies used to make touchscreens. In doing so, I was unreflectively putting materials and technology before people and their context, which could result in designs that do not serve any purpose well.

The collaboration I previously mentioned involving Corporation X's electrical group and members of the premium group started in early Autumn 2016. That I am aware, none of the members had experience of using HCD (Section 2.6.2) to research a purpose for a new product based on human needs and behaviour. As a result we were attempting innovation with E-textiles based on technological capabilities, an approach to innovation referred to as technology push (Norman and Verganti, 2014; Rothwell, 1994). At the time, the technical approach of the group fitted the research methodology I was using. Under my heading 'performance' conclusions about whether conductive yarns broke under a certain strain, independent of what they might be used for, were sufficient. The focus on technology of the collaboration is unsurprising given that Corporation X operated exclusively B2B, separated from users. An electronic engineer in the group drew up a matrix listing possible functions for E-textiles, which included "custom colourisation" for "appearance enhancement" and "heat sensors coupled with occupancy sensors" for biomonitoring, but without a rationale to investigate one technology over another the group lacked a focus.

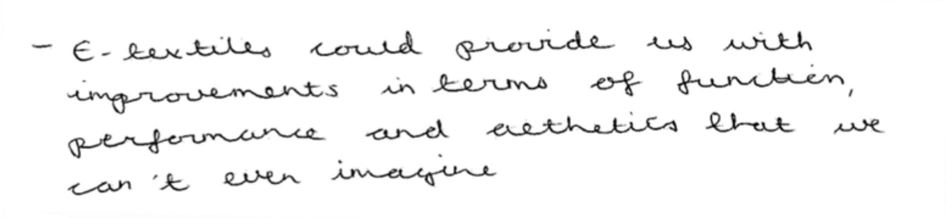
The lack of focus, my knowledge of automotive textile manufacturing, the influence of colleagues, and concern about the environmental impact of E-textiles, negatively influenced my attitude towards them. In the early pages of my research diary are my attempts to change, or at least inspect, my feelings. One entry resulted from a discussion with a colleague about alternatives to leather. Her question was, "what is it about leather that makes you go Ooo…?". In other words, what are the reasons we perceive leather as a luxury material? Looking to feel excited and inspired led me to brainstorm the question, "what about E-textiles could make me go Ahh…?" by which I meant, what about E- textiles could inspire me?

That list included:

- Something that has a purpose
- The experience of novelty
- Beauty
- Unexpected functionality
- Functionality that is not a poor substitute for another material and can only be achieved with an E-textile

Moon (2003, p.227) suggests to designers, when believing something to be bad or good, to "get over yourself" by playing a game of Devil's advocate and occupying the opposite of your habitual mindset. To further challenge myself, I considered arguments for and against E-textiles. This critical thinking technique, also referred to as inversion or “consider the opposite”, was used by the Greek Stoic philosophers (Levy, 2009). The arguments I wrote against E-textiles – that they will be expensive, difficult to produce, and other materials perform better – were full of the industry scepticism I was up against. Instead, when advocating for E-textiles my arguments were (Figure 4-10):

A


– E-textiles could provide us with improvements in terms of function, performance and aethetics that we can't even imagine

B -

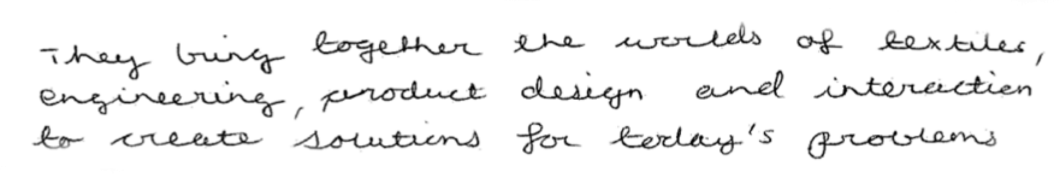

They bring together the worlds of textiles, engineering, product design and interaction to create solutions for today's problems

Figure 4-10 Research diary, p. 30: Arguments for E-textiles

The statements are vague, invoking the possibility of unknown improvements (Figure 4-10A). In the second excerpt (Figure 4-10B), I was parroting the concept of design as problem solving, an endemic view in design theory but less recognised by textile designers (Igoe, 2013, pp.91–103) including me. To say E-textiles could “create solutions for today’s problems” is naïve and loaded with assumptions. Nobel Prize winner Herbert Simon stated that “everyone designs who devises courses of action aimed at changing existing situations into preferred ones” (1996, p.111), but this definition does not account for the criteria that determine what is preferred. Simon’s definition design can be manipulated to consider anything a ‘problem’ if someone wants and will pay for the ‘solution’. The value of a solution can only be evaluated when its purpose is understood, the missing part of the value-impact equation described in Section 3.1. At this point in the investigation I had not resolved how to act on the arguments I put forward (Figure 4-10), but I had found that the industrial textile design process and organisational culture at Company X were not well suited to the task.

Textiles are conventionally shared with customers as samples, but if an E-textile is not connected to other components to form a system, it cannot function. Acknowledging the need to move beyond samples and include electronic elements in the ‘materials of the situation’, in November 2016 I purchased a range of conductive materials, microcontrollers, LEDs and other components. I believed, as expressed later in my PhD proposal of January 2018, that a barrier to the success of E-textiles was that textile designers rarely understood “material properties from an electronics point of view" (Research diary, p. 6). Also, I pondered whether product designers were familiar with managing an "incomplete understanding" of material properties and had "found ways around it". In response to my query, van Bezooyen (2013, p.283) suggests that, "the [product] designer's challenge is to know many materials a little and specialise where necessary".

4.3.1 E-textile design challenges

As a route to understanding the functionality of E-textiles, meaning what they can do, I gave myself electronics 'design challenges', including putting together simple circuits, understanding how to adapt code to program a microcontroller and building different capacitive sensors, shown in Figure 4-11B and 4-11C. Using Schön's (1983, p.79) phrasing, I was also trying to create my design world and understand the materials of the situation.

My research diary is scattered with notes relating to electronics and electrical principles (Figure 4-12), understanding of which I developed by building E-textile circuits and components. Lawson (2004a) found that designers struggle to use theoretical knowledge in the design process, instead relying on experiential memory. Through my design challenges I learnt theoretical notions such as polarity and continuity through experience, the circuits providing feedback as to whether I had correctly applied theory when an LED lit up or a computer reading appeared.

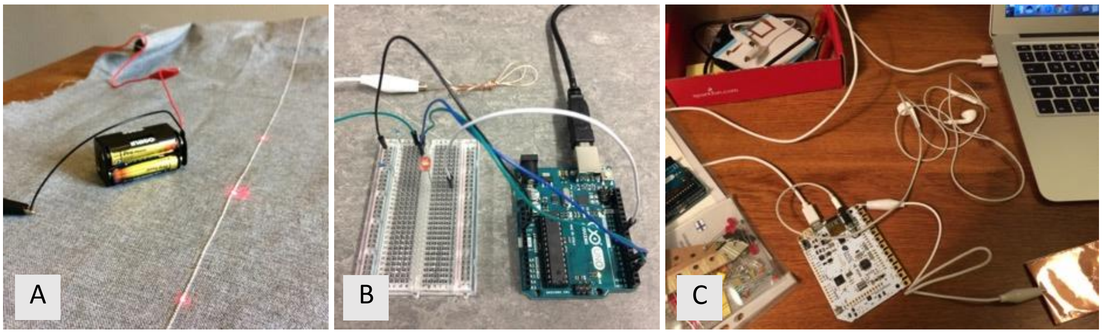


Figure 4-11 Electronics challenges, February 2016, A. Functioning LED E-yarn in an industrially woven fabric, B. and C. capacitive sensing circuits

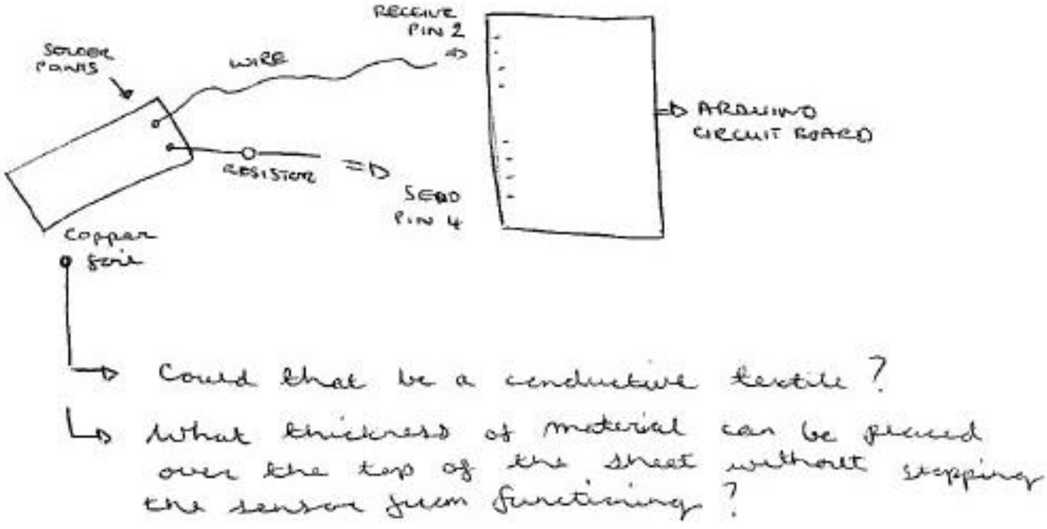


Figure 4-12 Research diary, p.23: Understanding capacitive sensing

The E-textile design challenges were both empowering and frustrating. I was developing my knowledge of electronics and giving feedback to the ATRG about the performance of the E-yarn, but the circuits and components I was working with were basic. There was a gap between what I wanted to achieve and what I could achieve. I was working beyond the optimal range of experience, defined in the concept of flow as where perceived skill and the opportunity for action are balanced (Csikszentmihalyi, 1990). However, engaging with these tasks gave me language to communicate better with colleagues from Corporation X's electrical group and with members of the ATRG.

In parallel I was conducting manufacturing trials to test whether NTU's E-yarn would function after being woven on industrial machinery. To weave the E-yarn on machinery available at Company X in the UK, the loom had to be stopped and the E-yarn put through the weft by hand before restarting the loom. This was because the rapier used to insert weft yarns into a fabric, comparable to that shown in Figure 4-13A, could not take the E-yarn across. The E-yarn was hooked by the rapier rather than held, and easily slipped off. Figure 4-11A shows the manually inserted LED E-yarn functioning in the fabric after weaving. A further trial in April 2017, on a Dornier loom with a positive grip rapier shown in Figure 4-13B, which was able to hold and transport the E-yarn, showed that with suitable equipment the weaving process for the E-yarns could be fully automated. Furthermore, the textile was washed, heat-set and laminated and the LEDs, soldered to the yarn's copper core, survived the mechanical and thermal stresses of the process intact.

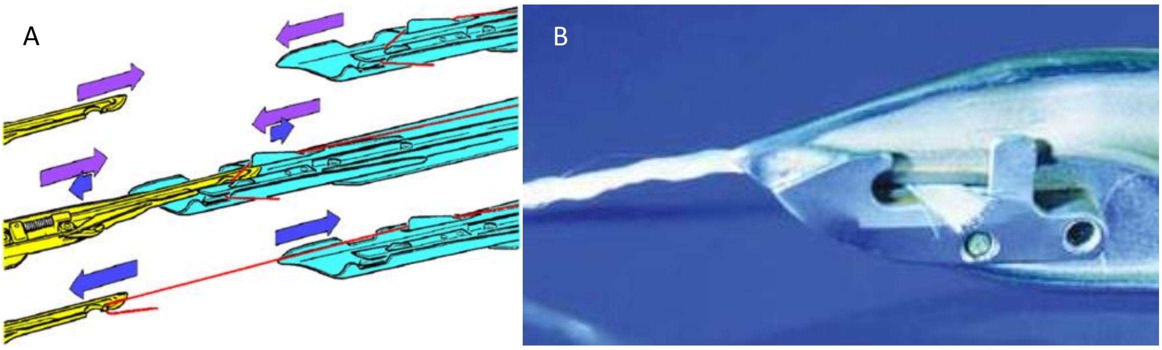


Figure 4-13 A. Yarn transfer in a double rapier system without positive grip (Gong, Chen and Zhou, 2018)*, B. Dornier positive grip rapier gripping a yarn (Dornier, 2020)*

The weaving trials brought other challenges to industrially manufacturing woven E-textiles using E-yarns into focus. For example, the position of electronic components in an E-textile is likely to be crucial to their function, but automated weaving technology, including the Dornier rapier system, cannot position the component on an E-yarn at a specific point in the textile's width (weft direction). It also cannot control the orientation of component in the E-yarn, which twists during the weaving process, resulting in the LEDs or other microelectronic components facing to the front or back of the textile at random. Whether it is a problem that E-yarns cannot be positioned at specific points and that they twist during the manufacturing process depends on the intended application. As a case in point, thermistor E-yarns have been found to take an accurate temperature reading without orientation being accounted for during measurements (Hughes-Riley et al., 2017). For temperature sensing functions, the position of the thermistors may not be crucial, but this depends on the use to which the E-textile is put. Neither the design challenges nor the manufacturing experiments could define the purpose for which I was designing, because these activities investigate the possibilities of materials and technology rather than their role.

I still had the topic of "new concepts of interaction" from my meeting with Customer C, which was further reinforced on 21st April 2017 at a meeting with Customer A. They discussed their interest in "a new language of gesture" and haptic feedback through textiles, but it was not clear why these areas were of interest, other than their novelty. My impression was that these ideas relied on the design references they cited, in particular the Google Jacquard Project, promoted in design publications (Howarth, 2015) rather than a purpose. This is unsurprising given that design references or precedents have been found to play an important role in the design process (Gregory, 1966; Lawson, 2004a).

From an interaction design perspective, Moggridge (2007a, p.725) suggests that when inventing something new the best place to start is to focus on the people for whom you are designing. In automotive textile design this presents problems. Normally, neither the CMF designers working for the OEM nor textile designers working for the OEM's suppliers have contact with 'users'.

Moggridge's statement implies the designer knows for whom they are designing. Additionally, it has been stated that users "can only articulate product value in terms of existing products" making it difficult for them "to predict the value of new products such as smart-textiles" (Ossevoort, 2013, p. 411). I suggest that like myself the CMF designers of Customer C were not exploring the user needs and aspirations that E-textiles could fulfil, rather they were taking their inspiration directly from design precedents.

Running through my research diary are attempts to imagine applications for E-textiles. Nilsson (2015) describes product design education as focusing on users and functionality, with material choices produced as the result of the design direction. By contrast, she reflects that for textile designers, materials are the focus of their design process. Unaware of the implications of what I was doing, I tried mapping my experience of driving and that of family members to see what insights might arise. Although I had not yet conceptualised it as purpose-led or human-centred, I had begun to subtly shift my design practice towards considering people, place, and product.

4.3.2 E-textiles demonstrators

At the beginning of May 2017, I was accepted to present at Theorem, a symposium and exhibition to be held at Anglia Ruskin University in July. I wished to use Theorem as an alternative forum for which to create and share an E-textile demonstrator (Figure 4-14). I used several of the E-textiles I had woven on industrial machinery containing conductive yarns or LED E-yarns. The concept was simple, I made a capacitive sensor with the "TouchBoard" microcontroller, produced by Bare Conductive®, to turn the textiles into proximity sensors. When part of the human body, most likely a hand, was close to the textile on the left it would trigger the LED E-yarn to light-up. A hand close to the one on the right would trigger an audio file to be played through the speaker concealed behind the panel[8] (Figure 4-15).

[8] The audio was the opening section of Kraftwerk's 1974 track "Autobahn", which means motorway, and the sound is of a car engine starting.

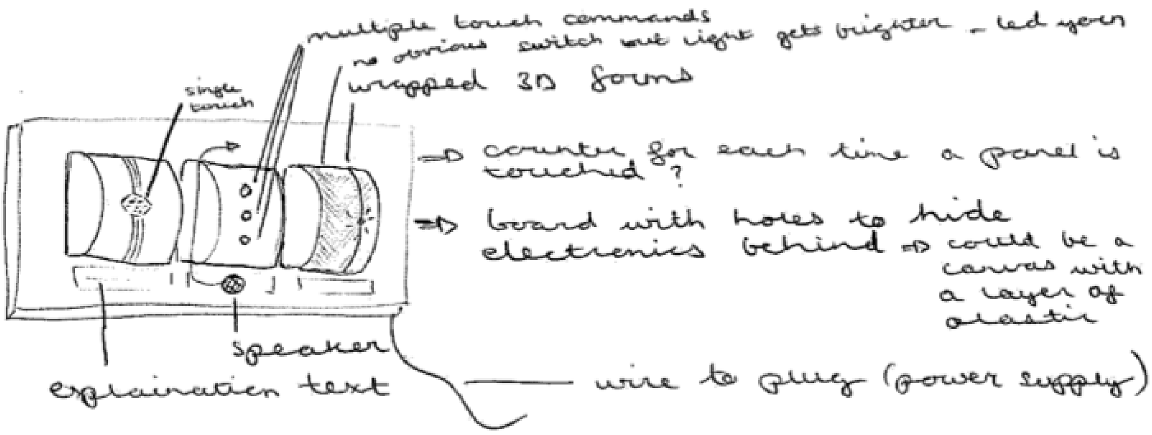


Figure 4-14 Research diary, p76: Theorem design sketch

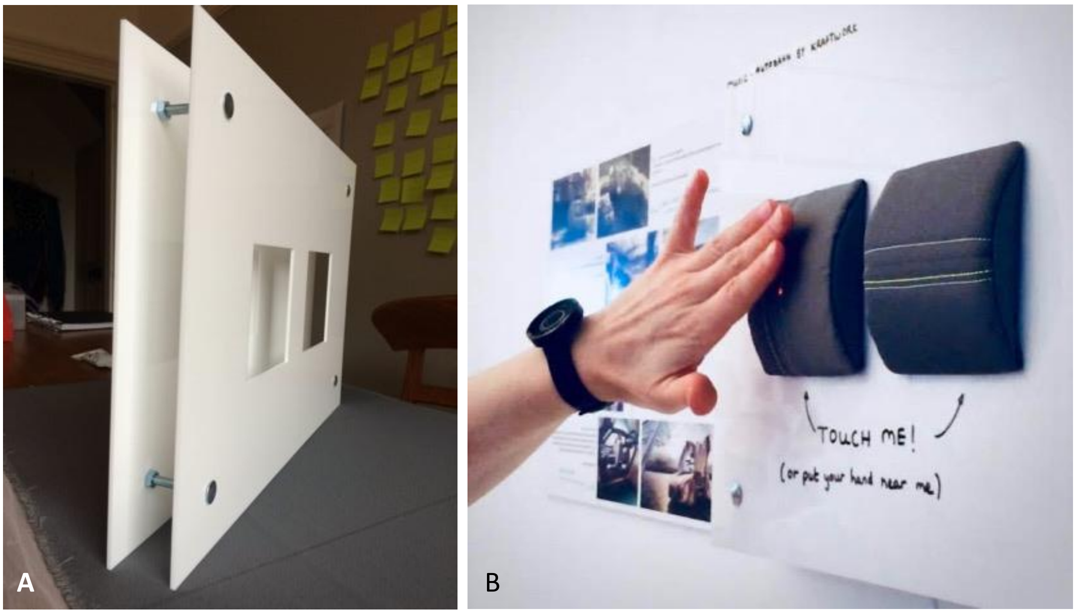


Figure 4-15 A. Double layer construct to hide electronics. B. Theorem demonstrator Installed, July 2016.

Following Theorem, I organised a round table discussion with colleagues to present the demonstrator, samples and E-textiles more generally. Imagine a long table with the demonstrator (Figure 4-15B) in the centre and 12 colleagues, a combination of textile engineers and designers, sat around. I briefly introduced the demonstrator and invited colleagues to interact with it, but rather than become a focused discussion on touch responsivity the conversation started to ping pong around different E-textile functions. These were wireless charging, pressure mapping, personal temperature sensing and to create lightweight slimline seats, because “buttons are a thing of the past” (Research diary, September 2017, p. 98).

In summary, sentiment towards E-textiles differed. Some colleagues pronounced them the future of automotive textile design, while others could only list the challenges of making them manufacturable. Towards the meeting’s close, I introduced the team to a proposal that had developed on the biweekly electronics call. Largely because of the technology that was available, the group had proposed that I weave a fabric containing NTU's thermistor E-yarn, which they imagined as a temperature monitoring component in a zonal heated seat system. The agreement from the team around the table was that I should make the thermistor sample.

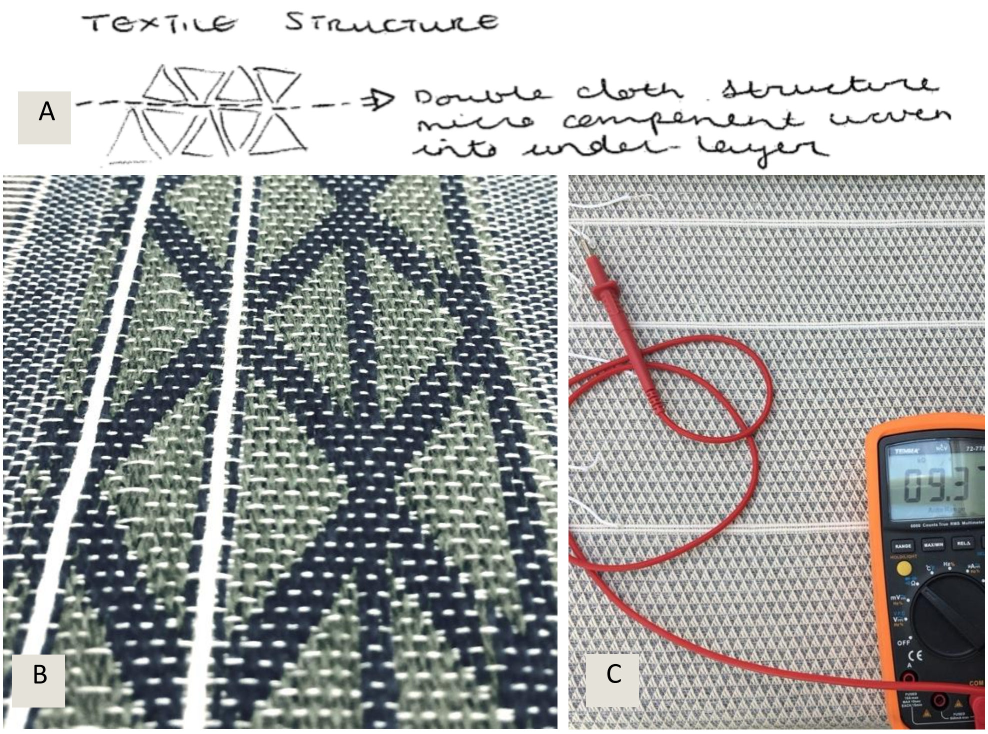


Figure 4-16 Research diary, p. 97: A. Textile construction sketch, B. Hand woven fabric sample, C. Testing the resistance value of thermistor E-yarns in the woven E-textile

I was given a layout defining the position of each thermistor by the premium division. Due to the problem of positioning E-yarn components when weaving on automated machinery, I first trialled designs on a digital jacquard loom, computer controlled but manually operated, to define a suitable woven construction. I produced the final fabric on an automatic jacquard machine at NTU, stopping at specific points to insert and position the thermistor E-yarn by hand. The thermistors fused onto the E-yarns were not visible and therefore I marked each to locate them, again illustrating the difficulties of manufacturing E-textiles. Given earlier conversations with Customer A about making functional features visible to sell an idea, I had considered how the E-textile could communicate its temperature sensing capability, but there was no obvious correlation between temperature sensing and appearance. Placed in the system of components that is the vehicle interior, other elements could more easily give occupants feedback about temperature sensing capabilities than the material they are sitting on. Once I had designed and made the fabric, the electrical division tested the thermistors to verify the reliability of the readings. Their results, reported in September 2018, showed an accurate correlation, supporting prior findings (Lugoda et al., 2018; Hughes-Riley et al., 2017).

This description of my experience during *Design Situation 1* is a condensed account. I do not have space to talk about the trials I ran using heat transferable conductive films or the German Master's student who tested the durability of textiles containing conductive yarns. I have omitted further description of these aspects of *Design Situation 1* because determining manufacturability or durability did not take me closer to contextualise the meaning of these results. Although I created several E-textiles with a function in mind, there was little rationale or research to render their design purposeful.

4.4 Discussion

At the end of *Design Situation 1*, I still believed that understanding the 'materials' of E-textiles was key to creating innovative designs. However, I could also see that to design with an emerging technology required additional strategies. My conclusion was that the design process for E-textiles needed to be linked to interaction and product design. The automotive textile industry is far removed from these areas and the customary process, using visual research and knowledge of materials and manufacturing methods, provides an incomplete picture when designing E-textiles. *Design Situation 1* illustrates that the traditional material centredness of textile design, when combined with emerging technology, risks becoming a technology-push effort without a clear purpose. While many innovations in the textile industry have been driven by advances in material science and manufacturing machinery (Shishoo, 2012), E-textiles invite a deeper exploration of their purpose.

Had I contributed to a broadly technical-rationalist project, such as the "Heat Harvest" project which investigated energy harvesting textiles (Townsend et al., 2017), I might not have questioned the lack of a defined purpose for the E-textiles I was making. Instead, I could have contributed to findings about the behaviour of materials as did the textile designer on that project (ibid.). But, given the research did not have this framing, the question *why* an E-textile should be designed became central.

Expanding my practice into the domain of electronics, I made E-textiles using conductive and E-yarns, building them into simple prototypes with relative ease, but the research highlighted the challenges of industrially manufacturing reliable E-textile products. Prototypes are representations of objects, in order for them to work effectively, what they represent and their role in the innovation process needs to be clarified (Holmquist, 2012c). Currently, textile designers tend to make samples rather than prototypes. A sample of a textile is to scale, it is merely a smaller quantity, otherwise identical to hundreds of metres. Based on *Design Situation 1,* this thesis argues that to create successful E-textiles, textile designers and the industry need to learn how to make and use prototypes during the innovation process.

My inexperience designing prototypes meant that the exhibit I created for Theorem, when shared with colleagues, did not have the effect I had hoped of clarifying development steps. They perhaps perceived it as too technologically primitive, or not aesthetically or functionally interesting enough and it did not encourage ideas to coalesce around a direction. I also lacked design research strategies to define and explain the purpose I was designing for. Yet making prototypes was valuable in allowing me to see the physical and digital elements that make up an E-textile system. Understanding E-textiles as systems led me to re-evaluate what the term 'material' means in relation to them. Section 1.5 introduced the idea that E-textiles occupy a place between materials and end-products. They are more defined and less transformable than conventional textiles, which changes the decision-making process needed for their creation.

Techniques to explore the purpose of E-textiles, by understanding the contextualised needs and aspirations of the people for whom they are created, can underpin the design of prototypes. Textile designers could explore speculative design, not the big S 'Speculative Design' of Dunne and Raby (2013) that evolved out of critical design, but nonetheless conjecture about the future. If as a textile designer you were no longer tied to predefined uses for your textiles, what would their purpose be? Speculation about the role E-textiles could have requires regard for 'the bigger picture'. For a textile designer to engage with E-textiles, this thesis argues they must consider what the textile will become. The purpose of E-textiles can be better defined while the technology itself develops to a higher level of readiness for industry. Some problems connected to the sustainability of E-textiles could also be addressed as the electronics and textiles industries are being steadily forced to improve the social and environmental impacts of the manufacturing and disposal of their products (Cook and Jardim, 2017; Irimia-Vladu, 2014; BMW, 2017)

Hierarchy and lack of cross-functional innovation teams have been found in studies of textile manufacturing, and other industries where craft skill is required, to hamper innovation (Yair, Press and Tomes, 2001; McAdam and McClelland, 2002; Lockwood, Smith and McAra-McWilliam, 2012). Undoubtedly the organisational structure of Company X and my experience there strongly influenced this stage of the investigation. My dual role as researcher and employee throughout *Design Situation* 1 made it difficult for me to take risks, as for customers and colleagues my professional role took precedent. Company X tended to be risk averse and had a hierarchical structure which, as theories of creativity and innovation would suggest (Amabile and Pratt, 2016), was not conducive to experimenting with novel approaches or materials. In many production areas, the company did not have staff dedicated to new product development. This negatively influenced attitudes to unfamiliar techniques, processes and materials including E-textiles.

I address the limitations and biases of *Design Situation 1* in the subsequent *Design Situations* by shifting the focus to other designers and their process. In Chapters 5-7, I present three further

Design Situations in which I investigate the design process of E-textiles for interior spaces beyond the vehicle interior. Although I was a participant in these as a tutor, facilitator, and designer, I could step back and watch others while they engaged with E-textiles. Through interviews and group discussions, I integrated other perspectives into my understanding of the design process for E-textiles. Once outside Company X, the data collection constraints were removed and, with the participants' permission, I could record and photograph the unfolding events. This allowed me to reflect on action not only during events but also retrospectively. To provide a counterpoint to *Design Situation 1,* the fourth *Design Situation,* discussed in Chapter 7, involved a multidisciplinary team also from an automotive and transport textile manufacturer.

In Design Situation 1, I attempted mixed methodology which split the inquiry into the areas of performance, manufacturing, function and aesthetics, but answering how an E-textile could be manufactured, how it might look, or what functionality it possessed, did not clarify its purpose. If, as Moggridge (2007b, p.726) states, the essential first step when designing something new is to "understand the latent needs and desires" of those who will use the design, then the absence of the user in the industrial textile design process is a barrier to the creation of successful E-textiles. The textile design process used in automotive textile design was ill-equipped to research and invent how E-textiles could be used. I could not formulate a justification or rationale to develop one type of E-textiles rather than another. What I needed was a purpose to lead the design process. Hence, from *Design Situation 1* emerged what would become the central research question of this thesis:

How can the textile design process be adapted to create a purpose-led process of designing E-textiles for interior spaces?

The subsequent *Design Situations* therefore investigate this question through a series of workshops and design projects involving students, academics, and industry representatives. They address the limitations of *Design Situation 1* and build on the insights I gained from the experience.

5 *Design Situation 2*: ArcInTex Workshop

> *It made people really consider the purpose and the problem of a product. In a way it made people stuck as they became a bit too considerate and less playful.*
>
> *(Participant-facilitator H: Team B - closing questionnaire)*

In *Design Situation 2*, teams were asked to move from a situation of nothing – no pre-determined application, no user, no specification – to something: a design proposal for an E-textile to be used in a non-residential interior space. As the excerpt above shows, while the workshop activities meant the participants considered the purpose of the E-textile they were designing, they also found themselves "stuck". Replicating the uncertainty of my experience in *Design Situation 1,* the process was difficult. This chapter will elaborate the reasons participants felt stuck and the choices they made to 'free' themselves. It sets out how the workshop was planned in response to *Design Situation 1's* diagnosis of the difficulties faced by textile designers in envisaging a purpose for emerging E-textile technology. These difficulties stem from its uncertain nature, textile designers' lack of familiarity with techniques to envisage a new purpose for their designs and their conventional separation from the user.

Design Situation 2 was a two-day workshop titled 'Interior E-textiles: Fuzzy Challenges' that will be referred to as the 'ArcInTex workshop'. It was held on 5th and 6th December 2018 as part of an ArcInTex network event titled "Knitting the Gap: Textiles meets Architecture meets Textiles" (Nottingham Trent University, 2018). The ArcInTex network was set-up to link researchers from the fields of architecture, interaction design and textile design, to explore techniques, methods and perspectives on building, dwelling and living (ArcInTex, n.d.). The event was an ideal forum for this second *Design Situation*. Each of the disciplines involved in the network are connected to the design of E-textiles for interior spaces. The workshop, one of three that attendees could choose, investigated the fuzzy front end of designing E-textiles, the fuzziness to which its title refers. To align with features of the automotive textile industry, while also broadening the scope of the investigation, the workshop examined the design of E-textiles for non-residential interior spaces where, like in the automotive industry, textiles are an element in a larger design scheme.

5.1 Contextualising *Design Situation 2*

In *Design Situation 1*, I was guided by conventional textile design practice focused on materials, manufacturing techniques and aesthetics. While this practice is well suited in stable material-product relationships, when the product is being invented alongside the material it is less useful. Additionally, E-textiles are arguably not materials, instead they are closer to products, shaking the conventional relationship between a textile and what it will become. Although investigating the needs and desires of users has been recommended as the first step when inventing something new (Moggridge, 2007a, p.726), in the case of an emerging technology like E-textiles their role is unclear and therefore who the user is, is also unclear. Velloso et al. (2018, p.609) propose that while “user-centred design methods are excellent for fulfilling user needs using mature technologies, they are still limited in handling emerging technologies”. Hence, *Design Situation 2* explored techniques to address the challenge of purposefully designing E-textiles.

The starting point for the workshop was the fuzzy front end of the design process. There was no pre-identified users or context. To explore the purposes E-textiles could serve in non-residential interior spaces, the workshop had first to allow participants to decide what interior space and for whom they were designing. I wished for the participants to consider how people’s needs and aspirations change based on context, for example, an airport versus a primary school. The workshop needed to elicit reflection on different experiences. In the example of a primary school, this would mean choosing to consider the needs of the teacher, pupils or parents. The participants would construct the problem for which they were designed by generating a scenario formed of people and place.

There are various ways to create a design scenario. During the Heat Harvest project, the focus of which was thermoelectric energy harvesting technologies using textiles, electronics and smart materials, referenced in Section 2.5, Townsend and Ylirisku (2015, p. 93) refer to this process as “context construction”. Unlike this investigation which examined interior spaces, they framed the Heat Harvest project around an idea they called the “Internet of Textiles” (IoT^x) and the themes: interaction, memory and processing. In a workshop that was part of the project, participants were asked to envisage uses for the Heat Harvest technology. The workshop also aimed to overcome the tendency in science-led material development of “extensive consideration of technical aspects at the cost of the experiential insights” (Townsend and Ylirisku, 2015, p.93). To construct a context, they provided participants with collages of imagined individuals or personas to encourage empathetic ideation of textile-based products[1]. This was followed by a phase of material exploration in which the participants were asked to create “situational sketches” which communicated meaningful purposes of the materials in relation to the personas (ibid. p. 96). Finally, the participants were asked to develop the sketches into stories. The workshop resulted in 12 product ideas, but when reviewed none were directly applicable to the project.

In the month that *Design Situation 2* took place, Velloso *et al.* (2018, p.609) held a workshop at the 30th Australian Conference on Computer-Human Interaction to “bridge inquiry-led human-

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[1] Personas are fictional characters that embody characteristics of the intended user, humanising demographic or ethnographic data.

centred design methods with invention-led technology-centred methods" for emerging interactive technologies, including eye trackers, AR and VR headsets, and smart materials. The workshop's title references Holmquist's (2012a) notion of 'grounded innovation' which argues successful innovation should balance both the blue-sky thinking of invention, including brainstorming, with HCD inquiry, such as focus groups and observation (Figure 5-1)[2]. As the workshop's outcomes were not published, I cannot provide comment on the effectiveness of the strategies used, but the question the workshop addressed is sufficiently relevant to merit its mention.

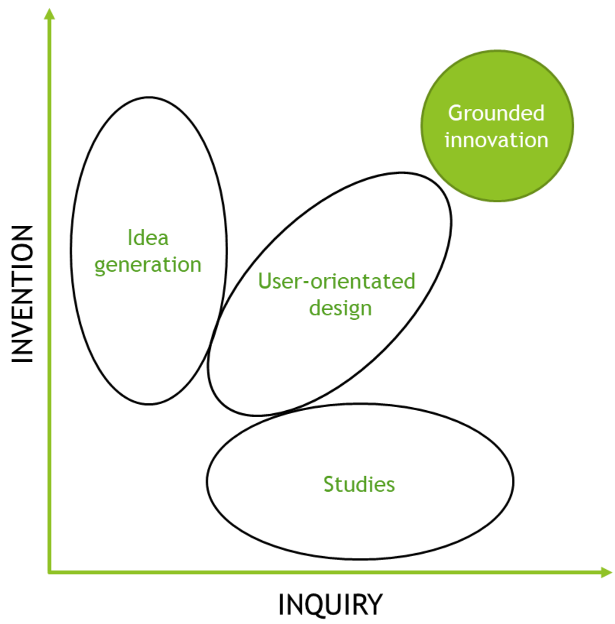

Figure 5-1 Holmquist's (2012a) *positioning of 'grounded innovation' between blue-sky invention and user inquiry*

To create a starting point, or to use Townsend and Ylirisku's (2015) phrasing: construct a context, Velloso *et al.* (2018) asked participants to prepare a scenario of personal relevance in advance. During the workshop the scenarios were distributed and participants were tasked with identifying the user needs the scenarios suggested. They used mash-ups, a technique involving the juxtaposition of ideas (IDEO, 2019), to explore how emerging technologies might address those needs, before creating low-fidelity prototypes and finally reflecting on risks and ethical implications of their designs. These two workshop examples illustrate a range of strategies available to designers to define a context, situation or setting for which to design when working with emerging technology. The challenge the designer faces is to find situations for which the technology in question is relevant.

[2] Grounded Innovation has no connection to the qualitative research methodology Grounded Theory.

One aspect of constructing the context both workshops addressed that *Design Situation 1* did not, was to ask, "who am I designing for?". Miaskiewicz and Kozar's (2011, p.426) Delphi study found that personas benefit the design process by helping to overcome the distance between the user and the designer and bringing the user "to life" so that their needs and goals drive the design process. Experiments have also found that personas act as a priming device in idea generation, '"preloading" the mind with stimuli that facilitate memory retrieval and processing (So and Joo, 2017, p.471). At this stage in the investigation, understanding the role of an imagined user in the process of designing E-textiles for interior spaces was unclear. The approach the workshop adopted to help participants consider for whom they were designing was a structured idea generation technique known as bootlegging (Holmquist, 2012b). Rather than develop a detailed persona or bring a scenario from their experience, I asked the participants to brainstorm around the prompt 'user group' followed by 'interior space' to construct a context for which to design.

Structured idea generation, that provides prompts to support ideation, has been found to produce more varied, novel and relevant ideas than brainstorming alone (Moon and Han, 2016; Daly et al., 2012). This finding puts in context my experience in *Design Situation 1.* I had largely relied on unstructured brainstorming and remained unsatisfied with the ideas that resulted. Various modifications to brainstorming have been proposed. These include 'extreme characters' where ideas are generated around, for example, Superwoman or the Pope (Djajadiningrat, Gaver and Fres, 2000), and methods for idea combination or juxtaposition, such as 'Mashups' (IDEO, 2019) used by Velloso *et al.* (2018) and bootlegging selected for *Design Situation 2*. Studies of technology management show that innovation often occurs as a novel recombination of existing pieces of knowledge (Verganti, 2009, p.153). Divergent thinking, where many diverse ideas are put forward, as opposed to convergent thinking where ideas coalesce around a single proposal, is closely equated with creative ideation (Mumford, 2001). While both types of thinking are required for design, as represented visually by the form of the Double Diamond Model (Design Council, 2019a) depicted in Figure 2-1, the initial Discover stage, the starting point of *Design Situation 2,* is considered to require divergent thinking.

In *Design Situation 1*, the CMF designers that were my customers, my colleagues and I had based our ideas for potential applications of E-textiles on products or prototypes we had already seen, such as the Google Jacquard™ Project (ATAP Google, n.d.). Our ideas converged too quickly around these design references. It is challenging to breakout of the 'thinking grooves' created by the friction of what we already know to arrive at novel design solutions. The phenomenon, known as 'design fixation', was originally defined as "blind adherence to a set of ideas or concepts limiting the output of conceptual design" (Jansson and Smith, 1991, p.3) and more recently as "situations where designers limit their creative output because of an overreliance on features of pre-existing designs” (Youmans and Arciszewski, 2014, p. 129). A form of this phenomenon occurs in gesture elicitation studies that is called legacy bias (Morris et al., 2014). The term describes where participants propose gestures based on their experience with existing technologies, such as the mouse. Using gestures based on legacy bias risks that we do not take full advantage of new technologies more suited to novel forms of interaction. There are very few E-textile products for interior environments. Reliance on this limited range of precedents is likely to inhibit innovation and must be overcome to generate designs that are novel, relevant and ultimately feasible.

In *Design Situation 1,* I had not fully appreciated the limitations of the primary idea generation methods of textile design – visual research, trend analysis, sketchbooks, mood boards and brainstorming – for envisaging a purpose for E-textiles. My experience highlighted that although aesthetic considerations are important in the design of E-textiles, if the design process is to be purpose-led then decisions about aesthetics should be informed by the design’s purpose. Exploration that uncovers the purpose for which the E-textile is being designed must be used to complement visual research. Furthermore, in user experience (UX) design, an area involved in the design of many E-textiles, Moon and Han (2016) found that brainstorming, used as the sole method of idea generation, produced less varied, novel and relevant proposals. Hence, the workshop trialled alternatives to the conventional research methods of textile design, to develop a purpose-led E-textile design process.

At this stage of the investigation, I believed that understanding the properties and behaviour of the various textile and electronic elements that come together to form E-textiles would support the generation and refinement of design proposals. Ashby and Johnson (2010) describe how novel materials can be the starting point of the design process, inspiring products that previously seemed impossible. Karana et al. (2015) and van Bezooyen (2013) have developed design processes expressly starting with and driven by materials. Material exploration, whereby designers engage with materials open-endedly to better understand their potential, has also been used in several E-textile design research projects (Persson, 2013; Townsend and Ylirisku, 2015). The goal of material exploration is not to solve a specified design problem, but to explore and discover material properties, providing experiential knowledge that may inspire novel designs. However, Karana et al. (2015, p, 49) warn that using material driven design processes with ‘smart materials’, which as stated in Chapter 1 many E-textiles are, is complex and risks creating designs that offer no “real value to people or society”.

The final consideration in planning the workshop was that the design generated had to be an E-textile. In *Design Situation 1*, I found it challenging to envisage the purposes E-textiles would best serve and situations where they would not be outperformed in terms of functionality, durability or other measures by alternative technologies. Unlike wearable applications of E-textiles, where comfort is fundamental, in interior spaces the integration of electronics into textiles may be a lower priority because rigid components can be embedded into foams or other surfaces. To envisage the purposes E-textiles could serve, the bootlegging activity included a step where participants considered the qualities of textiles. This was to encourage reflection on the properties that differentiate textiles from other materials.

In summary, the workshop investigated strategies to aid its participants create scenarios of a non-residential interior space and its occupants, and envisage how E-textiles could be beneficial. It had to overcome the problem of design fixation caused by reliance on precedent and allow participants to engage in a purpose-led design process. The final objective was to evaluate the contribution of material exploration to that process.

5.2 Planning and action

10 participants from a mixture of disciplines and both academics and students took part in the two-day workshop. Five participants had a background in textile design, making it the discipline most represented (Figure 5-2). To create an E-textile design proposal, I divided the group into two teams. I assigned participants to a team according to their responses to a questionnaire completed at the beginning of the session. The objective was to create a more even distribution of discipline, experience and confidence levels than might have occurred by chance or self-selection. The questionnaire asked participants to express their experience and level of confidence with E-textiles on a scale of one to five, where one was the minimum and five the maximum. This was to compare the teams and to remove obvious imbalances that could arise from having participants with significantly more experience or pertaining only to one discipline together in one team. Each team therefore was multidisciplinary and included participants with differing levels of experience designing with E-textiles.

The participants that are shaded in grey in Figure 5-2 also had a supporting role. One participant was a representative of Kitronik, a Nottingham based company specialised in the design and production of electronic project kits, and two were product design technicians from the NTU maker club, a group set up to aid students physically realise their ideas. To capture action my note taking was supplemented by that of two student participant-facilitators (D and H). The event was photographed and ended with a recorded group reflection session and closing questionnaire[3].

[3] Five participants returned the closing questionnaire - three from Team A and two from Team B.

Participant identifier	With which discipline do you most closely identify?	Team	Do you have previous experience working with E-textiles on a scale of 1-5?	How would you rate your knowledge of E-textile technology on a scale of 1-5?	How confident are you in your ability to develop a functioning E-textile on a scale of 1-5?
A	Textile design	A	1	5	1
B	Textile/ Interdisiplinarian	A	5	3-4	3
C	Textile design	A	3	2	2-3
D	Product design	A	1	2	3
E	Environmental engineering	A	1	2	2
F	Textile design	B	1	2	4
G	Industrial/(tangible) interaction design	B	3	4	1
H	Textile design	B	1	2	1
I	Electronic engineering	B	2	4	4
J	Product design/engineering	B	2-3	2-3	3-4

Figure 5-2 Teams and initial questionnaire responses

The workshop started with an icebreaker exercise in which I gave participants prompt questions relating to the workshop topic of E-textiles for interior spaces. I then provided a description of the industry context in which textiles for non-domestic interior spaces are currently designed. It explained that, as in my experience during *Design Situation 1*, the companies and designers in this sector often operate business to business (B2B) with little or no contact with the people that experience the textile once it is integrated into a product or interior. It also introduced them to the concept of the fuzzy front end and Holmquist's "grounded innovation" (2012a). Finally, before starting the activities, I gave them an overview of bootlegging (Holmquist, 2012b), which was going to be used to develop the design proposals.

It was during the opening section that the first interesting exchange took place. Having introduced bootlegging, Participant G, whose background was in industrial/interaction design told me, in what felt like an accusatory tone, that what I was doing was "gamestorming". The term is used for a set of techniques used to facilitate business innovation that were gathered, largely from Silicon Valley, by the authors of *Gamestorming: A Playbook for Innovators, Rulebreakers, and Changemakers* (Gray, Brown and Macanufo, 2010). According to Participant G, such an approach equated with an engineering outlook and was a technology-push method of seeking avenues for innovation. The participant expressed her feeling that E-textiles are frequently developed by textile designers with insufficient concern for users. Given the absence of the user from the conventional textile design process, highlighted by this thesis, this statement fits with my analysis, but it is not because of a wilful disregard for people by textile designers. What the participant's comment shows is a lack of understanding of the craft orientation of conventional textile design. The practice is focused on the creation of materials using aesthetic inspiration together with knowledge of yarns and manufacturing techniques.

I had tentatively selected bootlegging to address the absence of the user I had identified to be a problem during *Design Situation 1*. Although I did not actively seek to, it makes sense given the commercial setting of *Design Situation 1,* that I chose a strategy adapted to business innovation. Holmquist (2012b) does not reference gamestorming, but he developed bootlegging in workshops with participants from both academia and industry. From my textile design perspective, the technique was an attempt to bring the concept of the user into the textile design process.

Figure 5-3 outlines the workshop structure. I planned to take participants through structured idea generation and design ideation, followed by physical and digital material exploration. The intended outcome was for participants to design an E-textile proposal to be used in a non-domestic interior space and make related samples, prototypes, models or demonstrators.

Day 1	Activity	Data collection
10:00	Intro	-
	Bootlegging activity: Generation	Photos, participant's notes, sticky notes
	Bootlegging activity: Mixing	Photos, participant's notes, sticky notes
11:30-12:00 Break > Group divided into teams		
	Bootlegging activity: Idea generation	Participant- facilitators' notes
13:00-14:00 Break		
	Experimental making	Participant- facilitators' notes
17:00 Session end		
Day 2		
10:00	Start	
	Experimental making	Notes from participant- facilitators
13:00-14:00 Break		
	Exhibition set-up	Photos of exhibition
15:30-16:00 Break		
	Group reflection	Audio recording, questionnaire

Figure 5-3 Workshop structure

The initial step of the bootlegging process, depicted in Figure 5-4, requires words or phrases to be generated for several categories. In *Design Situation 2,* the categories 'user group' and 'interior space' were chosen to encourage participants to think of settings where an E-textile could be beneficial. The categories 'textile quality' and 'E-textile function' were chosen to encourage the participants to reflect on what makes textiles unique and find inspiration in the functional capabilities of E-textiles. They wrote their responses to these categories on sticky notes which they grouped on flip chart sheets, as shown in Figure 5-5.

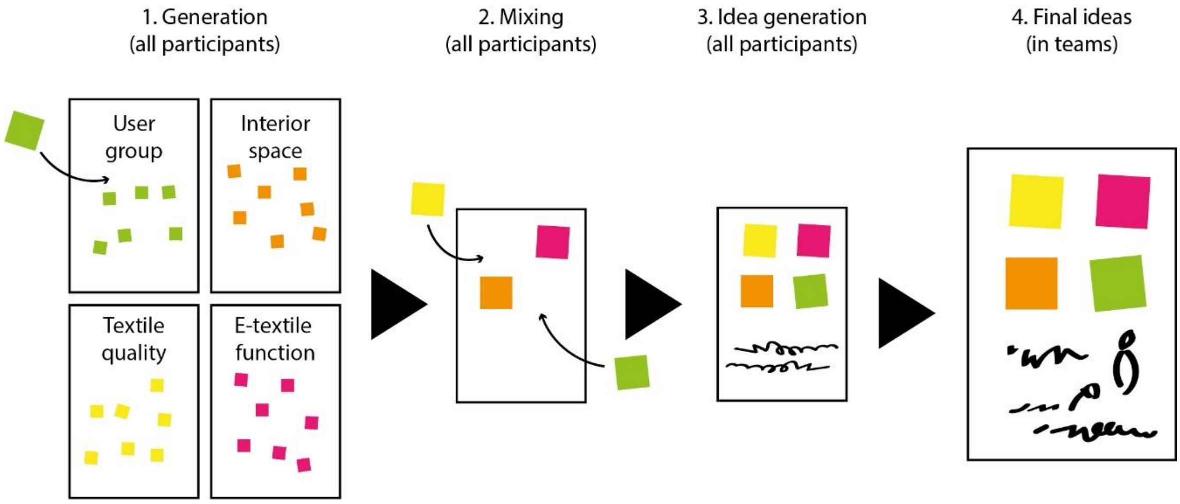

Figure 5-4 bootlegging steps

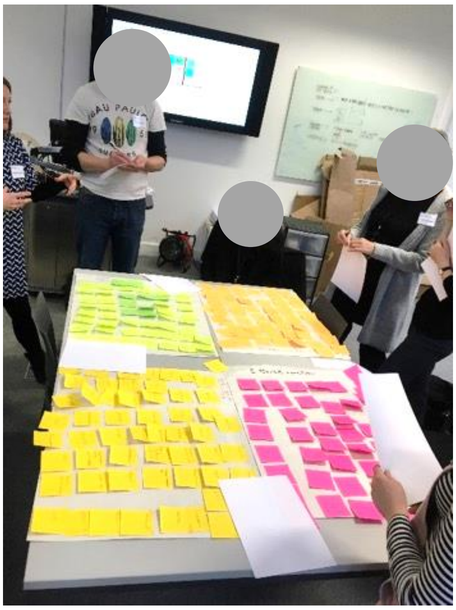

Figure 5-5 Step One: participants during generation phase of bootlegging exercise

Figure 5-6 to Figure 5-9 show the words generated by the participants for each category. Once they had generated words for each, and participants were struggling to think of anything that had not already been written, I introduced the next category. Analysing the word clouds reveals dimensions that each prompt elicited and limitations of the cues. The user groups they generated fall into several categories. They thought of professional user groups such as teachers, farmers and astronauts, as well as groupings based on hobbies or lifestyle. They considered age, for example children 0-5 and the elderly. They also recognised users living with dementia and mental health issues. The categories illustrate that the prompt user group delivers a monodimensional depiction. A person is not only a teacher. They also have an age, hobbies and a state of physical and mental health.

The words generated for interior space were both types of location: transport, commercial and public sector, and types of environment, such as a “self-regulating space” or a “multi-sensory environment”. Some were spaces that exist at present, while the example of a “hyper-loop pod” referenced an imagined future. Responses such as tepee and barn are types of construction and do not describe how the space is used or by whom, again showing the lack of detail elicited by this type of prompt.

Figure 5-6 User group word cloud

Figure 5-7 Non-residential interior space word cloud

Overlap between the categories: *textile* quality and *E-textile* function, meant they placed several words or synonyms in both, including breathable and thermoregulating or heat responsive.

‘Textile quality’ elicited words relating to sensations like soft and warm, emotive qualities such as erotic, fun and calm, and functional aspects of textiles that included their breathability, opacity and stretch. The participants explicitly referenced the transformable nature of textiles by including the words versatile and shape-changing, and implicitly by naming opposites such as concealing and revealing, opaque and reflective. They also linked several words associated with E-textiles to the category textile quality, including conductivity, capacitance and illuminated. E-textile function prompted the group to write verbs such as sensing, reacting, inflating and types of interaction: hard hit input glowing output. They also thought of areas of application or uses, namely medical support, warning and heart rate monitoring. The categories identified in the word clouds show that alternative or additional prompts could have been used to better define the user or interrogate an angle, for instance ‘textiles and emotion’ or ‘E-textile interactions’. The overlap between textile quality and E-textile function could have been decreased by asking for electronic rather than E-textile functions.

Figure 5-8 Textile quality word cloud

Figure 5-9 E-textile function word cloud

In the second step, I asked participants to create several scenarios composed of one sticky note from each category. Some participants described struggling to approach the second step without selecting words that fit a preconceived idea, which illustrates the problem of design fixation and the power of its influence. However, as participants created more than one scenario, those same participants also described pushing themselves to build scenarios from words they found appealing or completely at random, so taking advantage of ideas that might emerge from random associations. In step three, I asked the participants to conceive ideas for E-textiles inspired by their scenarios, as illustrated by the example in Figure 5-10.

Textile quality	: Colour
E-textile function	: Sensing
Interior space	: Public Transport
User group	: Carers

Note reads:
Calming environment for carers when travelling to and from work

Figure 5-10 Step two - Mixing: participant outcome

For the fourth step of the bootlegging process, I assigned the participants to one of two teams (Figure 5-2), inviting them to work in their teams to establish one or two scenarios. These could be developed from the sticky notes that each member had selected during the mixing phase to serve as a design frame. In the model of bootlegging as it had been introduced to the participants, scenarios used only one item from each category, but they were free to do as they saw fit. As the event facilitator I did not intervene in the teams' ideation conversations, as the aim was to observe how the teams interpreted the activity and what they generated. The teams' ideation conversations were captured in notes taken by the two participant-facilitators and I[4]. I requested that the teams narrow down their ideas to one or two design proposals that they could develop during the subsequent material exploration phase.

[4] Given the opportunity to repeat the workshop, I would have video or audio recorded the teams' ideation to reflect upon it after the event, and as a supplement to the notes.

To support material exploration, the participants had access to a broad range of textile, electronic, digital and other materials (Figure 5-11). A table loom, equipment for knitting and sewing and conductive print paste were available so they might make their own textiles, as was a 3D printer to make rigid components. In the Heat Harvest workshop described by Townsend and Ylirisku (2015, p.104), the technical researchers viewed textiles as “ready-mades” on to which technology could be added. The intention of providing textile and other making equipment was so participants could realise their ideas during the workshop and for textiles to be more than mere carriers of technology. The involvement of NTU’s Maker Club and Kitronik meant the participants had support, to realise their ideas and reduce barriers such as lack of programming knowledge.

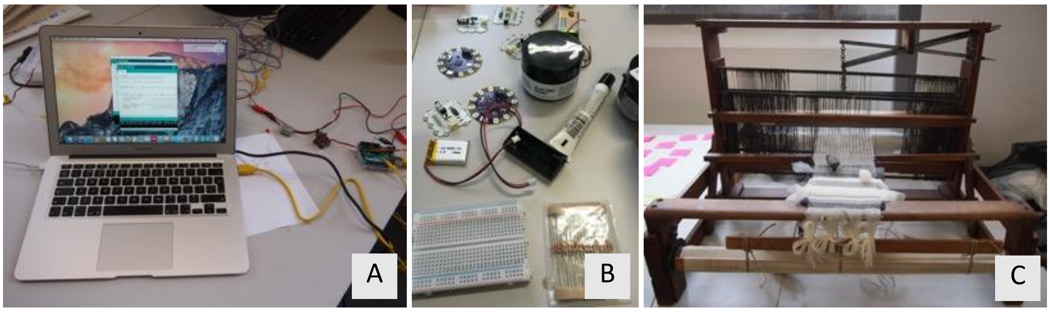

Figure 5-11 Making equipment and materials: A. Programming using Arduino IDE, B. Breadboard, microcontrollers and conductive paint, C. Table loom

In step four of bootlegging, the two teams adopted different strategies. The photo in Figure 5-12 captures the different approaches. It shows the closing moment of the sequence described by the narration which precedes the image.

Team B are debating rather heatedly how to find a purpose for their design work. One participant, whose background is in interaction design, will not stop asking "why?" Unable to resolve the details of their differences they at least agree to move on. With a vague proposal linked to well-being they get up and move over to the materials on the table to their right. Some of the team start to play with folding the textiles provided into origami pleats, manipulating the folded textile structure to make it open and close. While this is happening, Team A, at the table on the left of the room, is still engaged in a discussion to envisage and refine their proposal. They are asking, who will use it? How will they interact with it? What form, materials and technologies would make the functions and interaction possible?

Figure 5-12 Photo midway through workshop day one

Team A spent most of the first day developing their proposal theoretically and only moved to material exploration in the late afternoon of the first day. They considered a variety of purposes for their proposal. By contrast, Team B resolved the impasse caused by purpose, in the shape of the question "why?", by leaving their design proposal unfinished and letting a conceptual outcome emerge through making. The next section provides an interpretation of each team's approach to the workshop activities.

5.2.1 Team A

In his closing questionnaire, Participant E stated that the first elements Team A chose for their scenario were travellers, thermochromic and regulating, but they did not stop there. They did not adhere to the prescribed format of bootlegging of one item for each category, instead they gathered multiple items for all but textile quality. For this category they only chose thermoregulating (Figure 5-13). The group's flexible scenario correlates with the various purposes the team described for their design.

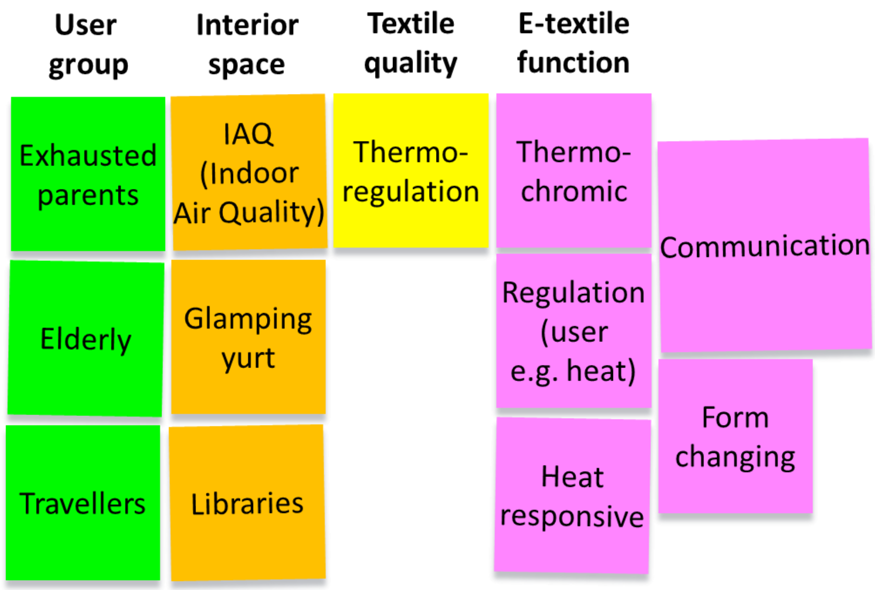

Figure 5-13 Team A: final scenario

The juxtaposition of elements produced two concepts: "reactive tents" and "a room within a room" (Figure 5-14). It was these two concepts that led their design process as they considered where and for whom they would have a purpose.

> *We were going to make some sort of tent structure or a structure to go inside a building. It had a focus on thermoregulation.*
>
> *(Participant B, Team A - group reflection)*

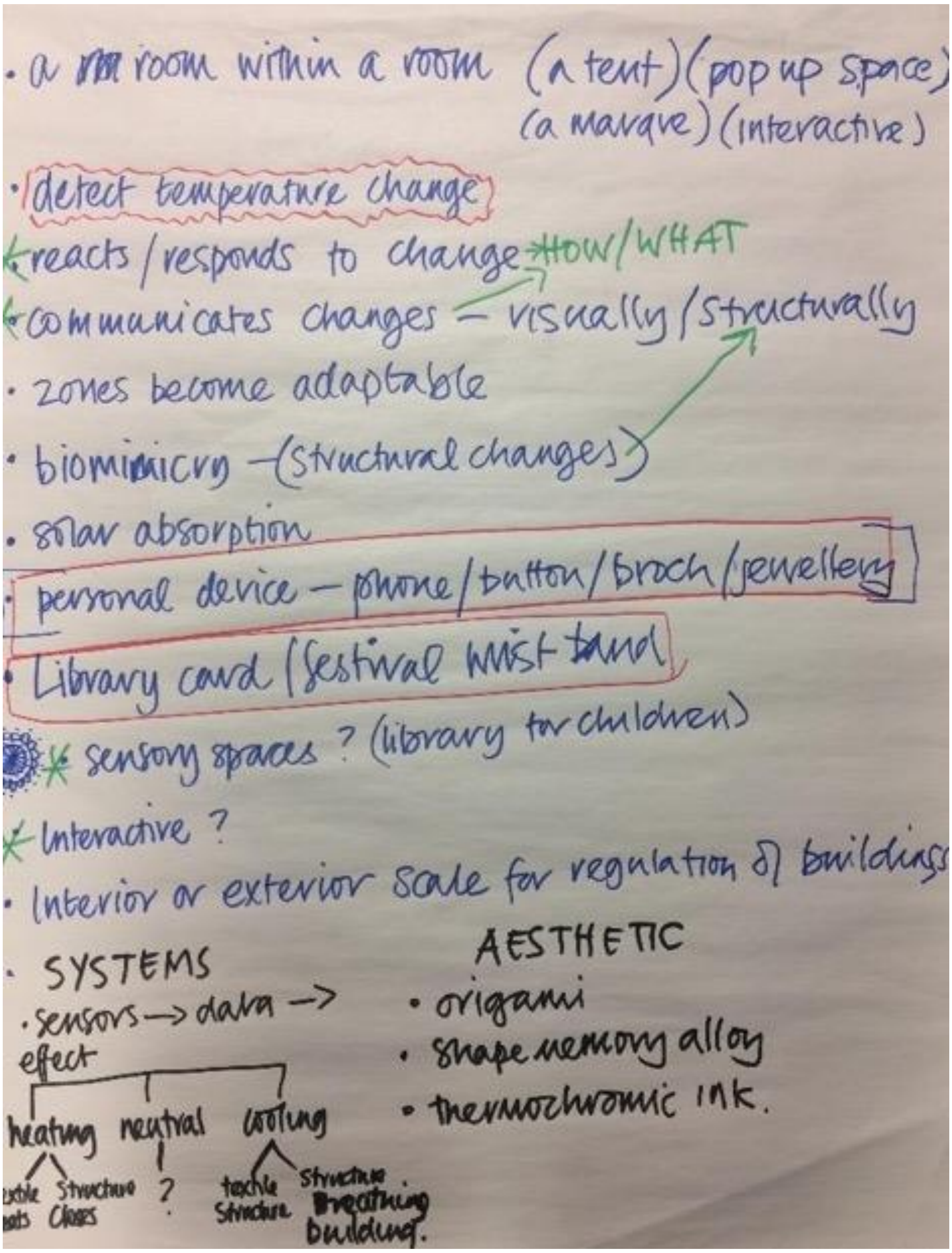

Figure 5-14 Team A ideation notes

The team examined how reactive tents that regulate air quality could be used in libraries and at music events, presumably linked to their selection of glamping yurt. The notes below, made by the participant-facilitator during ideation, detail the team’s exploration of their concept in different contexts.

Library Tent: would create an enclosed area for children to read. This would be a more engaging and fun space for them. Using sensory lights and temperature control to create a calm environment. Ventilation could be controlled through shape memory alloys or breathable materials.

Music events attract lots of people and cause cramped hot environments. Some people suffer from anxiety in crowded places. Tents made of E-textiles could help this. The tent could respond to the temperature through data from sensors. This could open-up more ventilation when the tent gets busy and hotter. On the other hand, it could warm up if too cold. LEDS and other decorative lights could be threaded into the fabric for light effects. The tent material could be made with thermochromic pigment, this would act as an indicator for people outside as to whether it will be too hot and cramped inside before they enter. They could have a colour scale on their wristband to compare the colour so they can work out the conditions.

(Participant-facilitator D, Team A - closing questionnaire)

Throughout the workshop the purpose of the proposal remained flexible. The first excerpt implicitly suggests that the purpose of their reactive tent for a library would be to entertain children and encourage them to read. The second, which places the tent at a music event, shows the group considering people who suffer anxiety in crowded spaces, a user group not mentioned in their scenario. In this context, the proposal's purpose was to regulate the temperature of the space and indicate to people before entering the conditions on the inside. In the closing discussion Participant B described a third possible purpose for their idea.

There are lots of houses that are not properly insulated so the idea of creating a structure within another structure that was better insulated and able to be warmed better could be great for elderly people.

(Participant B, Team A - group reflection)

Team A selected four distinct E-textile functions to include in their scenario and created a proposal which used all the functions they had considered. By contrast, they chose only one textile quality, that of thermoregulation, which maps onto their E-textile function "heat responsive" and was repeated by their inclusion of "regulation (user e.g. heat)". The emphasis placed on heat regulation suggest that this function, rather than people and place, was the focus of their ideation and may even represent design fixation. They designed their prototype to have E-textile heating elements and vents for cooling, showing how their choice of thermoregulation as a textile quality and E-textile function had informed their design decisions.

The choice of only one textile quality may reveal that the team felt it unnecessary to include other qualities of textiles because they overlapped with E-textile functions. When asked during the group reflection at the end of the workshop whether they could have made their design of materials other than textiles the team responded no. When prompted in this way they indicated the textile qualities sound absorption, comfort, warmth and softness that perhaps during ideation they had taken for granted and so not included in their scenario.

By the time they started material exploration, the team had a clear idea of what they wished to represent, rather than using the materials as inspiration. Of the various purposes and contexts they had considered, it was the proposal for a library that they chose to create. They created a low-fidelity model of the reactive tent with its cooling vents, heating and lighting (Figure 5-15). Thermochromic pigments were not available during the workshop, so the team simulated these embellishments, which they imagined would reveal literary phrases. They also made demonstrators to show intended functionality. They used a readymade E-textile containing resistive yarn and conductive tracks to demonstrate a textile that warmed when attached to a power supply. Additionally, they used the programming tool Blockly for Picaxe (Figure 5-16) together with the Igloo microcontroller to demonstrate the principle of an E-textile sensor able to register ambient temperature.

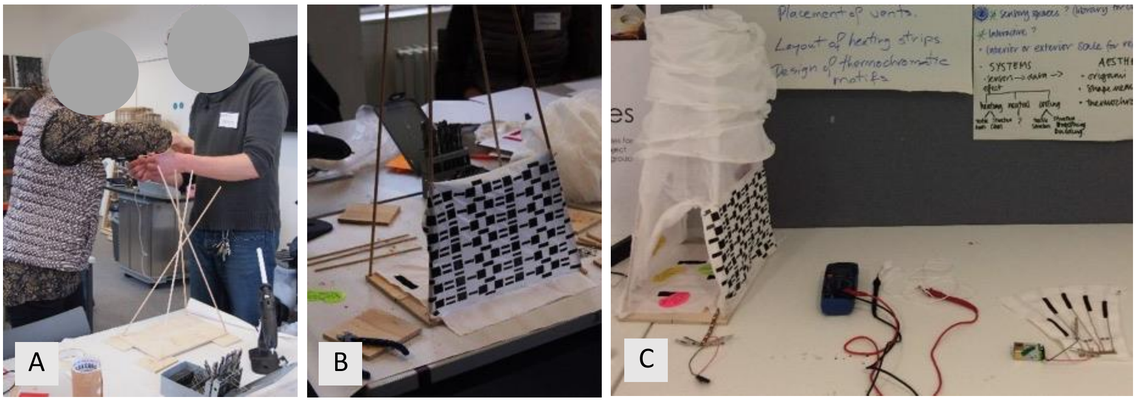

Figure 5-15 A. Team A constructing their model, B. Team A's model in progress, C. Detail of post workshop exhibition showing Team A's model and demonstrators

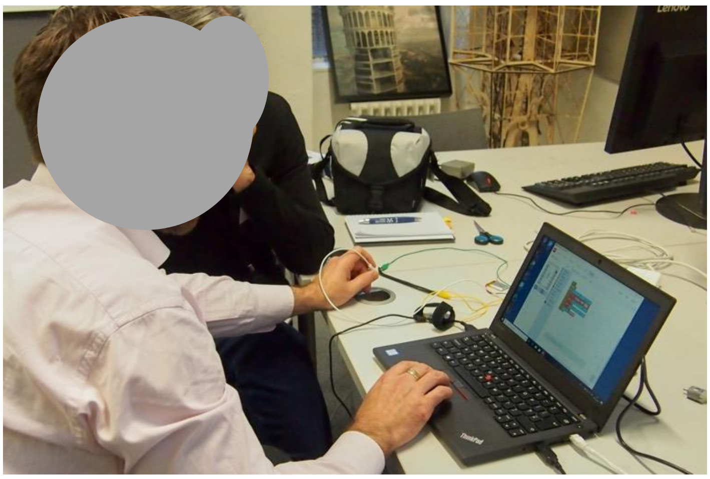

Figure 5-16 Team A creating a sensor with Blockly for Picaxe

During the group reflection that ended the workshop, Team A described how by integrating electronics into the textiles, the structure could be more easily put up and taken down. They perceived their design as sensory and poetic, with the textile providing noise absorption and a calming environment. While they had considered various use scenarios, this line of enquiry did not lead their process. As participant B expressed, “we were sort of more interested in just trying to see how we could think about the structure rather than a specific (user) group”.

Their chosen words for the category user group were exhausted parents, elderly and travellers. They considered how their concept of reactive tents and a room within a room was relevant to each user group, but rather than flesh out the user and imagine an individual, they extended their idea to a design for ‘everyone’. The team’s argument to support their decision was that they had chosen a public interior space and therefore it would be used by everyone. Designing without reflecting on any specific users makes it easier to fall into what Moggridge (2007a, p.726) calls “the trap of designing for yourself”. In the closing questionnaire, Participant E expressed the team had “struggled with the restrictivity of the user group” and designing for ‘everyone’ was their resolution. While the team viewed their move as being more inclusive, it was actually the path of least resistance. The absence of any debate about different users or research into the needs of different individuals, the team’s effort was far from Inclusive Design, pioneered by the Helen Hamlyn Centre for Design (Clarkson et al., 2007; Coleman, Clarkson and Cassim, 2016). Even if we only consider prisoners, not everyone is free to use the interior spaces the teams considered, and some types of user are more likely to be found in them. Exposing the naivety of the group’s comment, Steinfeld, Maisel and Levine (2012, p.69) assert that, “proponents of universal design must recognize that products and environments can never be fully usable by every person in the world”[5].

[5] Universal, Inclusive or Design for All has several definitions which are discussed by Steinfeld, Maisel and Levine (2012, pp.27–44). The British Standards Institute uses the term ‘inclusive design’ which it defines as “the design of mainstream products and/or services that is accessible to, and usable by, as many people as reasonably possible [...] without the need for special adaptation or specialized design” (British Standards Institute, 2005).

5.2.2 Team B

Team B built their scenario according to the prescribed bootlegging formula, using one item from each of the four categories and their outcome is shown in Figure 5-17.

Interior space	: Isolation booth
E-textile function	: Shape changing
User group	: General public
Textile quality	: Sensual

Note reads:

> Yoga - Considered breathing

> Breathing space

> Breathing - calm light

> Material that moves

Figure 5-17 Team B final scenario

In the closing questionnaire, the team's Participant-facilitator H described their process as starting with a discussion of each member's scenarios, followed by a stage combining similar ideas and "whittling down" to create a final scenario. This illustrates the divergence and then convergence of the team's ideation. The scenario the team arrived at was a sensual textile that could change shape. It was to be used when travelling by the general public as an isolation booth. Rather than explore possible user types, their choice of the general public equated to Team A's decision to design for 'everyone'. They associated their scenario with yoga, breathing and calm light. Despite reaching a scenario, the team then struggled to find further consensus to move their ideas forward, as expressed by the quote that opens this chapter. The excerpt shown in Figure 5-18 suggests the team experienced tension between finding a purpose – the "why?" of their proposal – and the inferred freedom of "creating and playing" with materials. The team responded to the impasse by abandoning attempts to further refine their proposal and instead moved to exploratory making.

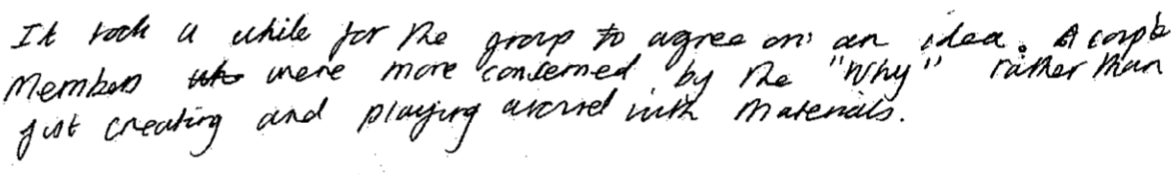
It took a while for the group to agree on an idea. A couple
Members who were more concerned by the "Why" rather than
just creating and playing around with Materials.

Figure 5-18 Participant-facilitator H, Team B - closing questionnaire

The group's difficulty is an example of the gap between invention and inquiry to which both Holmquist (2012a) and Velloso *et al.* (2018) refer. As a further illustration of the tension between generating ideas and grounding those ideas in a purpose, it is worth remembering that of the 12 proposals generated during the workshop described by Townsend and Ylirisku (2015) none were considered directly applicable to the Heat Harvest project. *Design Situation 2* suggests that locating a purpose, an answer to the question *why,* is more difficult than generating ideas from the possibilities new technologies offer.

Team B showed a lower level of cohesion than Team A. When they moved to exploratory making, they separated into smaller groups without clearly defined tasks or an overall aim. This meant they were experimenting in several directions in parallel, as shown in Figure 5-19. However, pockets of collaboration formed as the comments of Participant F, a textile designer, show, "I wasn't afraid to explain my 'crazy' ideas because I could not fulfil them on my own". Through collaboration, the participant, who did much of the exploration to find a suitable folding pattern for the textile but had no knowledge of mechanics or electronics, was able to create a moving structure. She also described the team as being "a bit depressed" on the first day "because we failed many times". This comment refers to the team's attempts to construct an opening and closing mechanism, but it may also reflect the earlier difficulties the team had experienced. The team included Participant G who had earlier referred to the workshop activities as gamestorming. The challenge the team faced was the confrontation between human-centred interaction design focused on user experience and material/technique-led textile design.

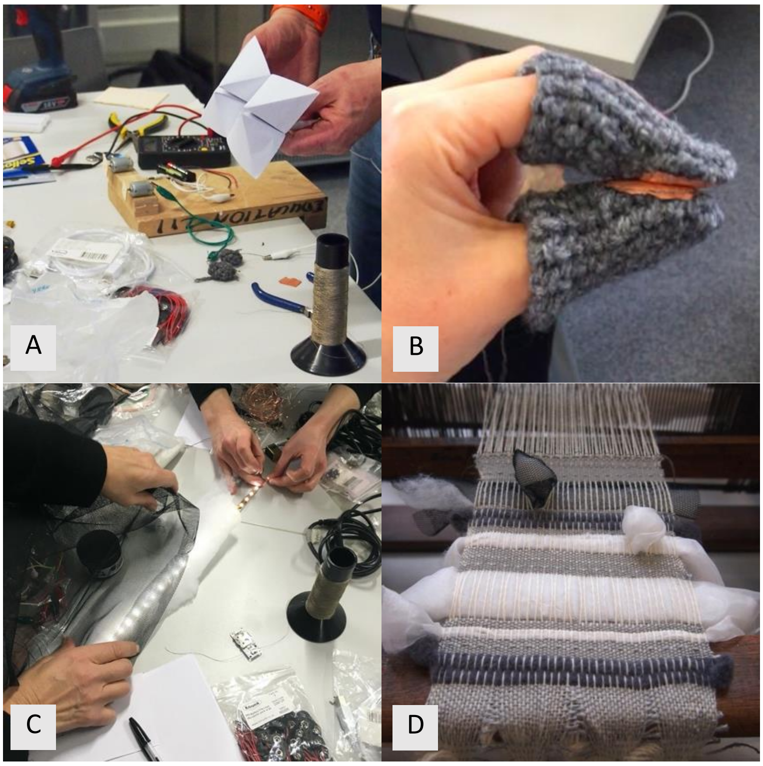

Figure 5-19 A. Exploring paper folding to create structures that could open and close, B. Activation mittens with conductive applique, C. Experimenting with textiles and light, D. Weaving experiments

Team B imagined their isolation booth as part wearable, part architectural. An object that could be carried packed flat when travelling and activated on command. They imagined it would give the user control of their immediate environment, which they described as normally being unpredictable and uncontrollable. The team considered it to be "more of a conceptual idea not totally practical" (Participant-facilitator H, Team B - group reflection).

The opposition set-up by this statement is not a simple one. 'Impractical' outcomes can act as provocations to better understand problems or opportunities (Treusch, Berger and Rosner, 2020). In speculative design (Auger, 2013) and critical design (Malpass, 2017), deliberately challenging and outrageous designs are created to stimulate reflection about the future. The team did not create an illustration or prototype of the complete proposal, instead they experimented making elements of the design (Figure 5-20). For example, they imagined the booth being activated using the 'chin mudra' gesture used in yoga and meditation, where the thumb and index finger touch. In their prototype, this created contact between conductive pads on two crocheted finger mittens (Figure 5-19B) which closed a circuit and so formed a switch. Using the 'chin mudra' gesture for the booth's imagined activation was in keeping with their themes of yoga and breathing. The group considered their idea as conceptual, but it was designed to address the stress and lack of control people have of their surroundings when travelling and offered the 'solution' of being able to isolate oneself. Although the question *why* created a challenge for the group, being pushed in this way perhaps meant purpose played a greater role in the team's ideation.

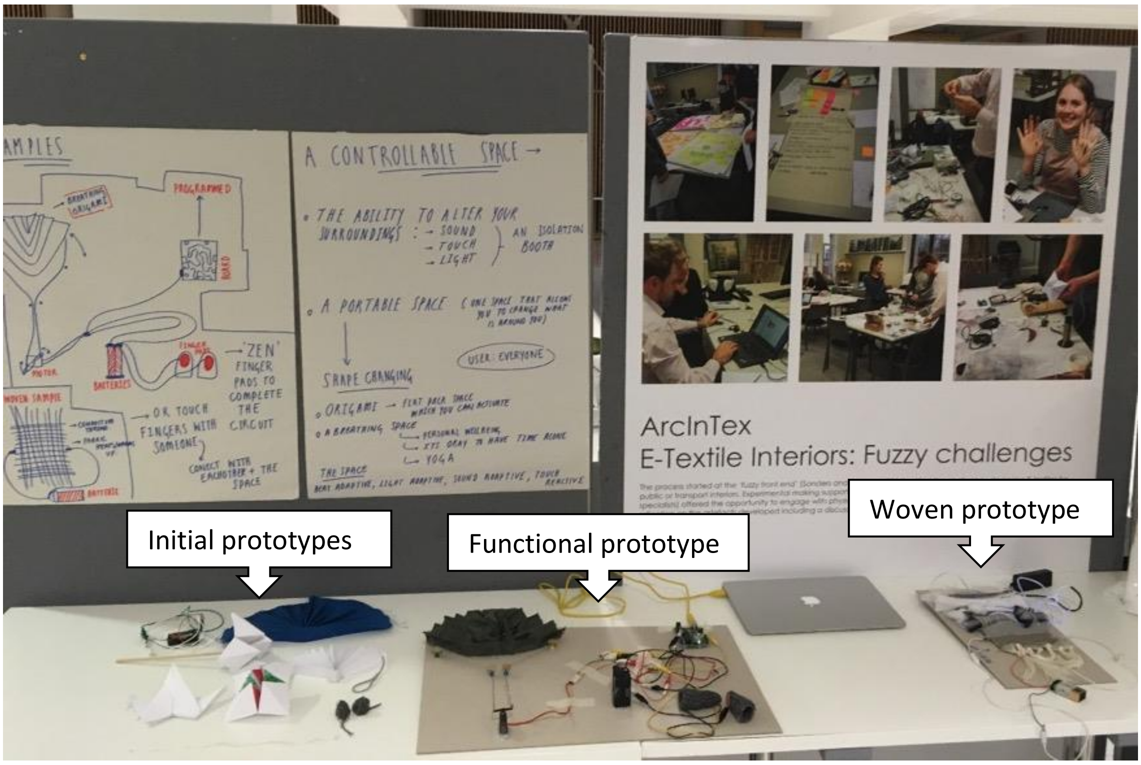

Figure 5-20 Team B exhibition showing prototypes and concept boards

Team B imagined their booth being composed of rigid supporting parts which would move a folding textile covering, which they first prototyped using paper (Figure 5-19A). A servomotor controlled by a microprocessor moved the rigid elements, allowing the fabric to open and close. Similar to early wearable computing (Mann, 1997) and commercial smart garments discussed by Hughes-Riley et al. (2018), the rigid and electronic components that allowed the structure to move were attached to the surface of the textile rather than integrated.

The team also probed the effect of light in combination with textiles, and Participant G wove a sample with an electroluminescent cable. Participant-facilitator H also wove a section of conductive yarn which they discovered heated-up through a process of resistive heating when connected to a battery. They imagined the lighting and heating elements they explored as giving the user control over their immediate environment when using the isolation booth. Although calm light was one note they had made on their scenario, they did not discuss how the quality of light could relate to user experience. While the team’s proposal responded to a perceived need, once the team went into the exploratory making phase, they did not reflect on the type of user experience they were creating. In line with their statement that the design was conceptual, they did not imagine the overall form of the booth and how it related to the human body either in their prototypes or the final concept posters (Figure 5-21).

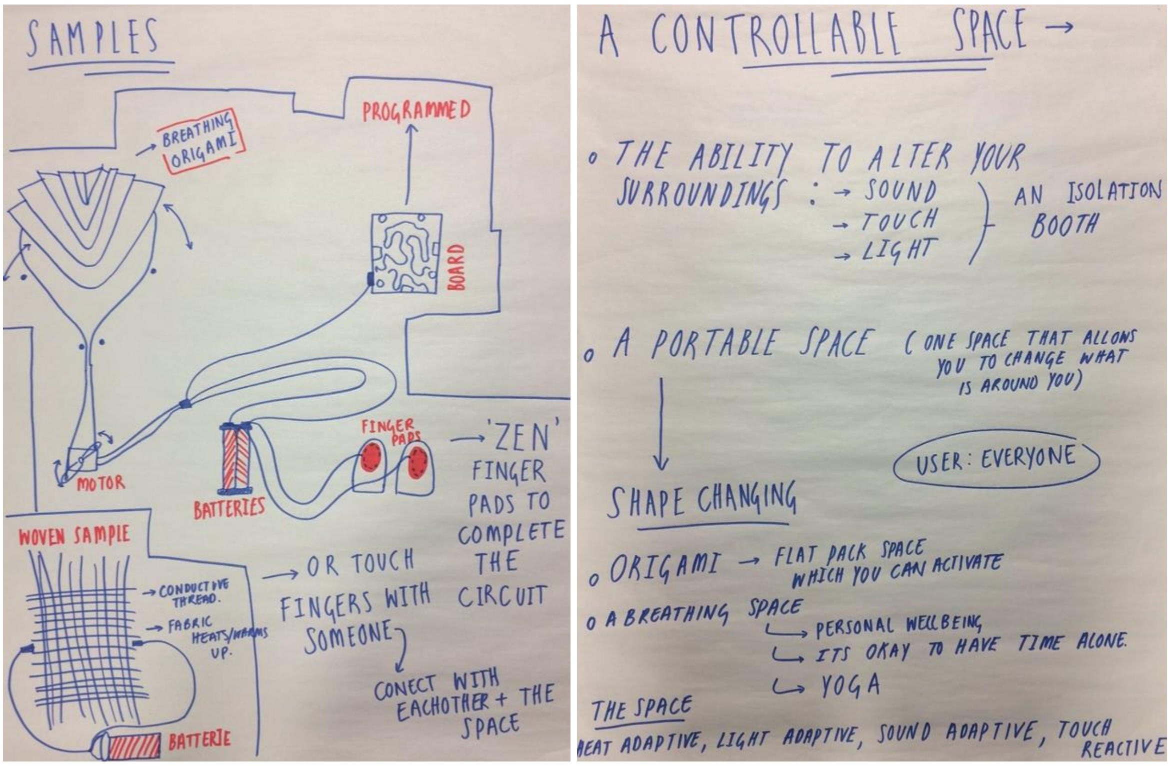

Figure 5-21 Team B concept posters

Team B created their concept posters at the end of the workshop for the exhibition, as when they moved to exploratory making their proposal had not reached this level of detail. The development of their prototypes was open and exploratory because their proposal remained vague. They created elements of their design, exploring the available materials, rather than attempting to model the booth in its entirety. The samples and prototypes presented by Team B came largely out of playing with materials and discovering how they behaved, a method common to textile designers. This is in contrast to conceiving a design theoretically and then realising it in physical form, as might fit a "form over material" model common to product design or architecture (Oxman, 2010, pp. 99–100). The unfinished and speculative quality of their proposal might make it a productive starting point for a longer term, more extensive piece of work.

5.3 Reflection

Through the stages of *Design Situation 2*, participants were asked to move from a situation of nothing to a proposal for an E-textile to be used in a non-residential interior space. The process was challenging and in different ways both groups found themselves stuck (Figure 5-22). For Team A, it was the user group that was a restriction on their ideation, while for Team B, having chosen the general public as their user, it was the question "why?". They experienced envisaging a purpose grounded by people and place as a limitation. As Van der Bijl-Brouwer and Dorst (2017) note, research into user and context does not necessarily provide straightforward or obvious answers. Stuck was also an expression of the friction between an open-ended process in which materials, in the sense of transformable elements, can be explored without reference to predetermined criteria for success verses design that centres on the user.

It made people really consider the purpose and the problem of a product.
In a way it made people stuck as they became a bit too considerate
and less playful

Figure 5-22 Participant-facilitator H: Team B - closing questionnaire

The response from Participant-facilitator H, whose background was textile design, shows that she considered the workshop activities able to ground the design in “the problem of a product” and “purpose”, but that this made the process “too considerate” and “less playful”. She was perhaps indicating her preference for, and familiarity with, a textile design process led by material exploration, a process that she experienced as playful. Playful exploration is a technique advocated by textile designers when working with new technology (Marr and Hoyes, 2016; Philpott, 2013). It is worth noting that this comment comes from Team B, who struggled to find consensus around their proposal. Yet, she was not the only participant who expressed that framing the problem around a context and user presented challenges.

To overcome the difficulties encountered designing for a defined user group, both teams ultimately opted to create a design for what they called ‘all’ or ‘everyone’. Participant B of Team A suggested that, “if you said we were working on a product I think it would have been easier to sort of work to a specific user, demographic, but thinking about it as architecture, I think opens it up” (group reflection). The participant distinguished between architecture and products, but the reactive tent they designed could easily be conceptualised as a product, as is a tent for camping. If thinking about the proposal as a product, Miaskiewicz and Kozar (2011) suggest that “products that satisfy 100% of the needs of a few personas will have a greater chance of success than products that serve 10% of the needs of the all-encompassing ‘everyone’”. If it is understood as architecture, it is also a misrepresentation to suggest user-centred design is unsuitable. In a study of students following a user-centred process for interior design, participants experienced the user as both a constraint and an inspiration (Oygur and McCoy, 2011). When the teams experienced the user as a constraint, the absence of an obligation such as a student might encounter in the form of grading criteria, meant to resolve the difficulty they simply discarded what they perceived as limiting.

While it is true that many people use the spaces both teams considered, including a library and public transport, the assumption that they are used by ‘everyone’ is naïve. “Two of us had everyone or all, and then we thought actually, what could we do for everyone? Everyone travels.” (Participant-facilitator H, Team B - group reflection). The difficulty the teams experienced tapping into the user or user group may have been avoided had they been asked to develop a range of personas. As stated in Section 5.1, building a detailed persona, thus creating an individual with whom to empathise, may have allowed the teams to see the user as a source of inspiration rather than a restriction. To achieve this, the process required an additional activity to build a persona or reflect on experience. Deeper reflection by the participants on a range of experiences may have revealed other needs E-textiles could have answered.

To counter these arguments in favour of personas, and reflecting the participants difficulty creating for multiple users, from the field of Interface design and HCI, Norman (2005, p.14) asks,

> *If it is so critical to understand the particular users of a product, then what happens when a product is designed to be used by almost anyone in the World?*
>
> *Norman* (2005, p.14)

Following the observation that many everyday items from cars to cameras were designed without systematic user studies, Norman (2005, p. 15) instead proposed Activity-Centred Design. Success of such a design process would be “devices that fit gracefully into the requirements of the underlying activity”. This statement reflects the theory of ‘jobs to be done’, which states that successful innovation comes not from understanding customers per se, but discerning what they are trying to achieve (Christensen et al., 2016). A simple example is that in wanting a 6mm drill bit, the requirement is actually for a 6mm hole. It is also linked to scenario-based design, which can be used early in the design process to consider who the users might be and what they want to achieve. It involves creating scenarios which are “narrative descriptions of envisioned usage episodes” (Rosson and Carroll, 2009, p.146). While not invalidating the critique of personas, Norman (2005) concedes that many aspects of HCD should not be rejected in an Activity-Centred Design process. The activities in question are human activities and entail that the designer understand why they exist, how they work and what they are motivated by.

The proposals created by both teams shared several features. Their overarching purpose fell into what the teams described as well-being. This is a broad generalisation and oversimplifies well-being, a complex and multi-faceted concept (Steptoe, Deaton and Stone, 2015; Manzini and Vezzoli, 2008). The teams were referring to hedonic well-being, passing feelings experienced moment to moment. Team B described their proposal as poetic, beautiful and magical, and Team B used the word Zen, referring to the Japanese school of Buddhism, to evoke relaxation. Both teams imagined their E-textile structures would calm those that used them, and provide acoustic, thermal and visual comfort. It is perhaps overly easy to use the blanket term well-being to support design and as a loose initial problem frame. It was similarly adopted in the LTM project which explored uses for an underdeveloped piezoelectric plastic and flexible OLED composite (Dell’Era et al., 2016), discussed in Section 2.5. However, if well-being is conceptualised so broadly and without reflection on its meaning, the resulting designs may not have the desired positive effect. To say we are designing for well-being has an intuitive ‘feel good’ factor that risks obscuring downsides such as the environmental impact of a design. It is also too vague to constitute a meaningful parameter.

For a more focused approach, once the context for a design is clear, principles from evidence-based design can be used to guide ideation and envisage a purpose. This approach was used by Heimdal and Rosenqvist’s (2012) in their investigation of textiles in hospitals. As an example, one of the principles they used was “patients’ need for social interaction” (ibid. p. 186). Evidence-based design as defined by Hamilton and Watkins (2009, p. 9) is “a process for the conscientious, explicit, and judicious use of current best evidence from research and practice in making critical decisions, […] about the design of each individual and unique project.” Such an approach, focusing on understanding the purpose of E-textiles and verifying assumptions about factors such as human behaviour, could guide design ideation.

Another common feature, extending Team A’s idea of a “room-within-a-room”, was that both proposals were a space-within-a-space. In contrast to the permanence of conventional architecture, the proposals created in the workshop were dynamic, transportable entities, which had the potential to be used in multiple contexts, as indicated by the comments below.

> *This is kind of like a pop up that is put up straight, very quickly and then taken out very quickly.*
>
> *(Participant A, Team A - group reflection)*

Both teams drew inspiration from nomadic people for whom a moveable textile home offers comfort and protection. This points to qualities of textiles, such as conformability and their relatively lightweight, that allow them to be used as portable structures. Team B’s isolation booth was portable and could be described as wearable, raising the question whether it was an interior space or something more akin to clothing. Paulus and Brown (2007, p.252) state that “idea generation involves both the retrieval of existing knowledge from memory and the combination of various aspects of existing knowledge into novel ideas” and bootlegging facilitated this process. Both clothing and tents are fundamental uses of textiles, which during the workshop were conceptually blended with emerging E-textile technology to create new forms.

The closing questionnaire highlighted that, of the participants that responded, most would have liked more time to experiment with programming or making E-textiles. This is perhaps an indication that they had expected the workshop to teach them about E-textiles. It may also relate to the disciplinary divide discussed in this chapter and the participants’ desire to engage in a material and technique led design process. It may also relate to designers use of episodic knowledge and the role of precedents in the design process. As a textile practitioner, the sense of wanting to know how to make things resonates. Participant-facilitator H expressed being daunted and “unsure how to even start using E-textiles” (Figure 5-23). The lack of examples and experiences the participants had to draw on may have made the design process more difficult, a difficulty they wished to address by developing experiential knowledge of E-textiles.

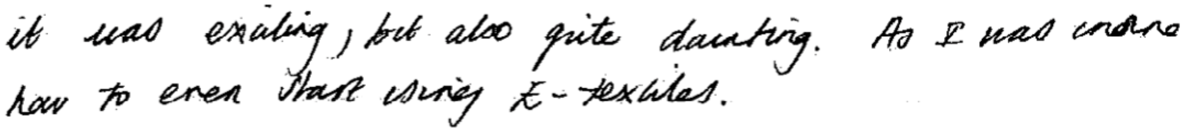
it was exciting, but also quite daunting. As I was unsure
how to even start using E-textiles.

Figure 5-23 Participant-facilitator H, Team B - Closing questionnaire

5.4 Discussion

For the reasons developed over the first four chapters, textile designers tend towards a process inspired by visual sources, materials and manufacturing techniques. Yet this process is ill-suited to designing with emerging E-textile technology. *Design Situation 2* was a multidisciplinary workshop in which textile designers were the most represented discipline. The workshop was planned to explore, through a process known as bootlegging, how participants constructed a scenario – composed of user, location, textile quality and E-textile function – to inspire an E-textile proposal for a non-residential interior space. The question is, to what extent could the approach of the designers in *Design Situation 2* be deemed purpose-led?

Counter to the purported benefits of personas in design (Miaskiewicz and Kozar, 2011), in *Design Situation 2,* choosing a user group for whom to design was perceived as a restriction rather than a source of inspiration. Instead of attempting to envisage a purpose for a specific user group, both teams chose to design for ‘everyone’, but as described at the end of Section 5.2.1, neither group’s approach should be confused with genuine Design for All, Universal or Inclusive Design. The workshop structure did not include steps that supported the development of a detailed persona and reflection on experience that might have brought the user to life, and the participants lacked the experience to carry out these steps independently.

The teams design proposals indicate that lack of materials and knowledge of E-textile construction is not necessarily a barrier to a purpose-led E-textile design process, as envisaging a purpose can precede making. At the end of the workshop, the participants indicated certain materials that were not available and expressed their wish to spend more time focused on the E-textile related elements, including programming, but these factors were not the main obstacle in their ideation.

Both teams thought of a loosely defined purpose for their proposals. For Team A the purpose of their concept “reactive tents” shifted as they imagined it being used in different scenarios. They dedicated time to theoretically developing their idea and its form before engaging with materials. As a result, Team A’s proposal was developed in greater detail. They envisaged how their design would function, the effect it would have on those that encountered it and the materials it would be made from, in particular the E-textiles. Team B’s design proposal responded to the perceived problem of stress when travelling and lack of control over one’s surroundings. The team spent more time on material exploration than theoretical ideation, never fully resolving the form of their design, but their open-ended approach left room for their concept to be expanded as part of a longer project. The structure of *Design Situation 2* gave purpose a greater role than had been the case in *Design Situation 1,* where arguably the two prototypes were created merely because of the technology available. Nevertheless, purpose focused on people and place was not always the guiding force.

Design Situation 3, described in the following chapter, investigates the effect of personas and experience mapping on the creation of E-textile proposals for residential interior spaces through a collaborative student project. It explores the role of making and relevant E-textile understanding, alongside HCD techniques as part of a purpose-led design process. Furthermore, in *Design Situation 3,* the textile design process is confronted with that of product design.

6 *Design Situation 3:* E-textiles for Micro-Living

> *The customer journey, user journey, I wouldn't ever have thought about doing that. I feel like it's definitely changed the way I've thought about design. I would definitely use that in my stuff again, because then … it's like you're designing for a purpose now instead of just aesthetics.*
>
> *(TD-E, group interview)*[1]

For the textile design students and tutors that took part in the 'E-textiles for Micro-Living' project, user journey mapping changed our thinking about design. The technique showed us how the imagined experience of a 'persona' could be a source of inspiration. Each of the textile students, working in a team with a product design student, was tasked with imagining the experience of a persona they had created living in a domestic space only 18 m^2, hence the term Micro-Living in the project's title[2]. User journey mapping, also known as customer journey or experience mapping, is a tool used to reflect on and visualise an experience over a period of time (Howard, 2014). Personas and journey mapping, which look to the user as a source of inspiration, are not common in textile designer. For the textile designers that took part in *Design Situation 3*, exposure to these techniques triggered a reconsideration of their design process.

Design Situation 3 was a six-week collaboration between second-year BA (Hons) product design and textile design students from NTU that took place in spring 2019. It was instigated by the BA Textile Design Principal Lecturer, who I will refer to as the textile lecturer. I was invited to deliver E-textiles content to the students, who worked in mixed discipline teams of two or three to create an E-textile proposal. They were asked to seek out opportunities where E-textiles could enhance the experience of living in a small space, addressing the need for affordable homes that, referring to Heinzel (2018, pp.39–40), provide intimacy, protection, well-being and efficiency.

I was one of a team of tutors from the fields of textile, product and interaction design, and electrical engineering, supporting the students. I collected data in the form of questionnaires, workshop and tutorial recordings, group interviews, course materials and the student's work, as well as notes reflecting on the experience. My interest was in both the students and tutors, as

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[1] The students are referred to according to their discipline and the team to which they belonged, meaning TD-E signifies the Textile Design student from Team E, while PD-E indicates the product design student from that team.

[2] There are several definitions of Micro-Living (British Property Federation, 2018), the project brief defined it as a domestic living space just 18 m^2. In that space, the students had to consider the following basic amenities: a bed, washing machine, toilet, shower, sink, storage, sofa/armchair, cooking facilities, fridge and table.

representatives of their respective disciplinary perspectives. Interaction with the students and staff members involved in the collaboration served to build a picture, in relation to E-textiles, of the roles, knowledge, process and strategies of the disciplines that took part. The collaboration brought benefits to both disciplines by encompassing materials, products and users, but highlighted the challenge of working with emerging technology for which there are few precedents and where decisions relating to the product have consequences for the materials.

6.1 Contextualising *Design Situation 3*

Unlike *Design Situations 1* and *2*, I did not have control of the overarching structure or brief of *Design Situation 3.* I was one of several members of staff delivering content to the students and influencing its outcome. Beyond its inclusion in this thesis, the Micro-Living project was a pilot by NTU researching opportunities at undergraduate level for collaboration between disciplines. It also contributed directly to the product design students' summative grade for their second year and indirectly to that of the textile design students. Therefore, I had to balance my research with responsibilities towards the students and the interests of the university. My actions had a supporting rather than lead role, as greater influence was exerted by the module structure and each of the disciplines' course leads.

In the hybrid methodology of this thesis, *Design Situation 3* leans away from action research and towards an observed case study. Its inclusion as a case draws on purposive variation sampling, described in Section 3.2.1, but in the vein of action research, through our involvement the participants and I grew both professionally and personally. *Design Situation 3* delivered valuable insights about the process used by the disciplines involved and their respective strengths and weaknesses in relation to E-textiles.

The Micro-Living project was an elective pathway for the textile and product design students and was embedded in a second-year undergraduate product design module[3]. The overall module was titled 'Living Well in Small Spaces' and was an 'Industry Live Brief', meaning an industry partner was involved in its launch and evaluation[4]. The module brief, which can be found in Appendix C1, provided contextual information and three scenarios for the students to choose between, shown in Figure 6-1. The module required the students to design a product for their chosen scenario.

[3] The course teams presented the Micro-Living project to the cohort of second year product and textile design students, who were invited to take one of the approximately 10 places available for each discipline. Six textile design and seven product design students chose to take part.

[4] The partner was a design consultancy specialised in the design of transport and commercial interiors as well as furniture design, and they were offering those students whose work they selected the opportunity of a placement.

Scenario	Description
Privacy	Users are parent and child and often have conflicting needs
Entertainment	User lives alone and enjoys hosting gatherings of four-six people at home
Work	User and partner work from home needing a space that feels like a workplace

Figure 6-1 Micro-Living scenarios

The students who chose the elective 'E-textiles for Micro-Living' worked in a team with a textile design student and their product had to involve E-textiles. While for the rest of the product design cohort, it was an individual project. To support the teams in designing E-textile products, we provided seven dedicated sessions, which I delivered together with an interaction design/ electronic engineering colleague and the textile lecturer. The sessions were in addition to the tutorials and lectures programmed for the product design module. The teams did not attend any lectures or tutorials from textile design. The Micro-Living project replaced the first six-weeks of a twelve-week textile design module, called simply 'Project 3'. In these six-weeks the textile students were in effect taking a short course in product design.

Although some of the textile students had been involved in other electives that expose them to different design approaches, these remained embedded in their course. For example, in a collaboration with My Sight Nottinghamshire (Hunt, Piper and Worker, 2020) the students adopted a HCD approach. They created physically intuitive designs that were informed by the charity's service users, but the project was delivered by the textile design team[5]. By electing to take part in the Micro-Living project, nine hours of textile design tutorials and two 'minor workshops', each lasting one day, were replaced by product design tutorials and the E-textile workshops[6]. By contrast, the product design students were following a process with which they were broadly familiar and were supported by their regular tutors. My interpretation of the project's outcomes, for example the delay in textile making, considers this uneven weighting between the disciplines.

In 2009, Aalto University School of Arts, Design and Architecture started to open the textiles course to other disciplines. A 'Design' BA now exists that allows students to study textiles with other areas of design, including the option to focus on textiles as products. Niinimäki, Salolainen and Kääriäinen (2018) recount that creating these blended courses was not easy. It "takes time and effort to create a common language and an understanding of and mutual respect for each

[5] My Sight Nottinghamshire is a UK charity that supports local people living with visual impairment.

[6] The 'minor workshops' are designed to expand the students' knowledge beyond their chosen textile specialism (embroidery, print, weave or knit). The students normally choose two options which include topics such as moulding and casting, and leather manipulation.

other's working methods" (ibid. p. 67). The six-weeks of *Design Situation 3* was insufficient time to have reached a balance between product design and textile design.

The product design students were assessed at the end of the six-weeks based on the deliverables shown in Figure 6-2, whereas the textile design students did not have an equivalent list to follow. They worked alongside the product design students contributing to the research, concepts, visuals and developing textile samples. The textile designers had a further six-weeks after the end of the Micro-Living project to complete Project 3. When the textile students re-joined their cohort, we expected them to extend the research and ideas they had developed on the Micro-Living project, but they felt behind. The lack of clear textile design deliverables during the elective may partially explain why textile making generally happened only in its latter stages, complicating their entry into Project 3. However, this chapter will explain that this is not the only explanation for the smaller amount of textile samples made and that for a purpose-led textile design process delaying making may confer certain advantages.

Product design deliverables
A critical consumer journey of chosen design challenge (Privacy, Entertainment, Work) highlighting several potential opportunities for design interventions.
Presentation Boards, illustrating and describing the concept and space.
'Development Work' document including all sketches, drawings and photographic evidence of consumer insights, prototyping and feedback.
Visual consumer journey highlighting how the solution to the design challenge is used by the target consumer

Figure 6-2 Product design deliverables for 'Living Well in Small Spaces' project

The BA product design and BA textile design courses at NTU place different emphasis on developing concepts in CAD and the physical realisation of ideas, the former being the focus for product design and the latter for textile design. As evidenced by the list of deliverables (Figure 6-2), the product design students were not required to physically realise their concepts. By contrast, producing a range of physical samples is integral to the assessment criteria of the textile design course. In *Design Situation 1,* I had pondered whether product designers were familiar with managing an "incomplete understanding" of materials and had "found ways around it" (Research Diary, p. 6). The list above confirms that they are taught to create product ideas, projecting into a possible future, without testing the material reality of those ideas. Being able to make a textile, whether embroidered, knitted, woven or printed is instead fundamental across the field of textile design and engineering. The structural hierarchy of textiles, made visual by Tandler (2016, pp.39–64), makes their behaviour hard to model or render using CAD, so fabrics generally need to be made to understand their properties and confirm their appearance (Chen and Hearle, 2009).

The longer textile design Project 3, the first weeks of which the Micro-Living project replaced, prepares the textile design students for their final year by giving them their first opportunity to define their own brief. The whole of the textile design cohort, including the students that had chosen the elective, were asked to select one of the options listed in Figure 6-3 as their starting point. We assumed that the Micro-Living project would be compatible with one of the options, allowing the textile design students to continue their work after the collaboration ended. In contrast to the scenarios of the Micro-Living project and as highlighted in Chapter 2, it is difficult to see these starting points as problems according to our everyday understanding of the word. If design is problem solving, then the problems that textile designers solve are different from those of product design, fitting more neatly into the category of puzzles.

1.	Design an inspirational collection of samples for a defined season and market level for either fashion / interior / accessory application.
2.	Select a new process / material / technology and undergo experimentation to ascertain its potential product application.
3.	Develop your work around conceptual research and produce textile outcomes for a specific site and/or context.
4.	Develop a collection in response to a historical collection /archive in a contemporary way.

Figure 6-3 Project 3: Textile design 'triggers' - term from Studd (2002)

In planning the Micro-Living project, we had not fully appreciated how differences in the process of product and textile design would affect the students. Emphasis has been placed on the development of abstract models of the design process that homogenise rather than differentiate between different areas of design (Section 2.2). To use the example of the Double Diamond model (Design Council, 2019a), it does not explain how the Develop stage of the process for a textile designer might differ from that of a product designer. Additionally, the specific processes of textile design have received little attention on their own or in relation to other disciplines. *Design Situation 3* addressed this gap, providing rich insights into the textile and product design processes that can benefit future collaborations.

6.2 Planning and action

This section maps out the structure of the Micro-Living project. It discusses the elements determined by the product design tutors as part of the main module and the planning of the seven E-textile sessions. It follows the sequence of events, its interpretation developed from my lived experience, questionnaires, the students' designs and their reflection on the project, and recorded tutorials and interviews.

The structure of the module 'Living Well in Small Spaces' in relation to the Micro-Living project is illustrated in Figure 6-4. The module document, found in Appendix C2, shows the product design tutors' communication to the students of the module mapped to the Double Diamond model to orientate them through its stages. Although the textile design students at NTU are introduced to this model during their course, neither it nor an alternative graphic representation of the design process is used in this way to explicitly communicate project stages.

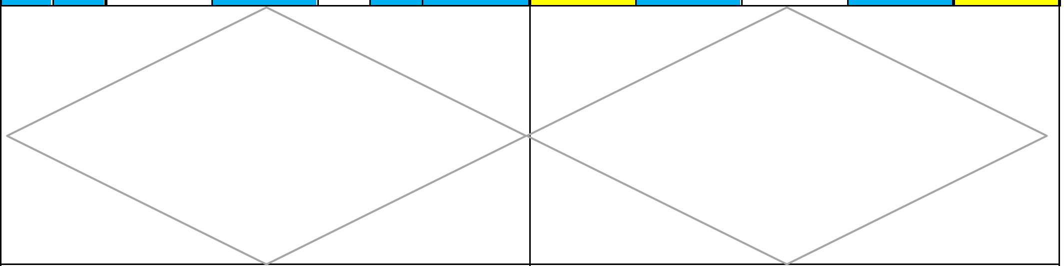
WEEK	WEEK 1		WEEK 2		WEEK 3			WEEK 4		WEEK 5		WEEK 6
DAY	TU	TH	TUES	THURS	TUES		THURS	TUES	THURS	TUES	THURS	TUES
ACTIVITY	Collaboration briefing	Tech intro & lab tour	lecture + intro to User Journey Mapping	intro E-textiles workshop	Tutorials & lecture	E-textiles workshop	E-textiles workshop	Guest lecture & Concept Review	E-textiles workshop	Tutorials & lecture	E-textiles workshop	Final Review
DOUBLE DIAMOND												
STAGE	DISCOVER Insight into problem				DEFINE Possible solutions			DEVELOP Selected solution		DELIVER Selected solution		
SESSION	1	2		3		4	5		6		7	
LEAD												
TDT		□	□	■	□	□	■	□	■		□	□
TDL	□	□	□	□	□	■					□	□
IDT						■	□		□		□	□
PDT	□		■		■			■		■		□
DATA												

Figure 6-4 Micro-Living project structure mapped to the Double Diamond

In Figure 6-4, the seven sessions of the 'Micro-Living' project are indicated in blue, product design module sessions in white and the module's assessment points in yellow. Sessions in white or yellow were attended by the entire second year product design cohort, while those in blue were exclusively for the students that had chosen to take part in the Micro-Living project. The lead(s) for each session is indicated by '■' in the row corresponding with Product Design Tutor (PDT), Interaction Design Tutor (IDT), the Textile Design Principal Lecturer (TDL) or me (TDT). Where no lead is indicated a session was delivered collaboratively. '□' indicates tutors that were present at each session and the data collection method is shown by a symbol representing notes, audio, video or photography.

The students and staff completed questionnaires at the beginning and end of the project. Additionally, we held a group interview with the product design and then textile design students on the day of the final review and two follow up discussions with staff several weeks later. The students worked in pairs, except for Team F which was a trio with two product design students. When compared to *Design Situation 2*, the contribution and interaction of the disciplines could be more easily identified. The group interviews were conducted with the product design and textile design students separately to gather a discipline specific reflection on the experience.

Coming into the project the two disciplines' differing focus was immediately apparent from their perception of the main challenge they would encounter. The initial survey (Appendix C4) showed the product design students were concerned about finding ways to integrate or apply E-textiles in their product concept, whereas the textile design students' concern was making E-textiles.

At the first session the students chose their partner and were given the project brief. In the second, they took a tour of the laboratory facilities of NTU's ATRG to introduce the students to E-textile technology, manufacturing processes and applications. The tour was followed by three talks. The first two were delivered from a technical rationalist perspective and discussed E-yarns (Dias and Ratnayake, 2015) and printed E-textiles (Torah et al., 2019). To counterbalance these technical presentations, I delivered the final talk. My objective was to encourage them to think broadly about what E-textiles could be by providing diverse references relating to architecture and interior spaces, such as a collaboration with carpet manufacturer Kasthall (Persson and Worbin, 2010) and GKD metalfabrics' 'Mediamesh' (n.d.). I also introduced them to the aspects of 'Home and Homing' described by Heinzel (2018, pp.39–40), to reveal affective considerations in relation to the domestic interior and support them in envisaging a purpose for their E-textile designs.

Immediately after this presentation the textile lecturer and I were approached by Team B. Following the talks and with the brief in hand, the textile student was concerned about how to carry out research for the project. She had perceived that the visual sources she would normally use were not well suited to the questions the project asked. Her perception reiterates my observation in *Design Situation 1* of a mismatch between the conventional textile design process and that of E-textiles.

In the second week the entire product design cohort and the textile design students taking the elective were introduced to journey mapping. They were expected to create a user journey map relevant to their chosen scenario. The product design students had already designed using personas, an example of which from the project is shown in Figure 6-5, but not journey mapping. To the textile design students both techniques were new. The aim of combining a persona with a journey map was to encourage the students to imagine an individual's experience of living in an 18 m^2 space (Figure 6-6).

FILE USER PROFILE USER PROFILE USER PROFILE USER PROFILE USER PROFILE USER PROFILE USER PROFILE USE

SARAH

26 y.o., independent contemporary artist, works from home. In relationship with Marco, came from Italy with him 6 months ago.

LIVES IN

15m² first floor apartment in Central London.

RELATIONSHIP TO THE APARTMENT

Long-term tenant.

ATTITUDE TOWARDS TECHNOLOGY

Not very tech-savvy, but open to new things.

AESTHETIC PREFERENCES

Prefers organic, natural & sustainable materials, colours, food. Crafted objects made by artists.

DESIRES

Live in a bigger (physically or visually) apartment.

Have an ability to customise the interior, add personal touch to it.

Furniture with less footprint so it can be stored away when it is not needed.

TYPICAL DAY

Wakes up at 6:30 every day to cook breakfast, meditate. Has breakfast with Marco.

Starts painting at around 9am.

Stores away her drawing equipment when guests are around.

Invites friends over (usually 1 during the daytime and around 3 in the evening).

PAIN POINTS

Not enough space/furniture to accommodate her friends.

Feels that apartment does not resonate with her style and feels less like home because of it.

Wants to attach art to walls, but it is not allowed. Apartment gets cold during winter.

Poor lighting in the apartment in the evening.

USP

Organic, crasftsmanship, sustainable, expressive, colorful, unique,

Figure 6-5 User persona, also known as a user profiles, created by Team B

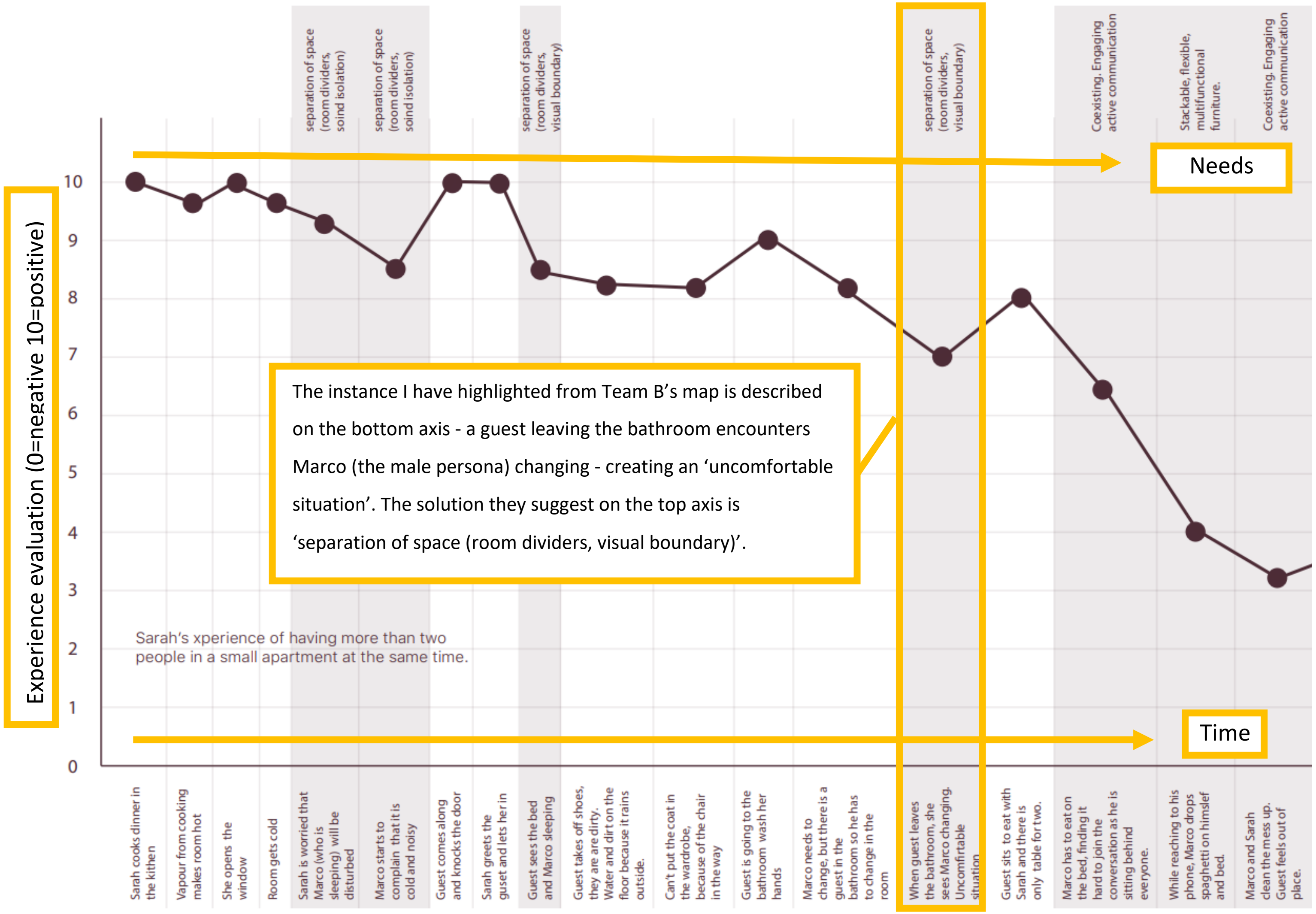


Figure 6-6 Example by Team B of a user journey map showing positive and negative experiences over a chosen time-period.

Team B, whose work is shown in the examples, created a hybrid of the ‘work’ and ‘entertainment’ scenarios (Figure 6-1). The students were expected to use their research to identify problems in their scenario for which to design E-textile product solutions. Both the students taking part in the Micro-Living project and the rest of the cohort, were expected to organise study time outside the scheduled sessions to choose a scenario from the brief, devise a relevant persona(s), map a layout of the space and construct a user journey map of their persona’s experience in the scenario. In the journey mapping example created by Team B (Figure 6-6), the students are imagining a couple, Marco and his partner Sarah, in the team’s hybrid scenario. The period mapped is a morning with a guest staying. Their user journey map shows experiences on the bottom X axis and an evaluation of those experiences on the Y axis. Team B’s user journey map also shows them linking experiences to products indicated along the top X axis. Their ideas included multifunctional textile objects to make better use of limited space, entertainment built into the surroundings and space dividers. In addition, the students were encouraged to mark out 18 m^2, shown in, to better visualise the space constraints and to develop a layout for the interior in which their E-textile product would be situated. Although Team B’s persona, user journey map and layout Figure 6-7 are particularly detailed examples, they are representative of the activities carried out by other teams[7].

Figure 6-7 Team B: Space layout plotted to scale

[7] Team B received the highest grade of the students that took part and were invited to interview by the consultancy that was involved in the project.

Returning to the Micro-Living project's specific activities, the challenge was to encourage the students to create novel E-textile ideas inspired by their user experience research[8]. At this point in the investigation, I was still unsure of the role of making in a purpose-led textile design process. I was torn between the view I had held at the beginning of *Design Situation 1* and the conclusion I had reached at its end. I had thought understanding E-textile elements was key to designing with them (Section 4.3) but had realised that understanding technical characteristics and capabilities does not necessarily produce a purposeful design.

I was also wary of anything we taught in these sessions becoming a design precedent for the students and causing fixation (Section 5.1). Given their limited knowledge of E-textiles, determined from the initial survey, it was impossible for the practical activities to match the reach and diversity of their design ideas. Together with the textile lecturer, I decided to deliver only one session of taught E-textiles content to the whole group, on the basis that it would be more effective for each team to receive tailored guidance on their specific design direction.

Session three was the first practical element of the project and introduced the students to E-textile elements and construction techniques and then to programming. The activities I used in the first part were developed by Davies and Hardy (2016) following Papert's (1980; 1991) Constructionist approach to learning, which although multifaceted can be summarised as "learning by making"[9]. Although it was established in relation to childhood learning, the approach also has relevance for undergraduate design education, as outlined by Psenka et al. (2017). Two constructionist recommendations I adopted were the use of a kit and the focus on collaboration. In the first half of the session, the group were asked to make a basic circuit and a soft battery holder from a kit of E-textile components[10]. This task was an opportunity for the students to build an understanding through hands-on experience of basic electrical principles, including polarity and continuity, and to illustrate how rigid electronic components could be designed as soft textile-based alternatives.

Emphasising their inexperience, the task of creating a simple circuit to light a LED from a kit of components was not automatic for all the group. Later in the session, while making the soft

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[8] Novelty is more difficult to define in the context of a student project than the definitions it carries, for example, in international reference guide the Oslo Manuel (OECD/Eurostat, 2018) which differentiate products that are new to a firm from those that are new to the whole market. The novelty of the students' designs was an evaluation by the tutors of the degree to which they considered them wholly new products concepts, new applications of E-textiles or a novel combination of elements.

[9] Seymour Papert's Constructionism is a learning theory, distinct from Social Constructionist epistemology.

[10] The design of the soft battery holder was developed through collaboration between NTU and Kitronik and is available online (Donnison, 2015).

battery holder, one of the textile design students cut the conductive copper tape she had used as a conductive track into a pattern. She had not considered that in doing so the continuity of the circuit was broken (Figure 6-8). Once the problem was explained she proposed a solution, but a lack of understanding of the adhesive copper tape she was using as the conductor, only conductive on one side, meant the solution would not work. Eventually, through an iterative process, she learnt how to create patterned designs where electrical continuity was maintained.

Figure 6-8 Soft battery holder element with incorrectly 'repaired' conductive tracks made of copper tape

The second part of the session introduced the students to programming using the 'Igloo: Picaxe wearable module' which is designed to be sewn, similar to the Lilypad components created by Leah Buechley (Buechley et al., 2008). The programming language used to program the Lilypad is complex, instead the Picaxe microcontroller is programmed using Blockly. It is a simple programming interface in which code is constructed out of pre-written blocks that can be arranged and variables adjusted, shown in Figure 6-9[11]. The intention was that through an initial introduction followed by support in the subsequent sessions, the students would, like the participants of *Design Situation 2* or I, be able to create simple programmed elements for their designs.

[11] Blockly operates similarly to the MicroBit system designed for educational purposes by the BBC. The Picaxe microcontroller offered the supposed advantage over the MicroBit of having been designed for textile projects.

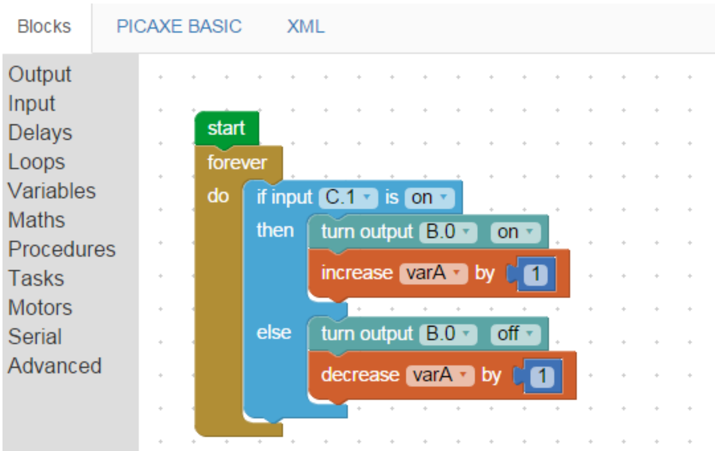

Figure 6-9 Picaxe 'Blockly' coding interface and example code

The session was hampered by difficulty in downloading the software, causing disappointment and frustration among the students. However, by the end they had all used Blockly to program the Picaxe microcontroller, making an external LED blink at their chosen rate (Figure 6-10). The setbacks described most likely did not help the students to engage with the programming aspect of their projects. However, as I will move on to explain, the broader product design module structure and its deliverables, none of which required a physical object to be made, were probably more influential in hampering this intention.

Figure 6-10 Micro-Living session three: Introduction to E-textiles workshop - programming

Session four at the beginning of week three drew on my observations of the exploratory making phase of *Design Situation 2,* described in Section 5.2.1 and 5.2.2. In *Design Situation 2,* ideas, such as the conductive crochet mittens that became the activation mechanism in one design, were conceived through exploring the materials available. Similarly, the students were provided with a range of electronic and textile elements and support for making. They also had access to the textile and product design facilities and equipment and each team was allotted a sum to spend on materials as they saw fit. Despite these provisions, it remained a challenge to manage the misalignment between the ambition of their design proposals, which could be communicated using CAD, and the budget, time and their skill at making E-textiles. Given the outcomes of *Design Situation 3* were to be graded, it did not have the same freedom as *Design Situation 2* where the designs were not subject to this scrutiny.

As session four progressed, most teams were still working to rationalise and envisage what they wanted to design. They had a deadline, one week later, to present six design proposals and a layout of the micro-living space for their selected scenario at the product design concept review. We asked each team to give an 'elevator pitch' for us to understand their ideas and give input. From these it became clear they needed both to develop more ideas and to refine those they had conceived.

The need to expand the number of designs created a disincentive for the students to explore the electronics or make textile samples at this stage. The students' ideas responded to different aspects of their experience maps and each required different textile characteristics and electronic functions. For example, Team D proposed everything from a touch sensitive illuminating carpet to a posture monitoring chair. While each of the designs was grounded in a purpose, it was difficult to suggest an approach for the textile student as each idea required a different type of textile.

The product design students did not have to limit their thinking to what they could make, which conflicted with the textile designers' desire to materialise their ideas. The breadth of directions, lack of deliverables for the textile design students and the uncertainty inherent to exploratory making, meant it was hard for the students to quantify the benefits of making textiles or E-textiles at this stage. With the pressure of a deadline, the students were looking for the most direct route to define six proposals to present.

The interaction between the students and us during the subsequent Micro-Living sessions unintentionally resembled the product design tutorials. The following excerpts are from the recording of session five when the students had five days until the concept review[12]. At this stage, only Team B had already conceived all six E-textile products.

The first pattern of dialogue was where the students explained their concept and we responded by suggesting a means by which they might realise the idea, as a sample or prototype, hypothetically or industrially.

[12] The transcript of the discussion with Team F is found in Appendix C5.

PD-A: So, with the heat reactive materials, since all the food that you're cooking is probably going to be hot, maybe placing it onto the table and the table changing to a different pattern whilst you're eating. It could be an entertainment talking point as well.

TDT: In terms of things that you'd actually be able to realise in the space that we've got for this project, one of the things that I've ordered is some thermochromic ink.

There were also instances where the students presented their concept and we asked them to clarify the problem or purpose they were designing for, traced back to their experience maps and connected to their persona(s). In these interactions, an example of which is below, we suggested or prompted aspects of experience to consider in the design.

TD-F: Yes, we thought about that already. Having like a pull-down space, because the bed is going to be above, and then have a screen or something be able to pull that down so you can kind of close it off a bit.

TDT: [...] if that screen becomes part of that zoning of the workspace, what things in your environment do you need to control when you're working?

Team B, who received the highest grade of the students that took part, formed their concepts very early in the project. When describing their work in the excerpt below, they had decided on the problem and were telling us the way the designs could be realised. We offered them alternatives or discussed the feasibility of their ideas. The textile design student had created a range of printed textiles and together they had experimented with 3D forms. The speed with which Team B defined their design proposals meant at this stage they had time to explore materials that fitted their design ideas. Their focus was on partitioning as their journey map had highlighted the need to be able to divide a micro-living space.

TD-B: I was thinking to print it like through digital print and then to make laser cut on it and then the conductive ink would be the last one because of digital print but...

TDT: Another way you could get around that is you could print on something like a polyurethane film.

At the other end of the spectrum, the next excerpt from a member of Team F shows the struggle some teams encountered connecting the experience of a persona to E-textiles. The team proposed the means they wished to use, which was Bare Conductive® paint, with little reference to the concept or problem. Our focus on the purpose of the students' designs meant our response was to ask what experience-based problem they were designing for. As a note of caution, their proposal of the means they wished to use instead of the concept or experience-based problem could also show that the team wished to use the session for making, a request we misread as a more basic lack of clarity. It could have been useful for the students if we had explored the means the team was looking to use rather than directing them back to the problem. This may have helped the team find ideas through material exploration and the textile student create samples. However, it would not necessarily have removed the team's "struggle" to "incorporate" E-textiles into their design proposals and could have shifted the focus away from purpose.

> *PD-F: I think our primary idea right now is the paintable what was it called again conductive… conductive paint to create the sounds, the acoustics. So, we kind of want to make essentially like a demo of that, right? That's our main focus right now. Programming that and having a demo and the graphics and we don't know how else. We're kind of struggling to find other ways to incorporate E-textiles right now, so that's what we're talking about.*
>
> *TDT: Into your ideas?*
>
> *Team F: Yeah.*
>
> *TDT: So how about you go back then to your problem, because obviously you're going to have to show, they want you to show multiple ideas for Tuesday. So, what are the problems that you've identified?*

Teams D and E presented us with the experience or problem for which they wanted to design or couched their ideas in terms of the problems to which they were responding. This approach to the interaction allowed the students to focus on the needs that they had identified via journey mapping and therefore the purpose of their designs. We responded by providing possible ways for them to realise their ideas.

> *PD-D: What kind of materials to be like… strong enough?*
>
> *TDT: I mean it's not going to be very heavy… I don't know. [Addressed to the textile designer] When you're doing… because you're embroidery right? When you're doing other projects […] how do you choose the material you embroider on to?*
>
> *TD-D: […] It's just usually all about aesthetics because […] we don't usually make them that functional. Well you'll say like, oh it's stretchy or it's not stretchy so it's probably more related to fashion or interiors or this or that, but we don't really enquire that much about the durability aspect and the function in terms of carrying weight and stuff.*
>
> *TDT: But maybe […] what you could do is find some little swatches of materials, of fabrics that you think would be a good base.*

This exchange exposes the minimal role purpose and suitability had previously played in the student's design process. The durability of textiles produced at undergraduate level is broadly not tested because the hand making equipment to which the students have most access does not produce results that perform to industry standard. As professionals, textile designers often contend with performance requirements. However, I would argue that not learning to envisage a purpose for their designs leaves graduates ill-prepared to work with emerging E-textile technology.

Throughout the sessions, the lack of textile design deliverables and the product design emphasis on CAD outcomes gave the students little incentive to materialise their designs. There were also practical constraints, the 30 minutes available to each team providing only limited scope to support making. The sessions were largely confined to discussion of ideas or providing materials and components for the students to work with in their own time. Despite our suggestions from early in the project of avenues the textile design students could explore, it was only after the product design tutors selection that most of the textile students started to make anything, as indicated in Figure 6-11.

TEAM	Textile design sample at concept review	Product design sample at concept review	Textile design sample at final review	Product design sample at final review	Electronic sample at final review	Integrated sample at final review
A	NO	NO	YES	Partial	NO	NO
B	YES	YES	YES	YES	YES	YES
C	YES	NO	YES	NO	YES	NO
D	NO	YES	YES	YES	YES	NO
E	NO	NO	YES	Partial	YES	NO
F	NO	NO	YES	Partial	YES	NO

Figure 6-11 E-textiles for Micro-Living project grades and physical making

The correlation the amount they made also indicates each team's motivation and is a measure of the level of collaboration between team members. In session three, Team B described themselves as "fitting together", saying "it just happened" and "it works". Whereas the textile design student in Team C said in the closing group interview "I just worked alone" and that the project had been "stressful… because she didn't include our work". At the end of session four, from which the textile design student was absent, the product design student of Team A, said "I'm going to look into making different ideations of like the tables and like have [textile design student] look into fabric", suggesting a separation of roles that is unlikely to have been helpful. Close collaboration aided teams in envisaging a purpose for their designs, but also allowed textile design considerations, including material choice, pattern, colour, and texture, to contribute to designs that served their purpose.

Evidence of the level of collaboration can also be found in the degree to which the students presented their work as a cohesive whole at the concept and final review. Figure 6-12 shows that

Team B merged their contribution on their presentation boards so no dividing line can be drawn. The product designer of Team B used the textile designer's graphics in her CAD representations of their proposals. Two designs for space-dividers even sprung from the team's exploration of 3D form using textiles and paper painted by the textile designer. By contrast, the contribution of the students from Team C was clearly separated, implying a lack of cohesion in the team and highlighting that the two students were working separately. Team B had a close collaboration and merged their contributions, as did Teams D, E and F[13].

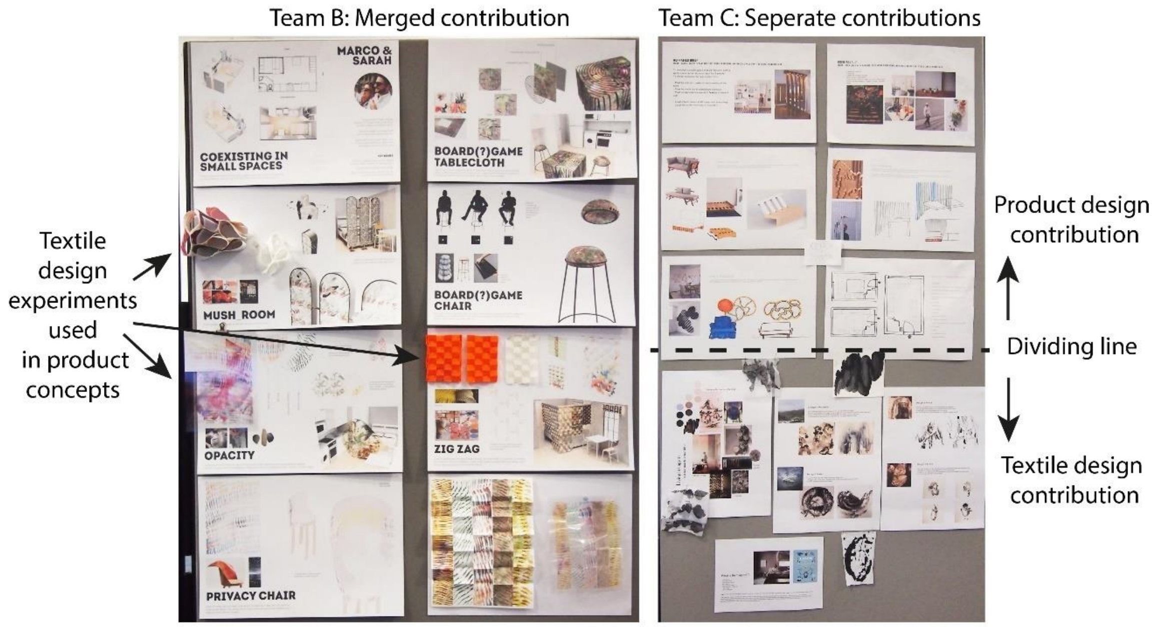

Figure 6-12 Concept review presentation from Teams A and B

At the beginning of week four, each team was asked to present six designs at a concept review, a description of each team's concepts is found in Figure 6-13. The product design tutors selected one design to be developed as the final design proposal. They communicated their comments and selection to the students on sticky notes affixed to the chosen concept. The students then had a further two-and-a-half weeks to finalise their proposal and complete the required deliverables. At concept review many teams presented ideas that were not related to E-textiles. These are left in white in Figure 6-13. Concepts that included E-textiles are highlighted in yellow and those selected by the product design tutors are in green. At the concept review, only Teams B and D had managed to develop six concepts all of which were E-textiles. The other teams either presented less than six or presented concepts that did not contain E-textiles.

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13 Images of all the teams' concept and final review boards can be found in Appendix C5.

Team	Concept Review - Week Four	Final Concept - Week Six

A	>>> Immersive E-textile space
	>>> Moveable interactive E-textile screen
	Bed come storage unit
	Storable table set into a recess in the floor
	Chairs that can be folded into the wall
	Thermochromic vessel cover
	Sound proofing inspired by the product 'clouds' produced by Kvadrat
	Thermochromic tea towel
		An immersive E-textile space for entertainment

B	>>> Customisable E-textile that can serve as a divider or curtain E-textile room divider which triples as flexible storage and light panel Privacy chair with E-textile reading light E-textile room divider that becomes transparent and creates visual space when needed Smart tablecloth inspired by MIT programmable drops Chair that is an E-textile control for the smart game tablecloth and other digital devices	A moveable and customisable ceiling attached E-textile divider system designed for rented accommodation
C	>>> Space divider actuated by shape memory materials Sofa bed design Tactile lighting combing textiles and illumination	A responsive space divider actuated by shape memory materials inspired by the Swedish concept 'Lagom', meaning 'just the right amount'

D	>>> E-textile productivity panel and storage unit
	>>> Collapsible E-textile illuminating screen
	Motion sense sleep tracking pillow
	Pressure sensitive illuminating carpet for night-time guidance when partner is sleeping
	Alarm clock blind
	Chair that alerts you to poor posture and extended periods of sitting
		A divider-come-storage-unit, designed to separate off space for work and relaxation, helping productivity and order

E	>>> A living textile wall with integrated sensors A multipurpose desk/storage/dining table/meditation tent A knitted E-textile ceiling/photography light and meditation tent with LEDs and speakers Space saving roll down bed E-textile lighting mimicking fireflies flip-up bike storage unit	A living textile wall with integrated sensors to monitor factors required for healthy plant growth, inspired by the concept of biophilia and design to make the best use of restricted space
F	>>> E-textile interactive room divider Storable chairs Platform bed unit with E-textile screen and lighting Pop-up kitchen Collapsible chair Splitable table E-textile storage sofa Musical E-textile instrument bed	A divider that would play sounds in response to touch for entertainment

Figure 6-13 List of the design proposals created by each team and their final design.

The list of concepts (Figure 6-13) provides evidence for several tensions in the project. The ambition of many ideas were beyond what the students had the resources or skill to make into functioning prototypes. For example, Team B envisaged a table cloth using MIT's programmable droplets, while Team D conceived a pressure sensitive illuminating carpet[14]. However, the students could have created mock-ups to render elements of their designs or simulate their appearance without creating a fully functional prototype. An additional challenge was that the textile designers belong to specific specialisms, namely knit, print and embroidery. The concept of the pressure sensitive carpet would not have offered much scope for making to the textile student whose specialism was embroidery, not a technique commonly used in carpet making.

A timeline of the project is illustrated by Figure 6-14. The red thread represents the textile design process for most of the teams, showing the extension to the project they would have needed to resolve their designs. In a conventional textile design process, the application, meaning the category of product the textile will become, is often determined in the initial project brief and dictates the characteristics of the textile. In *Design Situation 3*, most of the textile design students did not have this information until after the concept review. Therefore, the challenge facing the textile students before the concept review was what direction to take. At the end of the project the textiles were broadly speaking still initial ideas that needed to be refined.

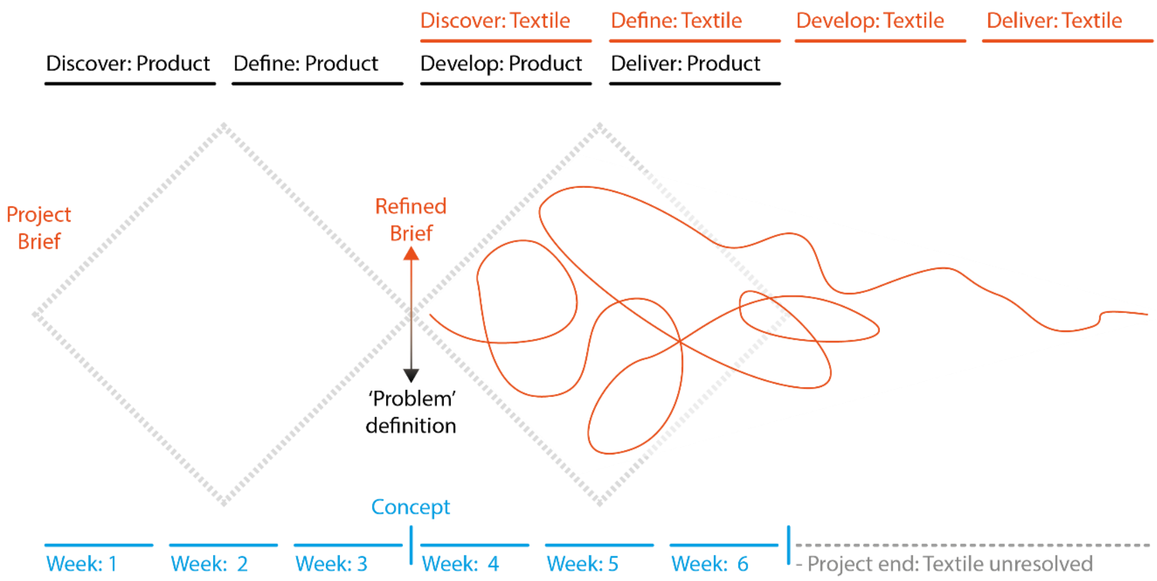

Figure 6-14 Micro-Living project: Textile design process alongside the product design Double Diamond process

The textile design students struggled with the idea of their designs needing to be reworked or becoming irrelevant because they were based on initial product ideas. As the textile design

[14] The MIT programmable droplets project uses electricity to move tiny liquid drops (microfluidics) based on the principles of electrowetting on dielectric (EWOD) with the aim of providing an alternative to pressure-based systems (Umapathi *et al.*, 2018).

student from Team F described in the closing group interview, "I went in and did some embroidery, and just kind of did it… and then it was like, actually we've already decided we're not going to do this anymore". Without textile design deliverables for the project, it was difficult for the textile students to see value in samples that did not feed into the work of the product designers. Those teams best able to navigate the uncertainty of the early stages did so through close collaboration. This observation underlines the positive effect of team working on mutual understanding and ideas generation found by Fisher (1997), expressed by the textile design student of Team E as a "little support system".

Team B and C were the exceptions to the general delay in textile making, but for opposing reasons. In Team B, where collaboration was close, the team moved between the textiles and the product. The textile design student "found it really interesting to work with shapes" (TD-B, group interview) and the product designer was inspired by the "unique properties of textiles" (PD-B, group interview). Team B used textiles as inspiration by deciding early in the project the purpose for which they were designing, which was to offer privacy by dividing the space. This decision allowed the team to lead their exploration of textile properties and aesthetics with a purpose in mind. The account by Team B's textile designer from the closing group interview shows the order of their decision making, with the electronics as the last element they found a way to include in their design.

> *We were thinking first about textiles and then how we were going to incorporate E-textiles and we found out many ways, but then that it's not possible to make that like we'd like to do. So, we were thinking then of other ways and then we found E-textiles and then we were thinking about how we were going to use them because we knew that we wanted to make some kind of divider for privacy.*[15]
>
> *(TD-B: Closing group interview)*

In contrast, the textile design student in Team C said, "I just worked alone". Her work showed many aspects of a conventional textile design process: drawing inspiration from visual references and exploring materials (Section 2.3). She made the choice early in the project to design textiles for the space divider curtain the team presented, but unlike others that worked more closely with their product design partner, the connection between the textile design work and user research was more tenuous. Although the textile designer experimented with LEDs, thermochromic ink and heat circuits and the shape-memory alloy nitinol, the purpose of these design choices in relation to user experience was less clear (Figure 6-15).

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[15] The student was not a native English speaker, so this excerpt has been edited for clarity. The original transcript is found in Appendix C7.

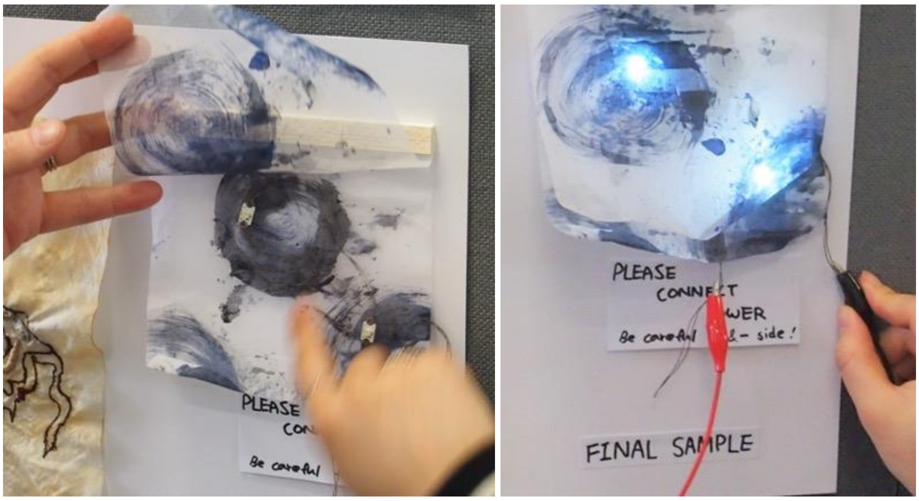

Figure 6-15 Textile samples created by the designer of Team C

Team B explored possible textile shapes early in the project, drawing on the textile design student's knowledge, but they felt the same could not be said regarding the electronics element of the project.

> *I think everybody got really excited about the properties of textiles and then just snapped some electronics there, because we could get input from the textiles students about their textile experience as we went but we couldn't get input about electronics, like get inspired that easily, so a bit more background in it would be nice, like along the way as the project flows.*[16]
>
> *(PD-B: Closing group interview)*

The idea suggested by the student's reflection is, as found by Lawson (2004b, pp.22–23), that rapid access to information is an important factor dictating design directions. Despite the Micro-Living sessions in which the students could discuss electronics, their perception was that to better integrate E-textiles into their designs they would have required more content to understand the possibilities they could offer. There are also technical challenges when designing with E-textiles. Extending such a collaboration to include students with a background in ICT may have improved the outcomes by allowing electronic elements to be considered "along the way" (PD-B, group interview). Opportunities, therefore, should be provided for collaboration between product design, textile design and ICT related subjects, combining knowledge of textile properties and constructions, user research strategies and ICT skills.

The framework for the project, created by the product design tutors, pointed the students to a design process inspired by the contextualised experience of an imagined persona, however, constraining their designs to E-textiles was challenging. A challenge further complicated by each

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[16] English was not the student's first language, so I have edited the quote for readability.

textile student being specialised in a specific type of textile technique. The bias in the project towards product design and CAD outcomes created difficulties and delay for the textile design students, but also left the product designers wishing for more opportunities to engage with textiles.

6.3 Reflection

The difference in emphasis between CAD and physical design work created tension in the project. This particularly impacted the textile design students who were further outside their customary process and more unsettled by the project. They had been moved from a material and making focus towards HCD in which envisaging a purpose is part of the process. In line with the textile design focus on the physical realisation of ideas, the students had expected "more making" (TD-F closing interview). Those teams best able to navigate their contrasting focus did so by adjusting their individual processes to create an approach that blended aspects of both disciplines, expanding their practice to encompass more layers of design. By the end of the collaboration the product design students had become more aware of the physical constraints of textile materials and techniques. While the textile students had learnt techniques to envisage a purpose for their designs.

6.3.1 Dependence and uncertainty

It is near impossible to carry out design stages in parallel when design decisions are dependent (Loch and Terwiesch, 1998), such as between the design of the E-textiles and the overall product in *Design Situation 3*. Van Bezooyen (2013) describes material selection in the traditional product design process as occurring during the Develop stage of the Double Diamond, once the product concept is fixed, but advocates consideration of materials earlier in the process. Although *Design Situation 3* encouraged the students to consider materials from the beginning, the textile designers did not fully commit to designing textiles or E-textiles until the develop stage, once the end-product had been defined by the tutors' selection.

When different disciplines collaborate, recognition of their relative position in the layers of design, running from the user to material, provides guidance as to where difficulties may occur. From *Design Situation 3,* I conceived the diagram in Figure 6-16 showing the layers of design and the dependence between the layers. The concept, discussed in Section 1.4, is a reference to Vallgårda and Redström's (2007) discussion of computational composites, where layers are used to describe the development of textile artefacts. Visually representing the layers of design made the position of textile designers much clearer. They are separated from the people who will eventually experience their designs, which is a barrier to a purpose-led process.

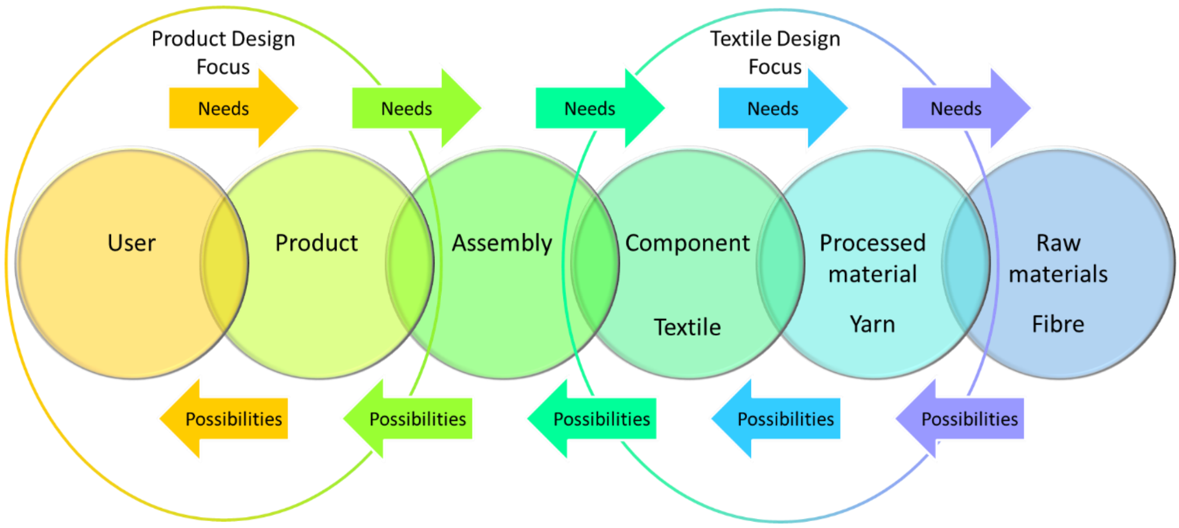

Figure 6-16 Layers of design showing the flow of needs and possibilities

For textile designers the user is distant, whereas for product designers it is more likely to be the materials, but there is a chain of dependence between design decisions. If the overall product direction is unclear, it is difficult, if not impossible, for the constituent parts, including E-textiles, to be designed. Where disciplines such as textile and product design, that occupy different positions in the chain collaborate, project structure should recognise the dependency of decision making. This may mean giving more time to certain stages than would be routinely allotted or extending the project overall, as illustrated in Figure 6-14, to allow layers to be traversed. More time and recognition of the layers also supports the development of mutual understanding and new collaborative practices.

6.3.2 Purpose and possibility

Traditional methods for generating ideas such as "reference to prior products", consumer focus groups or usability testing have been found ineffective in the design of new technology (Suchman, 2002, p. 97). With the functions of E-textiles still being developed by the scientific community, the roles that E-textiles will play in our lives are yet to be defined. The students were encouraged to envisage purposes for E-textiles based on the needs of their persona(s) discovered through journey mapping, and then received tailored tuition to develop those ideas. Some of the textile design students felt, "it was nice to be left independent with our ideas" (TD-D, group interview). Others struggled to use the power of imagination to envisage a purpose and had anticipated being "able to go and see different things in use" (TD-F, group interview), relying on precedents for inspiration.

Despite some students wishing to have been provided with more precedents for inspiration, the point made to them by the textile design lecturer in the closing discussion was that "there's a load of new materials out there that no one really knows what to do with… and you were trying to bridge that gap". Approaches to product design in which the possibilities of materials are explored from the beginning of the process for inspiration and direction, as advocated by van Bezooyen (2013) and Karana *et al*. (2015), have potential to be used in situations such as the Micro-Living project. However, it is unclear how a material driven process leads to a design with a valid purpose. Karana et al. (2015, p.49) warn that when using a material driven approach with smart composites, like E-textiles, “the newness of such materials might give designers the impression that a mere transformation of a new material to any product is of value”. Therefore, this thesis argues designers should prioritise envisaging a purpose and balance this with understanding a material’s capabilities.

6.3.3 Textile meets product

Teams A and C envisaged immersive, poetic uses of E-textiles for interior spaces, but tension in both teams meant the ideas of the textile designers were not fully embraced by their product design partner. The textile design student of Team A hinted at this tension saying, “everyone thinks in a different way or is […] more or less open to ideas” (TD-A group interview). The textile designer had envisaged an immersive, interactive and affective E-textile space for the purpose of entertainment and well-being. Given that the team’s final presentation contained two separate representations of their idea, the product designer’s the more conservative of the two, the comment suggests that the product designer had not been open to the textile designer’s more exploratory ideas.

At concept review, the designs selected by the product design tutors for all the teams were a form of space partition. This outcome suggests that the ability to partition space was the most fundamental purpose E-textiles could serve to aid people living well in small spaces. The textile lecturer could not attend sessions 5 and 6 or the concept review. When she re-joined the project in session 7, she felt the selected designs were overly conservative and similar considering the breadth of initial proposals she had seen. In one of the staff follow-up discussions, a member of the product design team suggested that the conservatism displayed may have been because of industry involvement. He proposed this had led the students to create designs with possible commercial feasibility but did not acknowledge the product design team’s role in the selection process. His response may have been to smooth over differences between the more exploratory creative materials approach of textile design and the product design focus on function.

The product design students said their conventional process was “all about the form and functionality” (PD-D, group interview). By form they meant the basic outline of the overall product, a prioritisation of “form over material" discussed by Oxman (2010, p. 100). In the closing group interview, the product design students explained that in their standard design process, they predominantly consider resistant materials such as wood, metal or plastic. They used these materials to create a “clean-cut” appearance with a “Scandinavian focus” (PD-E, group interview).

The suggestion made in the group interview and visible in the work itself, found in Appendix C6, was that through working with textile designers the product design students had developed a more material sensitive and affective response to their brief.

Through working with textile designers, the product design students gained an appreciation of textiles as materials and the benefits they could provide. During the project they discovered the importance of textiles in interior environments, discussed by Heinzel (2018), and the advantages they have over resistant materials in terms of weight and transformability. Although the product design students were not always open to the more experimental ideas of the textile designers, they were able to appreciate the benefits a more affective, material sensitive approach brought.

6.4 Discussion

Reviewing the project data, the biggest influence on the outcomes and student experience came not from the Micro-Living sessions, but from the module structure and the collaboration between the two cohorts. For the students, the textile lecturer and I being introduced to journey mapping was an important aspect of the project: “focusing on the user experience, that was really big” (PD-D, group interview), it’s “a good thing to learn because you know exactly what you’re trying to make them feel” (TD-A, group interview). Experience mapping offered a way to deepen understanding of the user and envisage a purpose by imaging their experience. This step of deeper understanding had been missing in *Design Situation 2.*

Although experience mapping provided insights into experience, both disciplines had difficulty connecting experience-based problems with E-textiles. Rich contextual data “does not provide straightforward answers to designers” (van der Bijl-Brouwer and Dorst, 2017, p. 5). Through its shortcomings, *Design Situation 3* allowed me to observe the challenges facing textile designers in adapting to a product design process. As their tutors we attempted to bridge the gap between experience-based problems and E-textile design possibilities. However, discussions in the Micro-Living sessions and the students’ reflection on their experience suggests more needed to be done to support this step in their design journey. This indicated that, for *Design Situation 4,* further techniques would be needed to allow me to link across the layers of design from experiences to E-textiles and the materials from which they are constructed.

Although the students wanted more time to have been dedicated to the capabilities of E-textiles, for the process to still have been purpose-led this would have had to be handled very carefully. The example of Team F who wanted to use Bare Conductive® paint is illustrative of this point. The paint conducts electricity, but that property can serve many purposes. My experience in *Design Situation 1* was that performance characteristics and functional capabilities are of limited help when trying to envisage a purpose for a design.

There is a delicate balance to be found between understanding capabilities and envisaging purpose when designing with emerging technology, an equilibrium not reached in *Design Situation 3*. One possible approach for the students to “get inspired” by electronics and their combination with textiles would have been bootlegging, the ideation technique used in *Design Situation 2* (Section 5.2). This technique could have helped the students consider a broad range of possible electronic functions and textile qualities that could be harnessed for an E-textile product. It is impossible to know without running the project again how more activities dedicated to understanding the capabilities of E-textiles would have affected the project’s outcomes. Even with more electronics content, the students’ ability to realise their ideas would still have been limited by time, resources and skill. Greater emphasis on electronics may also have shifted focus away from the user experience and the design’s purpose.

Niinimäki, Salolainen and Kääriäinen (2018) advocate using HCD concepts in the development of integrated textiles and electronics, but do not provide guidance as to how this should be achieved or acknowledge the challenges. I have consistently found in this investigation that in industry and academia textile designers were unfamiliar with HCD concepts. On the flip side, the product design students were unfamiliar with textiles as a material and expressed that prior to the project were unlikely to consider them for their designs. This indicates a gap between these two knowledge spheres that invites research into design methods bringing both user and materials into an expanded textile-product design practice.

This case highlighted the tension of using techniques taken from HCD to inform the design of a product when the material or technology is specified. To address the primary problems of living well in small spaces, E-textiles may not be the ideal means. The students were restricted to this category, potentially hampering the development of more appropriate solutions. This tension is further underlined by Norman’s (1986, p.61) statement that “user-centred design emphasises that the purpose of the system is to serve the user, not to use a specific technology”. E-textiles are not a specific technology but a family of technology hybrids, hence perhaps this tension does not exist, but *Design Situation 3* suggests otherwise. Given their potential negative environmental impact because of the difficulty in recycling the combination of materials they contain (Köhler, 2008), consideration should be given when choosing why, how and if to amalgamate these two spheres.

The scientific community has advocated the seamless integration of electronics into textiles, because, as substantiated by Zysset *et al.* (2013, p.227), this is seen as the means to gain acceptance from users for E-textile products. Counter to the assumption that greater integration will improve user experience, Townsend, Kettley and Walker (2020, p.100) propose a vision of wearable E-textiles in which systems are “deconstructed”, envisaging them as “a constellation”.

Suchman (2002, p. 99) advocates the use of "hybrid systems composed of heterogeneous devices" that she calls "artful integrations" and Kuusk (2016) explored electronic and textile hybrids with no physical integration in her investigation of sustainable smart textile services. This same principle of deconstruction can be applied to the design of E-textiles for interior spaces. In interiors textiles are less frequently or intimately in contact with our skin, reducing the comfort factors that motivate seamless integration in wearable technology. This layer of removal from the body combined with the possibility to exploit rigid surfaces of interior spaces, such as walls and supporting structures, mean a more open-ended hybridisation of textiles and electronics should be further investigated.

The Micro-Living project showed that textile and product design have much to offer each other. The textile design students stated that they had gained a broadened appreciation of the range of possible outcomes their textiles could be transformed into, and that their process had become more purposeful. By combining competencies, textile design can be conducted with greater clarity of purpose, while product design becomes more aware of material constraints and opportunities, as well as the affective potential of colour, texture and pattern. Personas and journey mapping can support a purpose-led E-textile design process, but these methods do not provide easy answers, especially as the nature of the response is fixed to a particular category of technology.

The next and final *Design Situation* examined how the gap between user research and materials could be bridged by trialling user journey mapping, but this time in combination with bootlegging used in *Design Situation 2*. *Design Situation 4* carried over from *Design Situation 3* the illustration of the layers of design, the concept of expanded textile-product design practice and used the Double Diamond model for orientation. The layers of design were shared with industry participants, who like me found this visualisation of their position revealing, providing a new perspective on their practice. Despite the students desire to "go and see different things in use" (TD-F, group interview), returning to the role of designer in the final situation, I chose not to include making activities in the workshop with industry participants. I did not want materials and technology to dominate. *Design Situation 4* tested the effect of conceptualising E-textiles as Electronic and Textile Systems (ETSs), comprised of both textile and electronic elements but with no requirement for physical integration, allowing greater flexibility and focus on purpose.

7 *Design Situation 4*: 'Design Thinking' Workshop

> *We just would say, OK, here's a seat, or a console with a textile on it, it's good. But we're not telling a story. We're telling a story because of the experience but I thought this, this […] the [user] journey was really cool. I've not seen that before, and that helps you to tell actually…, and think about, how the end user would experience this product during the life cycle, and I found that really useful.*
>
> *(Design Manager, closing discussion)*

The students of *Design Situation 3* were not the only group of participants for whom user journey mapping was an eye-opener. For the industry participants of *Design Situation 4,* the technique was also novel. They could see its benefits respect to their current process, which was described by the Design Manager as more reactive than proactive.

Design Situation 4 closed this investigation, returning to the area of transport interior textiles, the context of *Design Situation 1*[1]. It was formed of two parts. Part one was the 'Design Thinking' workshop held in Germany on 18th July 2019[2]. The workshop addressed the Discover stage of the design process described by the Double Diamond model (Design Council, 2019a). Company Y, the European transport component and textile manufacturer that took part, gave the workshop its name. They were not aware of my interest in a purpose-led process, but their use of the term 'Design Thinking' for the workshop's title aptly describes the HCD orientation of this research. Human-centredness, as Dosi, Rosati and Vignoli's (2018) literature review found, is considered a key element of design thinking. The brief for *Design Situation 4* co-developed with Company Y was:

> *To empower and provide tools for the design & development teams to create innovative smart electronic textile products for future connected, electrified and autonomous transport*[3]*.*

Part two of *Design Situation* 4 was dedicated to the Define stage of the Double Diamond model and resulted in my development of three Electronic and Textile System (ETS) design proposals for transport interiors, based on the outcomes of the workshop. I presented the proposals to Company Y in the form shown in Figure 7-1, which illustrates the Company's selected design. In

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[1] Company Y of *Design Situation 4* is a competitor of Company X of *Design Situation 1*. I am a former employee of Company Y, employed at another of its international locations between 2008 and 2015.

[2] Only one of the participants was a mother-tongue English speaker.

[3] The word product is used because, as Section 1.4 highlighted, for textile designers and manufacturers the textile is the product, or in the case of the workshop the ETS, in the sense that it is the outcome of their design process.

Design Situation 3, I proposed a more open-ended interpretation of E-textiles, which I term ETSs and first discussed in Section 6.4. By offering a more open and flexible interpretation of electronic-textile hybrids, ETSs give greater scope to prioritise purpose. Although ETSs are made up of textile and electronic elements, they require no physical integration unless necessary for a design to serve its purpose. The proposals in *Design Situation 4* examined the effect of this new interpretation. The purpose of each of the ETS design proposals was envisaged within a travel scenario that was developed from the data the participants collaboratively generated.

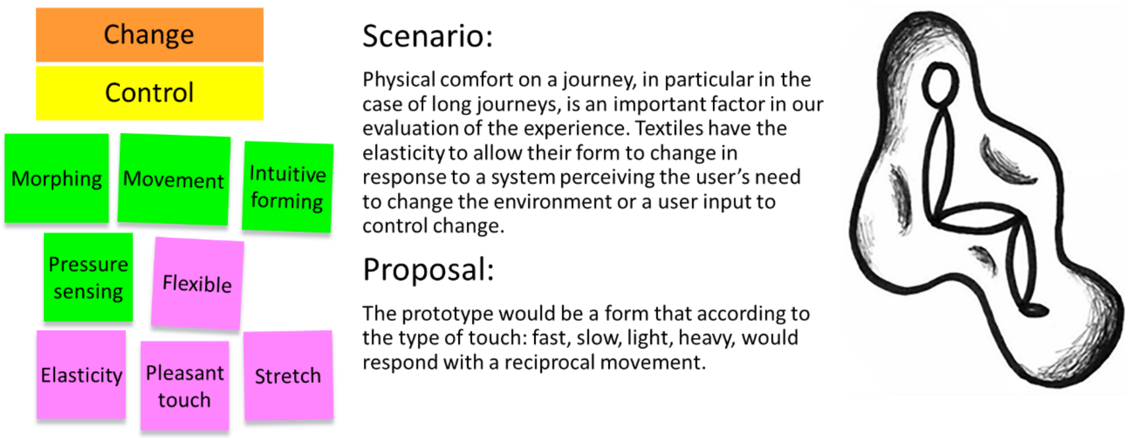


Figure 7-1 Design proposal two: Company Y's preferred design

In *Design Situation 1,* I had struggled to envisage a purpose for the E-textiles I created. In *Situations 2* and *3,* I trialled design strategies to better understand the process by which a textile designer can envisage purposes for E-textiles in interior spaces. These included bootlegging (Holmquist, 2012b), personas (Cooper, 2004) and user journey mapping (Howard, 2014). Observing and reflecting on the actions of other designers, I realised the challenges of using imagined human experiences as a design input where the aim is a purpose-led design process for E-textiles. As the students in *Design Situation 3* experienced, rich contextual data "does not provide straightforward answers to designers" (van der Bijl-Brouwer and Dorst, 2017, p. 5). Returning to the role of designer in this final *Design Situation* allowed me to experience the challenges first-hand, and find strategies to navigate from the data generated during the workshop to design proposals with a purpose.

Equipped with a new approach to textile design, in *Design Situation 4,* I was able to envisage a purpose for the ETS proposals from maps of imagined experiences. Through the workshop and my response to the design data they generated, the participants from Company Y saw a new starting point for the textile design process. As advocated by IDEO (Acumen Academy, 2020) and van der Bijl-Brouwer and Dorst (2017), themes helped me navigate from the journey maps the participants had created to a purpose for ETS in transport interiors. By not including a phase of material exploration in the workshop, the participants focused on people and place rather than materials and technology. *Design Situation 4* put into practice all that I had learnt from the previous *Situations*. It showed the value of HCD techniques, including experience mapping, in allowing textile designers and their industry to envisage and clarify the purpose of emerging textile technologies.

7.1 Contextualising *Design Situation 4*

The brief, co-developed with Company Y, shows textile and interior component manufacturers' desire to adapt to changes arising from the move towards electrified, connected and autonomous modes of transport. As outlined in Section 1.7.3, vehicle interiors are increasingly becoming smart environments. The move towards electric and autonomous vehicles radically changes how interiors can be designed (Stuart, 2015). Where previously the design of vehicles evolved with little in the way of explicit user studies (Norman, 2005), understanding user expectations for vehicle interiors is now a priority for the automotive industry (Nash, 2020; Pettersson and Karlsson, 2015). However, as *Design Situations 1* and *4* both show, textile designers and manufacturers for the automotive industry do not currently have experience gathering design insights from users and envisaging new purposes for their textiles. This thesis argues that with emerging hybrids of electronics and textiles this is a problem.

Design Situation 4 examined the applicability and relevance to the automotive textile industry of the techniques and ideas developed during the previous *Design Situations*. It tested whether these techniques and ideas could be used to purposefully design ETSs in industry. In part one, the Discover stage, the multidisciplinary group of eight participants worked through a series of activities to bring the user into their design process. In part two, the Define stage, I analysed the outputs produced during the workshop to create three design proposals in response. The company reviewed the concepts and selected their preferred idea. Finally, I took initial steps in the Develop stage towards physically realising the chosen proposal. *Design Situation 4* demonstrated a process for designing ETSs for transport interior spaces in which insights about human behaviour and practices, rather than trends or aesthetics, are the starting point.

I created a two-part structure to allow me to remain flexible as to the workshop's endpoint. The starting point was the fuzzy front end, the early stage in the design process where the nature of the deliverable is flexible or unknown (Sanders and Stappers, 2008). Given that the workshop was likely to be the participants' first experience of a design process that takes its inspiration from the user and their limited knowledge of ETSs, I assumed there would not be time to both develop insights about users and define design proposals in one day. I also wished to bring my textile design practice into the *Situation* to trial the process I was developing and to compare it to my experience in *Design Situation 1*. The workshop focused on the Discover stage. Whether it would move into the Define stage, towards a design proposal, was something I could decide in action.

The tendency I encountered and was guilty of in *Design Situation 1* was premature closure of the design process because of fixation on a limited range of design precedents. I was therefore cautious during the workshop of introducing the participants to design precedents either as products or the elements that make up ETSs. To make anything more than the most basic ETS or to uncover interesting features of ETS components through experimentation would not have been workable within the timeframe and with the resources available. Additionally, my experience from the prior *Situations* had led me to question whether exposing participants to underdeveloped ETS elements would assist the goal of fostering a purpose-led design process. If the aim was to focus on people and place to envisage a purpose, materials and technology risked being a distraction.

Although advocates of material driven design (Karana et al., 2015; van Bezooyen, 2013) would promote the inclusion of materials in the Discover stage, I concluded that their presence risked creating design fixation. This would limit engagement with the activities focused on people and place and introduce perceived constraints. At a workshop to envisage applications of smart textiles for teenagers, Ossevoort (2013) found that sharing the latest technologies with the participants appeared to limit their ideas to direct translations of the technology onto favourite items of clothing. For the students in *Design Situation 3,* the gap between their design ideas and the physical realisation of those ideas was problematic and led some groups to pay closer attention to technology than to purpose. The workshop objective was to foster a future orientated, purpose-led process and design ETSs, and would have been at odds with the rudimentary capabilities and crude appearance of many E-textile components. Referring to the ideas of Schön (1992), the presence of materials and examples would have made them part of the situation, therefore conditioning its framing. To focus on people and place, E-textile prototypes or elements were not included in the activities, other than implicitly through the categories: textile quality and electronic function, in the word generation phase of bootlegging.

The future orientated, purpose-led design process that *Design Situation 4* explored was influenced by Auger's (2013) description of speculative design. Speculative design is removed from the "commercial constraints that normally direct the creative process" and not bound by the limitations of existing technology (Auger, 2013, p.32). It involves conjecture about the future, bordering on reality and connecting what is now to what could be next. Although the outcomes of *Design Situation 4* were not intended for public exhibition, as is often the case with speculative design, it was also not tied to commercial constraints. The proposals tested ideas relating to possible purposes for ETS in transport interiors, acting as "cultural litmus paper" (Auger, 2013, p.12) for an industry audience.

In *Design Situation 3*, the students created personas and user journey maps to understand the experience of living in small spaces, but had difficulty connecting their insights to E-textiles. This difficulty highlighted the challenge of translating data about experience into a design for a specific category of technology. The students identified problems for which they could design, but E-textiles did not necessarily provide the solution. As argued in Section 6.5, considering ETS, rather than more narrowly defined E-textiles, gives room to explore a greater range of possibilities. Given the environmental concerns highlighted throughout this thesis, ETSs are also a potential route to more sustainable combinations of electronics and textiles.

7.2 Planning and action

The workshop plan, shown in Figure 7-4, outlined the activities, but was sufficiently flexible that I could respond as events unfolded. For part two of this *Design Situation,* the impossibility of foreseeing how the participants would respond to the workshop activities meant I did not predefine the steps I would take to transform the outcomes of the workshop into a design response. Practitioner activity – to construct, enact, explore or embody – can be the best way to shed light on a question or phenomenon (Archer, 1979). My practitioner-researcher role in the investigation, outlined in Section 3.1, meant my actions, particularly in part two, were part of the data on which I built my interpretation of this *Design Situation*.

7.2.1 Part One: 'Design Thinking' workshop structure

Company Y is a multinational transport textile and interior component manufacturing group. The one-day multidisciplinary workshop was held at one of their European facilities and the eight participants, selected by the company, were from different divisions of the group, as shown in Figure 7-2. All the participants were routinely involved in design and product development on a practical level and half of the group also at a strategic level.

PARTICIPANT ROLE	AREA
Design Manager	All (Background in Textiles)
Electronic Developer	Seating systems
Advanced Engineering Manager	Seating systems
Ergonomics Specialist	Seating systems
Textile Designer	Textiles
Textile Engineer/ R&D Manager	Textiles
Advanced Development Manager	Interior Components
Fibre Optics Engineer	Advanced Textiles

Figure 7-2 Company Y participant list showing their roles and product area

The workshop was designed to move with the participants through the Discover stage of the Double Diamond model to gain insights about user experience that would subsequently serve in the Define stage to create purpose-led ETS design proposals. Figure 7-3 illustrates this relationship between *Design Situation 4* and the Double Diamond model. The workshop and project covered the first three phases[4]. I was unsure whether any of the participants would be familiar with the Double Diamond model, but on the day, it became clear that they were not. Despite its shortcomings discussed in Section 2.2, the argument for using the Double Diamond was that it would orientate the participants and I in the process, and aid their understanding of how the two parts of *Design Situation 4* were related.

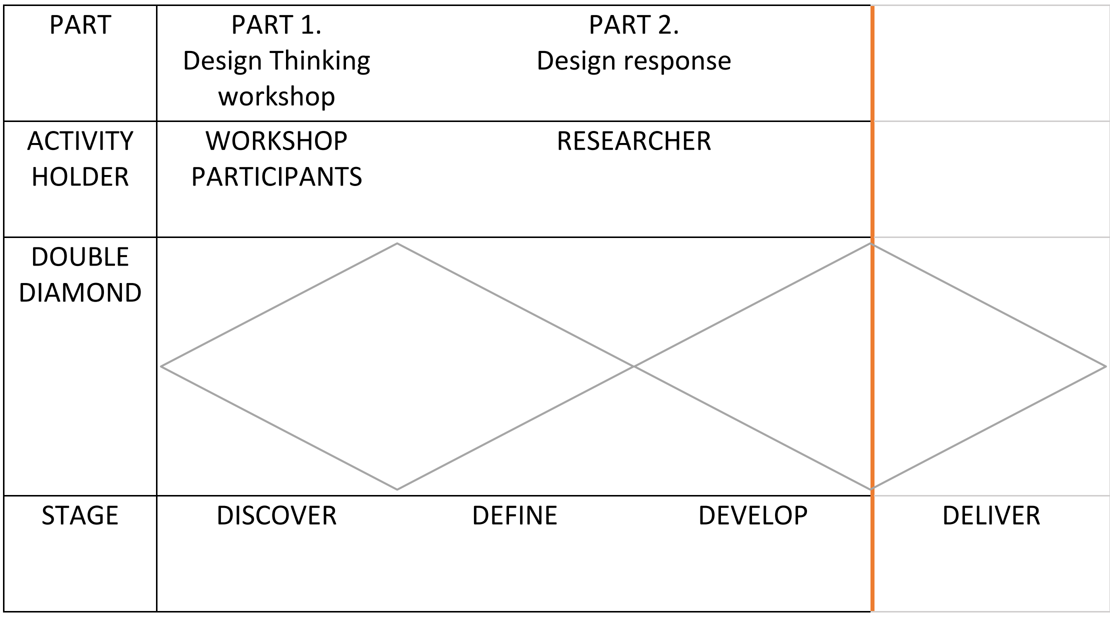


Figure 7-3 Design Situation 4 in relation to Double Diamond design process model.

The workshop was organised in 10 phases shown in Figure 7-4. Phase one, the introduction to which I will shortly describe, set the scene for the subsequent activities. The design techniques I used during the workshop to move through the Discover stage were bootlegging, trialled in *Design Situation 2,* and user journey mapping, employed in *Design Situation 3*. In *Design Situation 2,* the juxtaposition of ideas produced by bootlegging facilitated the teams' creation of E-textile design concepts. However, without a complementary activity to deepen understanding, the teams perceived designing for a specific user as a restriction and opted to design for 'everyone'. Although the teams perceived this choice as making their design more inclusive, this has no relationship with genuine Design for All, Universal or Inclusive Design practices (Section 5.2.1).

In areas such as interaction design and product design, rich depictions of the user called personas have been shown to increase the originality of ideas in brainstorming activities (So and Joo, 2017) and focus attention on people rather than the limitations and opportunities of technology (Miaskiewicz and Kozar, 2011). The combination of personas and user journey mapping employed in *Design Situation 3*, encouraged the students to understand an individual's experience of a small

[4] The Deliver stage was not completed due to Covid-19.

residential space, but they struggled to connect that experience to E-textile design proposals. *Design Situation 4* used a phase of user journey mapping with bootlegging, to connect the experiences mapped with the qualities and functionality of ETSs, by envisaging a purpose.

Workshop phase	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Phase description	Introduction	Design process	Group discussion	Bootlegging: word generation	Mixing	User journey mapping	Group discussion	Combining user journey maps and bootlegging Words	Group discussion	Conclusion and Presentation of NTU research
Approx. duration in mins	30	30	30	30	10	60	20	60	30	30
		Individual	All	All	All	2 Teams	All	2 Teams	All	
Data										

Figure 7-4 Workshop structure showing the 10 phases

7.2.2 Workshop introduction

Eason (2012) lists the key motivators of automotive textile innovation as changes to safety or environmental standards, customer performance specifications and the arrival of new materials and technology. The user is notably absent from this list, so to broaden the participants' notion of innovation, the introduction presented Verganti's (2009) categories of technology and meaning change, incremental and radical innovation. The workshop proposed the user as a source of inspiration and the idea of changes of meaning as an additional form of innovation.

In B2B development, the goals or needs to which each layer of design responds flow downwards from the design of the overall system (Wieringa, 2010). The participants of *Design Situation 4* confirmed that they were not accustomed with directly considering the experience of the user, other than through ergonomic factors, specifically seat structures suitable for an archetypal human body. Physical and cognitive ergonomic factors come in to play after a purpose has been defined. They relate to basic human physical and mental capabilities and limitations (Giacomin, 2014), rather than a broader appreciation of human experience. I presented the diagram shown in Figure 7-5 to the participants to highlight their position in the layers of design, which in the automotive industry are called tiers. The diagram illustrated to the participants that textile manufacturers are distanced from the user by two layers of design, the seat assembler and the vehicle manufacturer, known as the OEM.

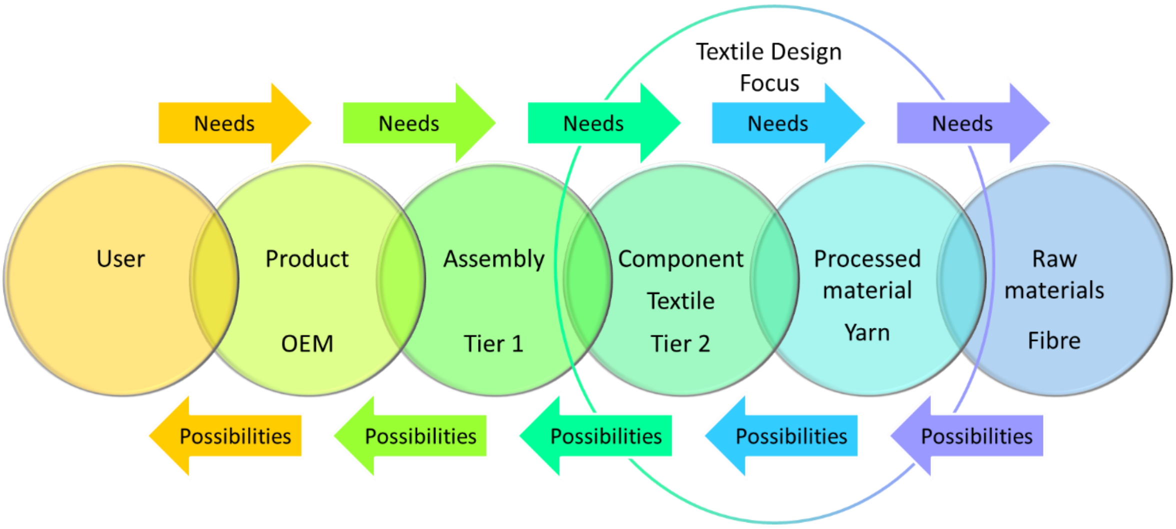


Figure 7-5 Transport textile layers of design

I also showed the group a video fly-through of the International Space Station's (ISS) interior (NASA, 2016). This was to take them mentally outside of their day-to-day professional and personal engagement with transport, to a place where it would be easier to imagine future scenarios. The technology in the interior of the ISS, unlike that of everyday forms of transport, is on display, as it was in early vehicles (Moser, 2003). As technology evolves its mechanisms become increasingly invisible. By showing how vehicle interiors have changed and comparing them with the current design of interiors for space flight, I was encouraging the participants to extrapolate and imagine future forms of transport and their interiors.

Figure 7-6 Still from Space Station fisheye fly-through (NASA, 2016)

I introduced to the concept of 'provotypes' to allow greater freedom in the subsequent phase of this *Design Situation*. Provotypes are prototypes designed to provoke insights about a scenario (ten Bhömer, 2016) and allow more freedom for speculation about the potential of ETS technology. Additionally, the introduction presented the idea that early prototypes can use analogous technologies such as those trialled in the LTM project (Barati, Karana and Foole, 2017), instead of the direct material sampling more common to textile design. In conventional textile design, when a designer wants to experiment with a new yarn or process, often they can do so in a manner closely related to how the fabric would be produced on an industrial scale. The reason for introducing provotypes and analogous technologies was to broaden the group's idea of what the outcome of the design process could be.

7.2.3 Workshop: The design process

In the first activity, I asked the participants to sketch and then verbally describe their design process, showing its inputs and outputs. For all but one participant, the process they sketched was not based on a formal model. They were personal and context specific representations. The exception came from the Electronic Engineer in the group, who described working according to the V-model of development of the Association of German Engineers - VDI/VDE 2206 (Pahl et al., 2007) (Appendix D1-H). As noted by Gericke and Blessing (2011), although different design processes may display similarity at an abstract level, the detail of the participants' sketches highlights the differences. The depictions also varied across disciplines and, as illustrated by the two streams in the Advanced Development Manager's sketch, whether the process was for an advanced development or aimed at series production (Appendix D1-F).

Six of the eight participants omitted the user when describing their source of inspiration and process. As Figure 7-5 of the layers of design illustrates, businesses like Company Y, who make components for complex systems, are separated from the user by several layers of design. One exception was the Ergonomics Specialist. The user figured centrally in her process sketch, but as described above, the focus was on the human body in relation to transport seating and the effects of long-term sitting (Appendix D1-D). It was not on an overall user experience or envisaging future experiences. The Design Manager's characterisation of the starting point of his process was as relating to "experience" (Appendix D1-C). He considered "what is happening around the world" as a source of inspiration which suggests cultural and political as well as technical references. Although he did not specifically refer to the user, his consideration of experience suggests a HCD orientation.

Both the Textile Designer (Appendix D1-E) and Textile Engineer (Appendix D1-G) acknowledged the role of "trial and error" in their process, but only the Textile Designer in the group explicitly recognized the role of tacit and embodied knowledge in her process. She placed "Me and My Eyes" at the centre and listed her education, experience with different media and design history, alongside visual references such as websites and magazines, as sources of inspiration. The Textile Engineer stated that knowledge of materials and experience can have a negative role in the generation of ideas by “blocking creativity!” (Figure 7-7). This notion supports my decision not to use ETS elements in the workshop. That knowledge can be a hindrance fits with recommendations that designers should cultivate ‘beginner’s mindset’, remaining curious, empathetic and open to possibilities (Dosi, Rosati and Vignoli, 2018; Acumen Academy, 2020).

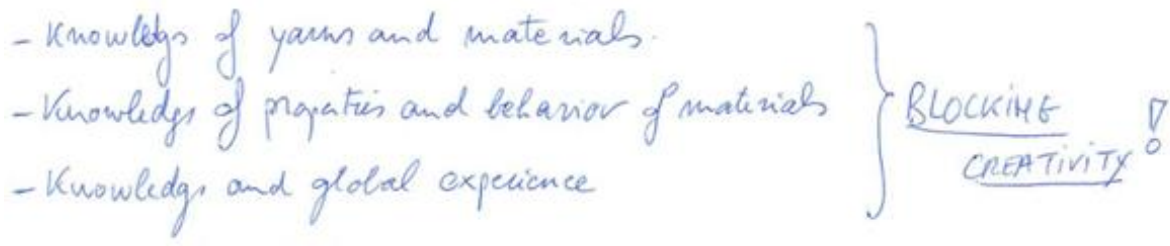


Figure 7-7 Detail from the Textile Engineer's design process outline

7.2.4 Workshop: Bootlegging and user journey mapping

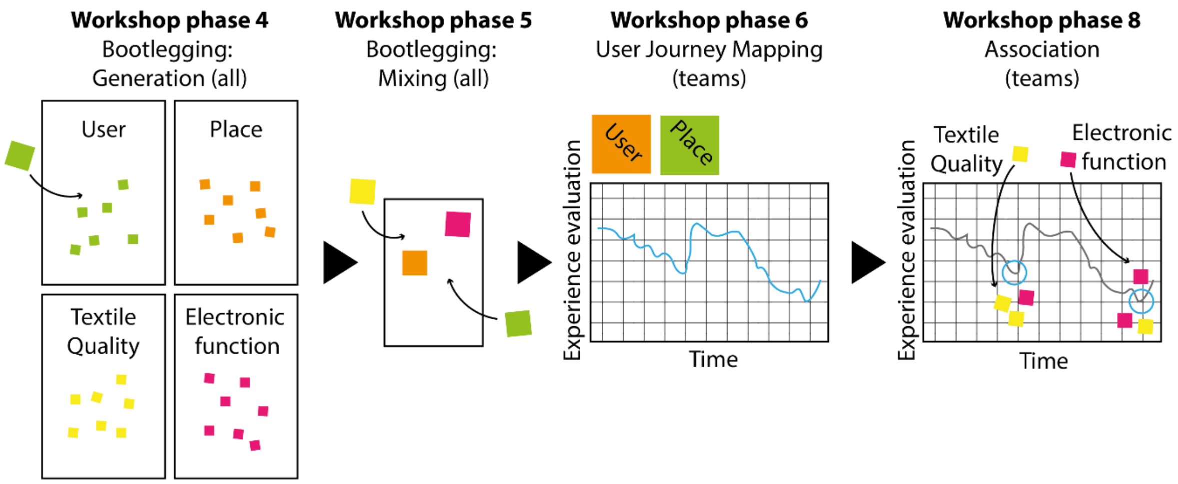


Figure 7-8 Workshop phases involving bootlegging and user journey mapping

Figure 7-8 shows the steps of combined bootlegging and user journey mapping. They carried phase four out as described in Chapter 5, the participants generating ideas for each of the four categories: user, place/setting, textile quality and electronic function. Figure 7-9 shows a still of the group engaged in the activity. I adapted the categories from *Design Situation 2*, this time, instead of the ‘Place’ being a public interior space, I invited the participants to think of a place or setting related to transport, such as a long-distance commute in 2050. Instead of E-textile functions, the activity required them to think more generally of electronic functions, both to anticipate future ETS functionality and to prevent prematurely envisaging functions they considered related to textiles. They were also asked to think of a 'User' rather than a 'User Group' to focus on an individual.

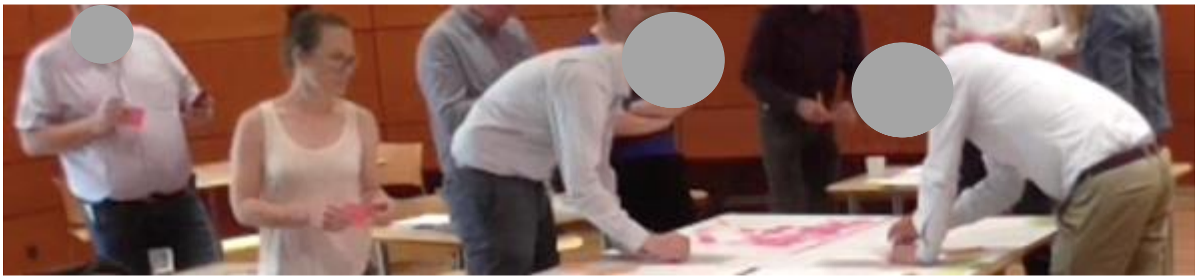


Figure 7-9 Group during word generation phase of bootlegging

After they had generated as many words as they could think of, I asked the participants in phase five to create scenarios by choosing one word from each of the four categories. Once each participant had created several scenarios, I split the group into two teams, the make-up of which is shown in Figure 7-10. Once in the two teams, I asked them to select two or three scenarios from those assembled combining user and place, and to create user journey maps for those scenarios. Including a textile quality and electronic function during phase five only caused confusion during the journey mapping activity in phase 6 because those elements were not required for the activity.

Participant Role	**Area**	**Team Phase 6**	**Team Phase 8**
Design Manager	All (Background in Textiles)	A	B
Electronic Developer	Seating Systems	A	B
Advanced Engineering Manager	Seating Systems	A	A*
Ergonomics Specialist	Seating Systems	A	A*
Textile Designer	Textiles	B*	A*
Textile Engineer/ R&D Manager	Textiles	B*	A*
Advanced Development Manager	Interior Components	B*	B
Fibre Optics Engineer	Advanced Textiles	B*	B

Figure 7-10 Workshop teams for phases six and eight

User journey mapping was new to all the participants and therefore the start was hesitant, I was with Team B, as indicated by an asterisk Figure 7-10. In Team A there was some hesitation, the Electronic Engineer did not understand the task until the Design Manager clarified it for him. Despite the initial uncertainty, the teams went on to create a series of user journey maps that imagined people in a diverse range of transport scenarios, and the Electronic Engineer became an active and engaged participant in the process. The maps created are briefly described in Figure 7-11.

Team:	User journey mapped
A	A non-technology savvy, retired person using an autonomous ride sharing service
	A doctor running a mobile clinic
	A parent and child(ren) using a travel pod to go to a leisure activity
B	A lone driver on a long-distance journey
	A group of university students using a large collective vehicle to take a 1-hour city tour

Figure 7-11 Description of user journey maps created by each team in phase 6

There were slight differences in the groups' approach to finding a scenario for which to create a map. Team A went through each member's scenarios and chose the ones they would explore in several steps, sticking closely to each scenario's original configuration. The scenarios for which they created a user journey map were an autonomous vehicle sharing experience for a non-technical pensioner (Figure 7-12), a mobile health clinic from the perspective of a doctor, and a parent and child(ren) journey to and from a leisure activity from the perspective of the parent.

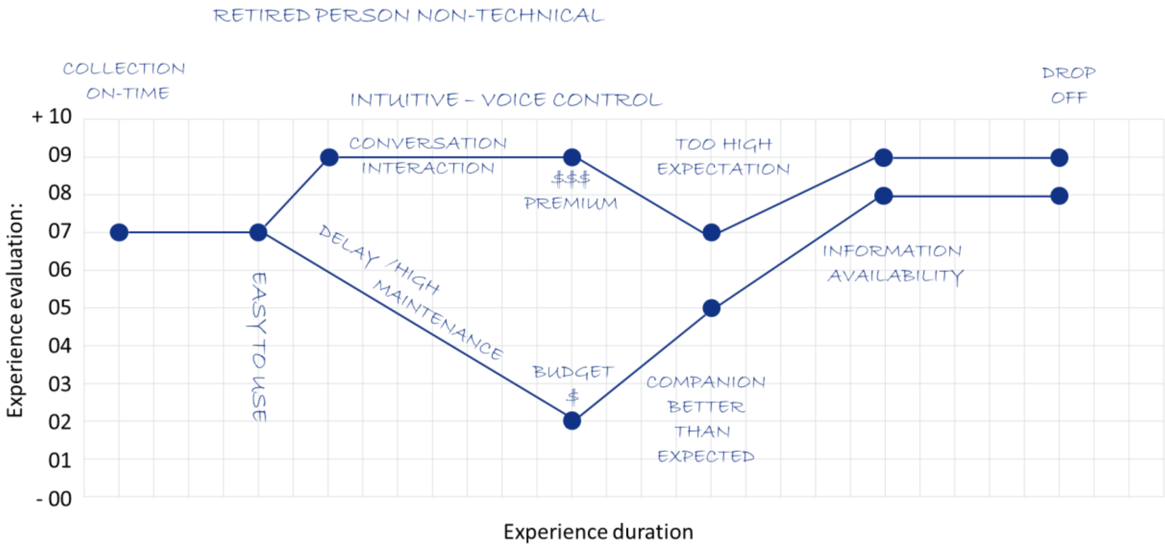


Figure 7-12 Team A: User journey map illustrating a non-technical retired person's experience of either a premium or budget autonomously driven transport service, redrawn for readability

The non-technical retired person journey experience, illustrated in Figure 7-12, diverges at the point the group considered a budget and premium option for the service, like a branching storyline. In the budget option, the user had no control over their travel companion, resulting in a fall in the experience rating once they were in proximity of a stranger. By contrast, the premium option allowed the user to choose with whom they shared the experience. The group assumed this would result in a more positive evaluation. They imagined the downturn in the higher experience evaluation of the premium service to be because the user discovered their chosen companion was less pleasant company than expected. The upturn in the lower experience evaluation marked the user realising their travel companion was pleasant company, resulting by the end of the journey in a similar experience evaluation for the premium and budget options. By painting a broad contextual picture and considering multiple users, Team A's maps depicted in less detail the relationship between the interior and the user experience than Team B's. The major influence on the experiences was interaction with other passengers.

Team B created two user journey maps, one was a lone driver's long-distance journey, shown in Figure 7-13. Differing in duration and level of human interaction, a short city tour by a group of university students was the second journey the group mapped[5]. Team B imagined one aggregate experience rather than the divergent narratives created by Team A. The Textile Engineer's recognition as they reviewed each participant's scenarios, that "in four cases we have only a single person", shows the start of how Team B aggregated each member's input to form one experience line. The map illustrated in Figure 7-13 of a solo long-distance journey depicted an ever-declining experience as fatigue and boredom set-in. The steady decline was mitigated by moments of change: in posture, music, taking a break or other interruptions to the monotony of driving such as pleasant scenery. The experience had a final up-tick near arrival at the destination.

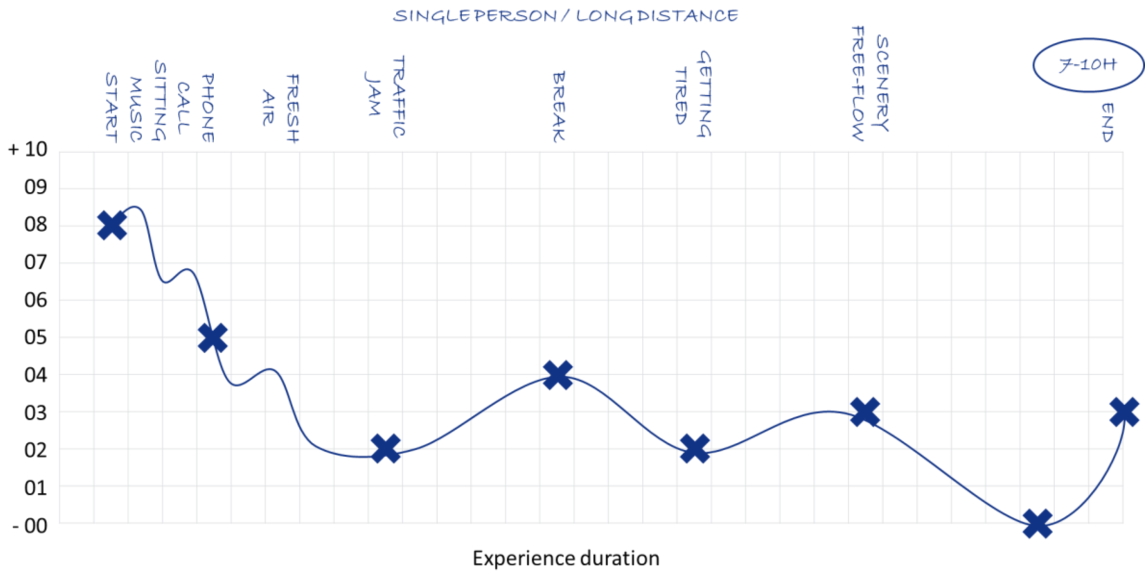


Figure 7-13 Team B: User journey map of a long-distance solo travel experience, redrawn digitally for readability

To construct the maps, both teams reflected on their own experiences and projected themselves empathetically into the experience of their imagined user. The excerpt below illustrates reflection on a pensioner's experience of an autonomous ride share service.

---

[5] My presence in Team B at the start of phase 6, despite aiming to allow the participants to direct the activity, undoubtably influenced their direction.

> *If I was a retired person and something came to collect me, I'd be really happy that it's come to collect me, but also a bit sad because I can't get there myself.*
>
> *(Design Manager - Team A: phase six)*

Although Team A sometimes referred to existing modes of transport while they constructed their maps, they frequently used more ambiguous terms. They described the retired person's autonomous mode of transport as a "mover", the doctor was in a "mobile clinic", rather than an ambulance and the parent and child(ren) were in a "pod". This suggests the introduction had primed them to think of future travel settings, and suggests more ambiguous terms leave more space for imagination. By contrast, Team B referred to current forms of transport, namely a car and a bus. Particularly in the case of the solo long-distance journey, their choice of a contemporary setting, that all four team members had experienced the previous day when travelling to the workshop location, meant the group built the scenario out of their own experiences.

> *(Team B: phase six)*
>
> *Fibre Optics Engineer: Even without any traffic when I start driving it's always like I have to get used to my car environment. At the beginning, first 20 or 30 minutes it's no problem…*
>
> *Textile Designer: Yeah.*
>
> *Fibre Optics Engineer: I think it's kind of exciting driving, listening to the radio, but…*
>
> *Textile Engineer: Yeah.*
>
> *Fibre Optics Engineer: After 30 minutes there's a certain point where it gets boring.*
>
> *Textile Designer: yeah, it gets boring.*
>
> *Fibre Optics Engineer: It gets exhausting.*

This excerpt raises the question, where is the line drawn between HCD and design driven processes, discussed in Chapter 2. The participants could be considered the users in my design process or designers in their own. In design literature using yourself as the target of the process is generally frowned upon (Norman, 2005), but some are more willing to acknowledge and advocate such approaches, including proponents of autobiographical design (Neustaedter, Judge and Sengers, 2015) and design driven innovation (Norman and Verganti, 2014). For the participants, who were unfamiliar with HCD processes, being able to reflect on their own experience was a way in to the approach and could be extended to involve other users at a later stage.

Phase eight, the final generative activity of the workshop, was to associate words relating to 'textile quality' and 'electronic function' to the experiences mapped[6]. Its aim was to start the process of envisaging purposes by connecting the experiences identified in the user journey maps to ETSs. Team A generated a series of notes, shown in Figure 7-14, as had Team 1 in the idea generation phase of *Design Situation 2*. The notes show the group were also considering aspects of the experience that did not relate to the vehicle interior, such as whether the mover for the non-technical retiree would be summoned via an app or a command button.

Figure 7-14 Team A: phase eight notes on textile quality and electronic function associations for a non-technical retired person's experience of an autonomously driving transport service, redrawn digitally for readability

Team B took a different approach. As they talked about the user journey maps, they discussed the possible textile qualities and electronic functions that could have a purpose in the experience and stuck the relevant sticky note on the maps. Figure 7-13 shows the solo long-distance map before they had affixed the associations and Figure 7-15 shows the result at the end of the activity.

[6] After explaining the activity, I joined Team A, trusting that the Group Design Manager would lead Team B and open to seeing what would happen without my involvement. The layout of the workshop space meant that Team B could call on me if necessary.

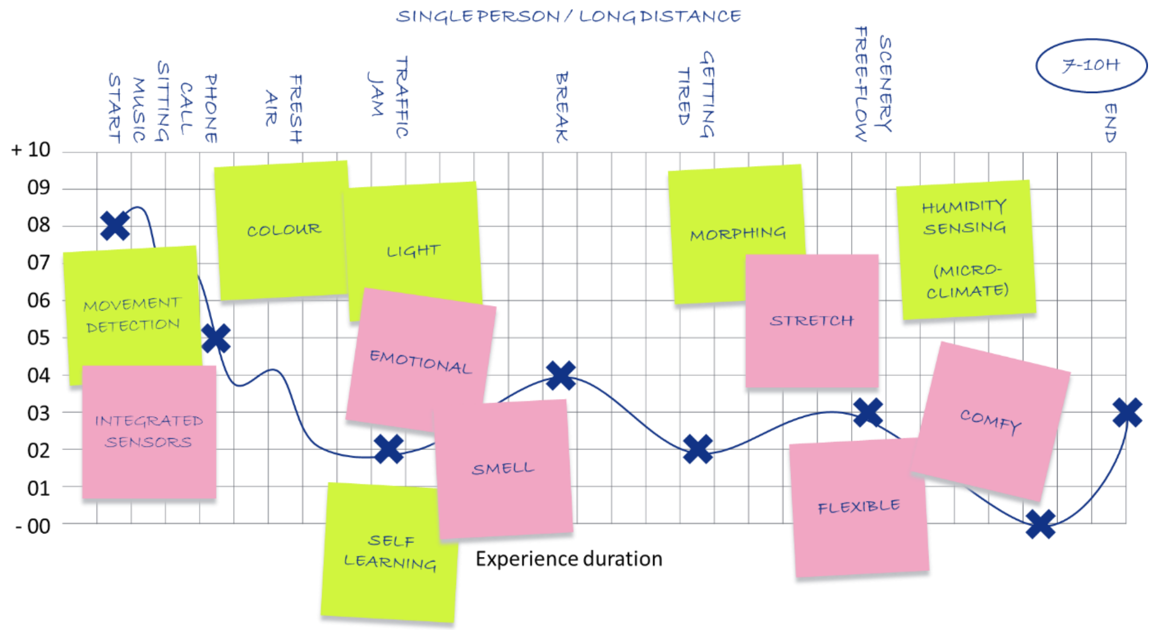


Figure 7-15 Team B: phase eight outcome with textile qualities and electronic functions affixed to the map of a long-distance solo journey, redrawn digitally for readability

The influence subtle changes can have on a solo long-distance journey came to light during the creation of the journey map shown in Figure 7-13. I had found this idea interesting and had mentioned it to the teams during the phase seven discussion. When associating textile qualities and electronic functions with the journey, Team B chose the electronic function "morphing" and the textile qualities "flexibility" and "stretch". These would allow the vehicle interior to change according to the external environment, as described in the excerpt below by the Design Manager. The group discussed that any morphing ability of the interior should be designed such that it would support driving and not cause disturbance. The purpose of the interior's morphing ability was to reduce the boredom and physical discomfort caused by long-term sitting by introducing changes and adapt the interior to best suit the external environment for safety and driver alertness.

> *On the physical areas, as you can see here, we have certain things like this morphing…. If you are on the motorway or you're in the city, because you have a different environment, you need a different experience. And that means the textile has to be flexible to stretch into different things.*
>
> *(Design Manger, group discussion - phase nine)*

In phase eight, both teams also discussed ideas that did *not* relate to ETSs, as had the students in *Design Situation 3*. One of the electronic functions Team B selected as relevant for a solo long-distance journey was humidity sensing, visible at the top right in Figure 7-15. They imagined a transport interior that would sense the interior's microclimate to increase occupant comfort. However, they went on to discuss how the ability of wool to absorb moisture could be used for passive climate management and how its natural antibacterial properties would aid odour management, foregrounding a conventional textile solution.

Team A also provided an equivalent non-ETS example for electronic functions. Team A talked about various non-ETS design elements when discussing the retired person's experience of an autonomously driven transport service and the doctor's experience running a mobile clinic. The examples included how to design the request system for usability and the role of voice control and heads-up display systems. Design often does *not* start with a technology. The more common starting point is a 'problem' as stated in Section 2.1. That multiple participants in *Situations 3* and *4* have envisaged designs that do not relate to ETSs demonstrates the challenge facing designers in a technology bound design process, as the technology may not address the most obvious or pressing problems. Despite this challenge, by the end of the workshop, ideas that would inform the design proposals had begun to emerge but required reviewing and refining.

7.2.5 Part Two: Design Response

The second part of this *Design Situation* was for me to continue the design work from the point the workshop ended. I used the bootlegging word clouds and scenarios, user journey maps and initial design ideas as inputs to understand a purpose with which to lead my creation of the ETS design proposals. As described, the workshop was primarily aimed at addressing the Discover stage of the Double Diamond model. Following the workshop, the next part of *Design Situation 4* was to use the outcomes generated by the participants for the Define stage, the objective being to design a series of ETS proposals that I would present to Company Y for their feedback. The proposals could be speculative responses, much like provotypes or concept cars, designed to test an idea, rather than designs that could go into production. There was also the potential that one idea might be physically realised such that it could be shared with Company Y and their customers.

What will become apparent reading the following section is that my approach to the creation of the design proposals, like the participants in *Design Situation 2,* was not to focus on an individual user. I aggregated information from all the maps and identified themes that occurred in multiple scenarios to create design proposals. I navigated from the data collected during the workshop, through a package of analysis, to a series of ETS proposals which were presented to Company Y in a summary document.

During the workshop I had noticed themes that appeared across multiple user journey maps. The first step in the second part of *Design Situation 4* was for me to check and then build on these initial thoughts. This involved transcribing and/or summarising the recordings of the various phases, identifying and categorising segments relevant to possible purposes for ETS and reducing the volume of data by creating graphical representations. Figure 7-16 places the user journey maps by type along three axes showing: journey length, number of passengers and whether the journey was work or leisure related. The edges of the diagram represent the extremes, while symbols placed close to the centre show travel scenarios belonging less distinctly to either category. For example, the doctor in the mobile clinic could be alone or in the company of a patient. The reason for categorising the journeys was to look for correlation in the experiences described across different travel scenarios.

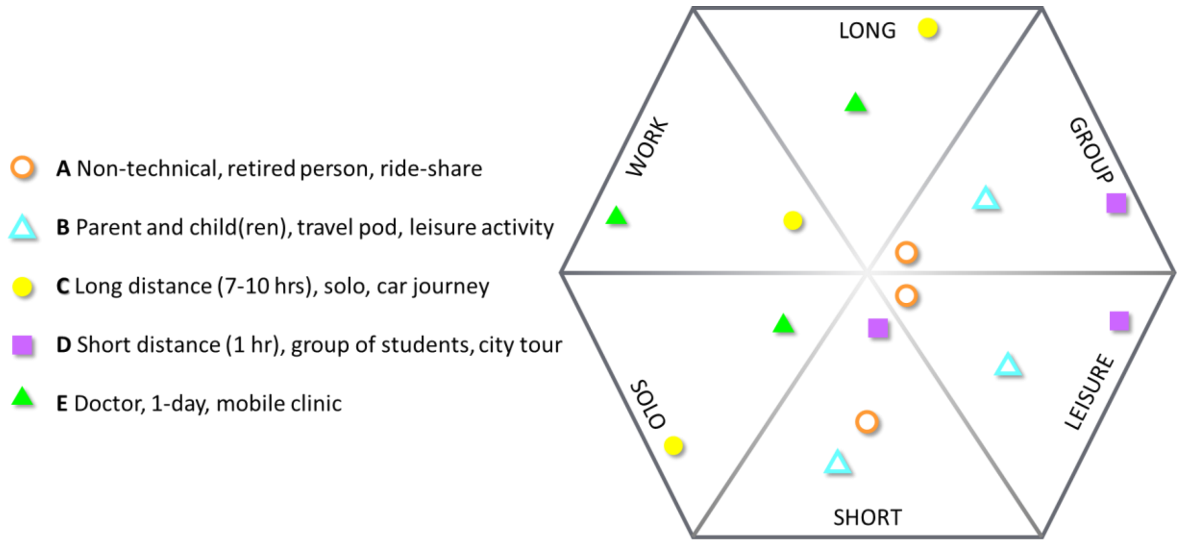


Figure 7-16 User journey mapping: Category analysis

To understand positive and negative influences on the experience of travelling, I picked out the factors discussed by the participants and present in the user journey maps. Figure 7-17 shows these factors roughly placed according to whether the participants evaluated them to be high or low points in the experience. They were placed centrally if their evaluation varied depending on the circumstance. I also differentiated between factors that I perceived as influenced by the interior of the means of transport, coloured black, and those in which the interior had no role, coloured purple. For example, the participants discussed free-flowing traffic as part of a positive transport experience, but a vehicle's interior has no influence on this aspect of travelling. It cannot make traffic flow more freely.

Figure 7-17Aggregation of influences on the user journeys

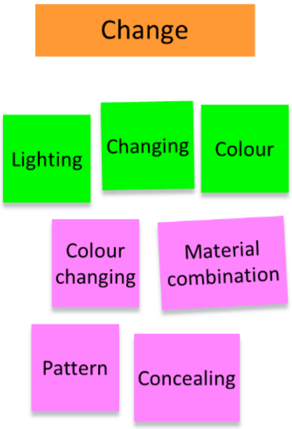
To move from the experience maps and word clouds created in the workshop to a design proposal, I went through several steps. My approach to what I will call the 'design data' had similarities with the thematic coding process: familiarizing yourself with the data, generating initial codes and then searching for themes (Braun and Clarke, 2006). The strategy of identifying themes is advocated to advance the strategic impact of HCD (van der Bijl-Brouwer and Dorst, 2017; Acumen Academy, 2020; Dorst and Stolterman, 2015). Here I explored the strategy for its potential when designing for a pre-defined category of designed material system. Looking at the factors I had extracted and considering the user journey discussions, I identified four themes: Change, Interaction, Control and Information, shown in Figure 7-18. These themes were the first stage, created to connect the design proposals to a purpose.

CHANGE	INTERACTION	CONTROL	INFORMATION
• Speed • Sound • Smell • Acoustic • Light • Colour • Stimulation • Posture • Scenery	• Human-Machine ○ Unconscious ○ Conscious • Human-Human ○ Privacy ○ Division of space ○ Sharing space ○ Facilitation	• Touch • Voice • Wi-Fi • Charging (wireless)	• Visual • Acoustic • Haptic ○ Destination ○ Journey ○ Outside world (friends, family, etc.)
INSIGHT			
Change in the interior environment during a long journey can reduce boredom and fatigue.	Ride sharing and autonomous vehicles present new opportunities to facilitate, or the need to manage, interaction with other passengers.	Individual control over the environment and of interaction can reduce stress in shared transport spaces.	Information about the journey, the destination and the outside world can reduce stress and boredom when travelling.

Figure 7-18 User journey mapping: Themes and insight statements

I connected the themes to what IDEO might class ‘insight statements’ (Acumen Academy, 2020), such as ‘change in the environment during a long journey can reduce boredom and fatigue’. I then developed the insights into scenarios that related the proposals to a context and purpose. The insights came from the participants’ journey maps, but research supports assumptions the participants made. For example, information can reduce perceived journey time (Machado, José and Moreira, 2012) and the ability to control our environment can reduce our “biological and subjective stress response” (Bollini *et al.*, 2004, p. 245).

The next step was to link the themes and insights shown in Figure 7-18 to the textile qualities and electronic functions that the participants generated in phase four of the workshop. I did this by grouping the words from the two categories around a theme. In this order, my selection of material and technology was dependent on the purpose for which I was designing. The last step was to create a composite as the basis for each of the three proposals. This meant gathering a limited selection of the electronic functions and textile qualities associated with a theme and linking these, via an insight statement, to a travel scenario in which an ETS could have a purpose. Finally, each proposal had a written description and accompanying illustration. The three proposals are depicted in Figure 7-19, Figure 7-20 and Figure 7-21. Designing an ETS rather than having to consider how electronics could be integrated into the fabric gave me far greater freedom and scope to explore ideas.



Scenario:

Change improves the experience of long-distance travel by helping to prevent tiredness and boredom. Vehicles have increasingly adaptive lighting able to illuminate the vehicle interior in different ways according to the driving settings i.e. red for sports mode. Using metameric properties textile designs could have visible or invisible patterns according to the lighting. These patterns could be used as a safety feature or to enhance the mood created by the interior and lighting.

Proposal:

The prototype would consist of patterned textiles and a light source able to produce different colours of light. The patterns of the textiles would change according to the colour of the light.

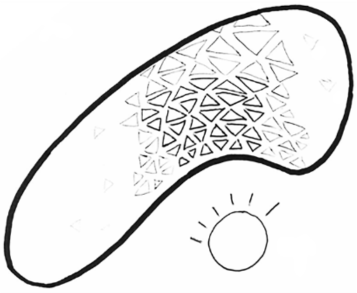
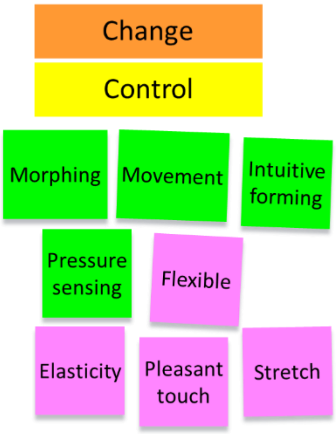


Figure 7-19 Design proposal one



Scenario:

Physical comfort on a journey, in particular in the case of long journeys, is an important factor in our evaluation of the experience. Textiles have the elasticity to allow their form to change in response to a system perceiving the user's need to change the environment or a user input to control change.

Proposal:

The prototype would be a form that according to the type of touch: fast, slow, light, heavy, would respond with a reciprocal movement.

Figure 7-20 Design proposal two: Company Y's preferred proposal

Scenario:

In situations where a transport interior is shared with one or more people, the interaction between the occupants of the space can enhance or undermine a person's experience. Interiors can be designed to facilitate interaction or to allow occupants to manage their desired level of interaction. Textiles can be used to create adaptive interiors because they are lightweight and flexible. They can be draped and folded, stretched and held as tensile structures. The connections of textiles at specific point could act as switches to activate functions such as noise cancelling, lighting or music.

Proposal:

The prototype would be a sculptural object where the textiles could be moved and connected to produce different forms and functions.

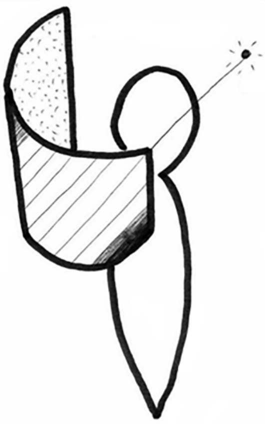


Figure 7-21 Design proposal three

I shared the analysis of the workshop's outcomes and the proposals with Company Y to gain their feedback. In a telephone conversation after receiving the analysis document, Company Y's Design Manager and Engineering Manager expressed their interest in proposals one and two. They saw proposal one as something the company could continue to develop as part of an existing joint venture. However, to realise the idea, they wanted to use woven fibre optics, often considered an E-textile technology. Realised in this manner, the proposal would have a closer level of integration between the electronics and textile than I had envisaged. They had not understood proposal three as the dynamic and interactive idea I had intended and so had discounted it. They selected proposal two, a touch responsive morphing ETS. Transport textile manufacturers put on shows for their customers either as pop-up exhibitions or at trade fairs, much in the way automotive manufacturers present concept cars at motor shows. They explained their desire to move away from displaying what they produce as 'textile wallpaper', to creating flagship objects which embody a concept. The company saw proposal two as something that could fit this aim.

7.2.6 Making

Once the company had made their selection, I explored how proposal two might be transformed from an idea into a physical object. The decision to design an ETS – defined as a functioning whole composed of electronic and textile elements without requirements for any level of integration – remained important while I investigated how proposal two could be realised.

Discussed in Section 2.4, developing ETSs inherently draws on multiple disciplines. I called upon others with expertise in electronics, interaction design and architecture to discuss how to create, as defined by proposal two, an ETS able to sense and interpret a person's touch to produce a morphing response. The purpose behind the proposal was to lessen the boredom and discomfort of long-distance travel and the speculative ETS prototype would allude to a morphing vehicle interior able to fulfil this purpose. There were various means by which such the ETS could be constructed, including pneumatic bladders, tensioning springs or magnets and springs in a deconstructed solenoid[7]. I also met with an architect involved in designing the award-winning inflatable Lille Museum of Modern Art pavilion (2hD Architecture Workshop, n.d.). Inspired by MIT's aeroMorph project (Ou et al., 2016), the inflatable embroidered actuators developed at Eindhoven University of Technology (Goveia da Rocha et al., 2019) and conversation with Company Y's Advanced Engineering Manager, I deemed inflatable structures the most appropriate means to achieve the design's purpose. Air chambers are already used in some seat

[7] Solenoids are coils of conductive wire which "can create a magnetic field from electric current and this magnetic field can be used to generate a linear motion" (Kumar, 2019).

constructions. For Company Y using this solution represented an extension of existing manufacturing expertise.

To make *Design Proposal 2* using an inflatable structure required a textile that could stretch or move, a chamber able to hold and release air, an air pump to fill the chamber, sensors to detect touch and processing capacity to translate the sensing data into a command to pump air into or release air from the chamber. I trialled different textiles to see whether I could use them as the air chamber instead of polyurethane (PU), which is currently used for vehicle air bladders, or the tightly woven coated nylon fabric used for inflatable architecture. The various textiles I trialled were too air permeable, making them impossible to inflate using a small air pump. I concluded that the best option would be to use the textile as an outer layer covering an impervious bladder of PU or similar. By not requiring the textile to be airtight the possibilities for the textile's design expanded. It could use shrink structures that would expand and contract and be semi reflective to enhance the visual effect of movement.

I also experimented, as shown in Figure 7-22, using a conductive textile as the sensing element in the system. This initial test indicated it was possible, but further work would have been required to understand whether it would function within the design of the system or whether an alternative sensor element would be more reliable, accurate or durable.

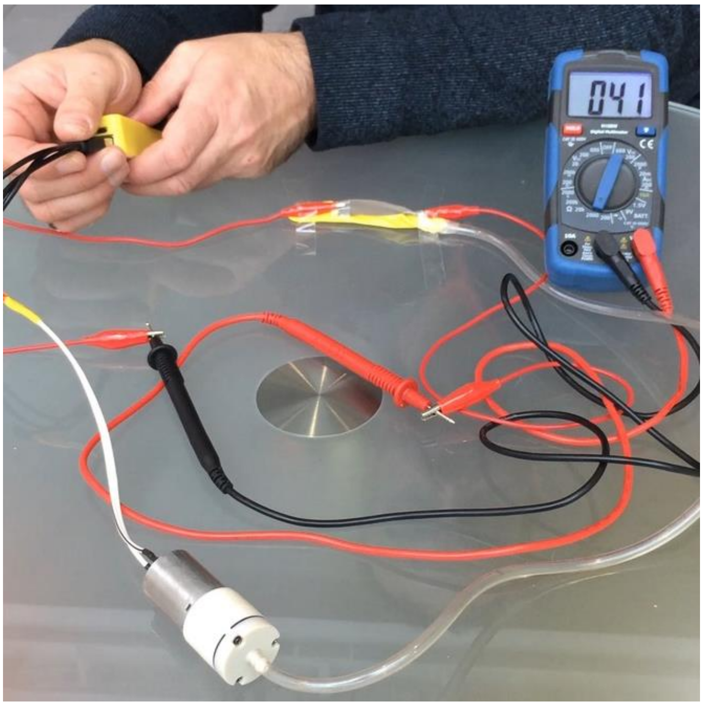


Figure 7-22 Testing a conductive stretch textile as the sensing element together with an inflatable component and air pump for Design Proposal 2

Because of Covid-19, and in agreement with Company Y, I did not complete *Design Proposal 2*. Its partial realisation, however, allowed me to continue the purpose-led design process into the Develop stage. It illustrated that designing an ETS, rather than an E-textile, gave greater freedom to lead the design by purpose.

7.3 Reflection

The various divisions of Company Y all make a product that is a component within a means of transport. They are removed from the user by several layers of design. The participants' sketches of their personal design process confirmed my assumption, based on professional practice prior to beginning this investigation and during *Design Situation 1*, that user experience was not a standard source of inspiration. Through the workshop, the participants gained a new awareness and appreciation of the user as a source of inspiration, offering an alternative to reacting to requests filtered through the layers of design.

7.3.1 Part One

The combination of the two techniques employed during the workshop could be further refined. On reflection, including textile qualities and electronic function in phase five was misleading and caused confusion[8]. If the workshop were repeated, phase five would only require a user and a place/setting to be selected in the mixing phase. However, I still believe it is beneficial to generate words relating to material qualities and electronic functions prior to creating the user journey maps. This is so participants are not producing words to fit ideas formed while creating the maps. If the focus is on envisaging a purpose, the textile qualities and electronic functions should only be associated with the user and context after the journey maps have been created.

Breaking up the bootlegging process by inserting user journey mapping was an effective way to bring deeper consideration of how people experience interior spaces. In *Design Situation 2,* where user journey mapping was not used, the participants had no framework to develop ideas relating to how an interior space might be experienced and instead opted superficially to design for 'everyone', which risked resulting in design that was far from inclusive. User journey mapping gave the participants in *Design Situation 4* the opportunity to reflect on how individuals might experience different transport settings. Team 1 considered how different individuals might experience the same interior space and the variables that could change an individual's experience of that space. The teams drew on personal experience, as well as imagining and empathising with

[8] Phase five of the workshop, which was the mixing step of the bootlegging process, required that the participants select one sticky note from each of the four categories to create a scenario.

experiences of which they had limited first-hand knowledge, such as that of a doctor running a mobile clinic.

In the closing discussion, the group suggested that those who know a context intimately may not be best placed to generate radical innovation. Schön (1983, p.61) argued that as a practice becomes increasingly routine and spontaneous, practitioners risk becoming inattentive and narrow in their thinking, a phenomenon termed ‘overlearning’. For Schön (ibid.) reflection in and on action to appreciate the “uncertainty and uniqueness” of situations was how it could be overcome. The participants felt that the perceptual shift brought about by considering contexts outside their core business area facilitated their generation of ideas. For example, the user journey of the doctor took the participants into the unfamiliar domain of ambulance and healthcare design. For the participants the doctor represented a form of ‘extreme user’, a user with characteristics and requirements beyond convention (Holmquist, 2012b; Pullin and Newell, 2007). Considering the needs of such users is a means to provoke new thinking and challenge convention, also when developing ‘universal’ products designed to be used by many (Pullin and Newell, 2007). As shown in the quotes below, the participants felt that their lack of knowledge was an advantage.

> *I think if we had talked about our core business areas we would have gone into more things which we already know, and by looking at an ambulance, it’s something we don’t know so we question things a bit more, even though we are probably not the experts, but one could take that information and take it back into your core business and probably would have taken a few steps forward.*
>
> *(Design Manager, closing discussion)*

> *As non-specialists new things could come out.*
>
> *(Textile Engineer, closing discussion)*

A further step in the process that could be explored in subsequent iterations would be to involve actual users with experience of the context to verify or contradict the assumptions contained in the user journey maps. Users can be involved in the design process in a broad variety of ways, as discussed by Giacomin (2014) for HCD and Sanders and Stappers (2008) for co-design. As outlined in Chapter 2, design processes involving users face the criticism that they lead only to incremental innovation (Norman and Verganti, 2014) and that users cannot help a designer envisage new uses of ETS technology (Ossevoort, 2013, pp.409–411). An initial Discovery stage may be a way to address these criticisms, while the subsequent involvement of users could test the purpose envisaged to lead the design process.

7.3.2 Part Two

The journey maps did not offer a direct route to an ETS design proposal, instead their transformation required several steps. I drew themes connected to a purpose from the maps to lead the design process and abstracted away from single users and journeys. However, in contrast with *Design Situation 2* in which the participants had found designing for a user restrictive and resolved to design for ‘everyone’, the user journey maps provided a framework for reflection on multiple user experiences. In this way, the imagined experiences that had been mapped became a source of insights. I looked for problems that were a common feature across multiple journeys in a manner reminiscent of thematic coding (Braun and Clarke, 2006), inductively identifying four themes: change, interaction, control and information, as having a determining role in the travel experiences.

As argued throughout this thesis, the role of E-textiles or ETSs is in many contexts yet to be defined. I was investigating design techniques that would allow me to envisage the purpose ETSs might have in the future. The *Design Situation* described in this chapter focused on envisaging a purpose that could lead the process of designing an ETS, rather than the physical realisation of a design. There is no direct link between the journey maps and the appearance or haptic of the textile, but by envisaging a purpose that leads the design process, decisions about the textile’s construction and appearance can be made with reference to that purpose. Sometimes, this will mean fully integrating the electronics into the textile, but this should only be the case where this best serves the envisaged purpose.

When synthesising the data produced in the first part of *Design Situation 4*, I benefitted from Team 1’s use of the open-ended terms: mover, mobile clinic and pod, not directly linked to existing modes of transport. The terms offered freedom for my imagination to conceive the interior space without seeing a car, bus or ambulance interior. My aim was to create a design proposal that had a purpose envisaged through reflection on the experience maps and not become mired in the current technological possibilities of ETSs. From the user journey maps emerged aspects of the experience of travel that are factors today and will remain so in the future, such as interaction with other passengers, which can be positive or negative, and the physical and mental drain of long-distance travel. While ETSs cannot make our transport networks flow more smoothly, they can impact interaction and could also play a role, as envisaged in the selected design proposal, in reducing the monotony of long-distance travel.

In part two of this *Situation*, collecting the instances of positive or negative experiences from all the user journey maps, and showing which of those related to the transport interior, allowed me to isolate those areas an ETS could influence. This action highlighted other important aspects of experience the interior or an ETS cannot influence, such as traffic flow. The user journeys also showed that not all the problems experienced can be removed, for example, the boredom of long journeys. As designers, we can only make attempts to ease these issues and ETSs may not be the best way to do so. If I were not a textile designer, an alternative proposal in response to the user journey maps might have been to design a better traffic management or public transport system to reduce the number of vehicles on the road.

After the completion of *Design Situation 4*, from September to November 2020 I took IDEO's nine-week "Introduction to Human Centred Design" course (Acumen Academy, 2020). The course teaches a series of steps to first research and then move from design data to a proposal in a manner I discovered to have parallels with my design data handling. It instructs designers to generate themes from design data and then insight statements about those themes. Additionally, the course teaches designers to develop the insight statements into "how might we (HMW)…?" questions around which to create design proposals. As advocates of HCD, IDEO caution against scoping HMW questions too narrowly by prescribing how the design should be created. This is a challenge for textile designers as the design is likely to be a *textile*, or as in this investigation is textile related.

In a follow-up conversation with the Design Manager and Advanced Engineering Manager, they expressed the workshop had "made them think and learn" but had also "delivered". It had shown them that the user could be a valuable source of inspiration in their design process, and I had translated the workshop's insights into design proposals that could be realised. Although *Design Situation 4* illustrated the tension between a purpose-led and a technology centred process, it showed how the design process for ETSs in industry could become purpose-led.

7.4 Discussion

Customer or user journey mapping is often employed to "provide a graphic visualization or a map of a customer's or user's experience with the product" (Howard, 2014, p.11). With hindsight, the name user or customer journey mapping for the technique, as I employed it in this *Situation* and *Design Situation 3*, is inaccurate and potentially unhelpful. The individuals whose experiences were being mapped were neither users nor customers, as there was no pre-existing product or service they were using. These imagined individuals were a catalyst for empathy and imagination. User-centred design, has been criticised because the individual becomes merely the user of a tool and the process is "goal-directed' and focused "on the closure of predetermined, technical problems" (Gasson, 2003, p.30). In this investigation, the technique would be better referred to as experience mapping which conveys its use for exploration rather than to map and design predetermined functions.

The techniques used in *Design Situation 4* were user journey mapping and bootlegging, which uses word association to help designers overcome design fixation by juxtaposing elements that would not normally appear together. I generated themes related to purpose from these outcomes to lead the creation of designs. These techniques are not novel in themselves. As Holmquist (2012b), the creator of bootlegging addresses, juxtaposition is a creative problem solving technique also used by artists, writers and musicians. The novelty lies in their use in a textile design setting and more specifically at the fuzzy front end to design ETSs.

Design Situation 4 offers insights into a design process, not only for ETSs but also applicable to conventional textiles, where inspiration comes from contextualising and understanding people's experiences. Company Y's positive response to *Design Situation 4* indicates that design techniques allowing textile designers and manufacturers to explore and draw inspiration from the user have potential in the textile industry. As expressed by the participants, the techniques trialled could also be used to design conventional textiles and other vehicle components. By taking the time to explore the experience of users, the process becomes less dominated by the capabilities of the technology. For a company with no prior experience with the techniques employed in the workshop, the positive response of the multidisciplinary team suggests there could be many companies that are removed from users by one or more layers of design for whom the techniques could have relevance. Given that the techniques are used in product, interaction and service design this is perhaps unsurprising, but this investigation has shown how they might be used to design material systems that hitherto were designed with little awareness of the user.

8 CONCLUSION

This investigation began exploring E-textiles for the automotive industry, but it expanded, as in parallel has my textile design practice. My initial research approach was closely linked to how I had been taught and had professionally practiced textile design over the course of 15-years, nonetheless, I found myself in difficulty. I was accustomed to responding to the requests of industry customers and developing textiles through visual research combined with my knowledge of materials and manufacturing processes. Customers were interested in 'smart' or electronic textiles, but they did not know what they wanted them to do or be. I was no more informed as to what purpose they could or should fulfil, nor did I know how to go about envisaging one.

Rethinking the textile design process to be purpose-led transforms how it should be taught and practiced. People have been using textiles for decoration, warmth, comfort and shelter for millennia, so we take these many uses for granted, but we are still defining what purposes E-textiles might serve. This uncertainty, a defining characteristic of emerging technology, combined with my concern about the environmental and social impacts of their adoption, motivate my search for a purpose-led process to design E-textiles.

Defined in Chapter 1, a purpose-led process answers the question, 'why should an E-textile be designed, what is its purpose?' E-textiles are likely to be more environmentally harmful than conventional textiles due to the difficulty of recycling them, and have possible negative social impacts, such as loss of privacy (Köhler, 2013a; Kuusk, 2016; Sametinger et al., 2019). In developing E-textiles, it is therefore important to understand their purpose as the missing part of the equation that allows us to weigh their value to individuals and society against negative environmental impacts and social consequences (see Section 3.1). This thesis does not appraise the value or impact of its outcomes, that assessment lies beyond its scope. Instead, it centres on how previously peripheral concerns about envisaging a textile's purpose can become integral to the design process.

Conventional textiles are materials which enable "other designed products to come into existence" (Igoe, 2010, p.78). To design them does not require that the textile designer invent what they will become. Layers of design, be it fashion, product or interior, separate textile designers from the end-product and the individuals that will experience that product (Figure 8-1). This separation forms a barrier to a purpose-led process. The intervening layers of design obscure from the textile designer the individual who will experience the textile once other designers have transformed it into a product or part of an interior. Acknowledging the existence of the separating layers is the first step to transcending them.

As with any material or device, E-textiles have limitations, they cannot do everything, which is why the diagram of the layers of design has two directional flows. One is the flow of needs relating to the user then product and so on that allows a design to serve its purpose, and then there is an opposite flow of possibilities opened by each layer of design. At the layer of ETS materials the possibilities might relate to being conductive or not conductive, stretchy or rigid. Moving up the layers of design the possibilities become whether, for example, a device can emit light or generate electricity. Some understanding of materials and technology is necessary to work with ETS, but we should prioritise understanding purpose and needs, working with others where necessary to fill gaps in knowledge.

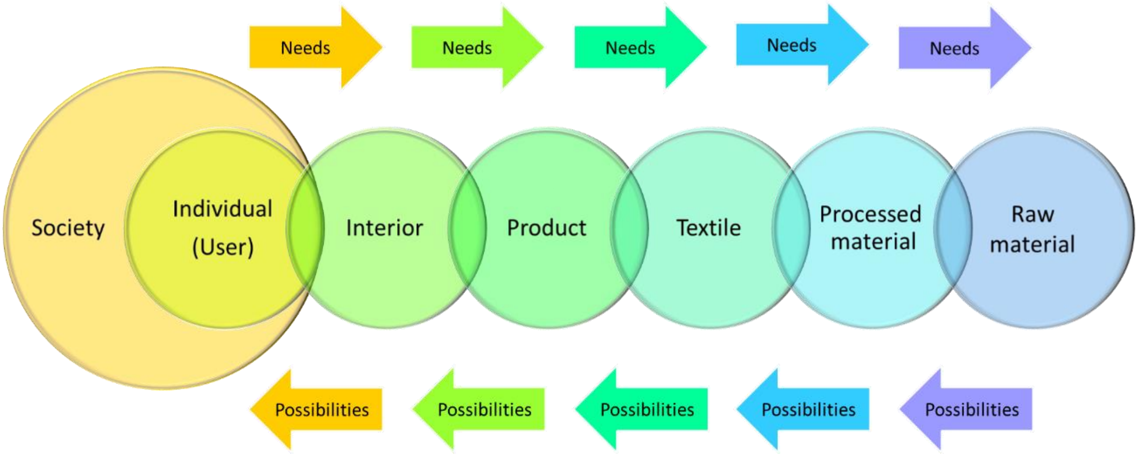


Figure 8-1 Layers of design showing the flow of needs and possibilities

Design literature refers to the individual for whom an outcome is intended as the user. While ubiquitous in product and interaction design, the term is less common in textile design, and at the start of the investigation I did not think about the 'user' of my textiles. Its ubiquity in discussions of design mean the term entered the language of this thesis, but with hindsight it is problematic in this investigation, as it suggests a person who is already using something. Instead, in the *Design Situations,* participants and I were imagining people, their context and behaviour to inspire something that did not exist and was not yet being used. When attempting to envisage a purpose for emerging technology, we might better describe the user as the muse, a figure whose role it is to inspire the creative process. One step further, in participatory design the user becomes the co-creator and designer of their own experience. Putting participatory design aside, there is a point in the design process, once the designer has conceived an artefact, that the muse arguable does becomes the user, because at that point there is a design they are imagined using. This thesis refers to users, but invites future research to consider alternatives for textile design and design processes where the aim is to invent something new.

So normal is the absence of the user from the process of designing textiles and other complex materials, that researchers have accepted it as a given during other textile and material design research projects. For example, during the Trash2cash project (Niinimäki, 2018), investigating ways to increase circularity in the production and consumption of textiles, and the LTM project (Dell'Era et al., 2016), where the aim was to accelerate the commercialization of OLED-piezoelectric composites, users were involved only partially or not at all. In both cases the needs considered were those of the adjacent layer of design, meaning the manufacturers and brands that would transform the 'materials' these projects developed into products. However, manufacturers and brands would be better described as stakeholders. They have a stake or interest in what a material can do and how much it costs, but their relationship to it is temporary. It moves through their manufacturing process and out into the world to be experienced by the real users.

The uses of textiles in interiors and for clothing are well established, as such the design of textiles can remain separate from the design process for the product, garment or interior they become (Nilsson, 2015, pp.20–33). It is the transformable nature of textiles that allows this separation. For even if a textile has been designed with a specific purpose in mind it remains open to alternatives. A tailor could easily repurpose a fabric designed for a bedsheet to make a shirt. E-textiles, however, are different, their uses are not well established and they are also less open to transformation. Once an E-textile has been designed as an antenna it cannot then become a heated textile. The investigation's conclusion was that to become purpose-led the process of designing E-textiles must expand beyond that of conventional textile design to understand the product the textile will become.

Metal-coated yarns and fabrics are E-textile elements that are multipurpose, like conventional textiles, but these basic elements only have functional capabilities once they have been combined with other elements. As discussed in Chapter 6 and elaborated in Section 8.2 below, this thesis proposes a redefinition of E-textiles as Electronic and Textile Systems (ETSs). These are composed of electronic and textile elements, but, unlike E-textiles where electronics are physically and linguistically subsumed into textiles, the elements of an ETS can remain entirely separate. This broader interpretation makes it easier for us to use each element of the system as best serves the design's purpose, instead of being distracted by technical concerns about the elements amalgamation. Also, by increasing the diversity of materials in the product and making batteries harder to find and remove, seamlessly integrating electronics into textiles is at odds with eco-design principles (Köhler, 2013b) and ETSs offer a more sustainable alternative.

The empirical work of this investigation comprised four interrelated *Design Situations* involving the design of E-textiles or ETSs for interior spaces, shown in Figure 8-2. The insights discerned from the four *Design Situations* highlight areas to consider when designing ETSs, namely the difficulty of conceiving purposes for a specific category of technology and the need for an expanded practice. Section 8.3 outlines the hybrid role of the textile designer in a purpose-led E-textile design process recommended by this this thesis, extending from user to material, and strategies designers can use in this new role.

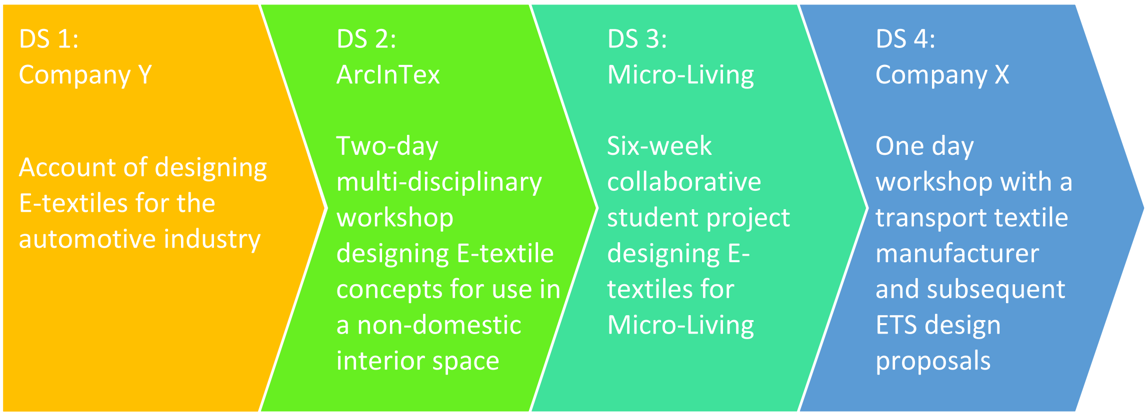


Figure 8-2 Summary of the four action research Design Situations

The strategies trialled and refined in this research, discussed in Section 8.3.2, can also be used when designing conventional textiles, which are also material systems whose properties can be tailored to suit a given purpose (Tandler, 2016). This research has also been influenced by and has implications for the design of other smart material systems, such as the OLED-piezoelectric composite investigated by the LTM project (Dell'Era et al., 2016). In Section 2.5, I used the roles for designers in the LTM project, outlined by Tempelman (2016), as a point of comparison with the conventional role of textile designers. Like E-textiles, these smart materials are in search of applications, so the purpose-led approach this thesis advocates is also relevant for their development. As experts in the design of materials, textile designers can lead the way to a purpose-led design process for material systems.

8.1 Purpose-led

Attempting to design E-textiles in *Design Situation 1,* I learnt that their nature, less open to transformation, and increased complexity, required a different approach to their design. This finding, together with my concern about the environmental and social implications of their adoption brought me to the question that subsequently guided the research:

How can the textile design process be adapted to create a purpose-led process of designing E-textiles for interior spaces?

The question, 'why should I design this textile, what is its purpose?' is one that textile designers have been able to take for granted. The earliest traces of the human production of textiles dates back 30,000 years to fibres assumed to be sewing thread that held together clothing made from animal hides or the remains of ropes and baskets used in domestic activities (Kvavadze et al., 2009). Although not solely a question about purpose in relation to use, when Igoe (2013, p. 51) asked textile designers, “why do we design textiles?”, they found the question difficult both to understand and to answer. A textile designer creating a textile for an interior space does not have to invent the textile’s use, whether it be a curtain, carpet or bed cover, but the functional capabilities that arise from integrating electronics necessitate a fresh approach.

Technical researchers often hypothesize many uses for the materials they develop. The somewhat hyperbolic quote below optimistically suggests that E-textiles will be beneficial across a range of sectors. Although the quote specifies their function as collecting, processing, storing and displaying information, function and purpose are not synonymous, so it is unclear what purpose this functionality would serve and therefore what benefits it could bring.

> *E-textiles will be able to collect, process, store and display information and as such enrich a wide range of application areas from fashion and functional clothing to healthcare and interior design.*
>
> (Lund et al., 2018, p.2)

Textile design researchers have similarly left the end use of the textiles they created open ended (Matthews, 2013; Glazzard, 2014; Philpott, 2011; Veja, 2014; Robertson, 2011). This previous research has understandably concentrated on textile materials, making and aesthetics. By contrast, the process advocated in this thesis places materials, technology and making of E-textiles at the service of purpose.

The focus on purpose has meant the conventional textile design concern for aesthetics has been little explored. In textile design the word aesthetics is used to refer to a textile’s appearance, but it is also a philosophical notion that deals with experience and beauty (Dewey, 1934). Igoe (2013, p. 76) elaborates that textile designers “must design something that speaks to sensation”, something that “captures a ‘feeling’” and in doing so “make judgements on global aesthetic concerns”. Aesthetics are no less important in a purpose-led E-textile design process than in the conventional textile design process. However, the textile designers in each of the *Design Situations* had less time to develop this aspect. The connection between a design’s intended purpose and aesthetics is not straightforward. For example, what appearance or touch would be appropriate for an E-textile to divide space and provide privacy in a small, rented apartment? This was the question facing Team B in *Design Situation 3*. Aesthetic experiences are influenced by the object, person and situation (Jacobsen, 2006). To navigate this complexity, the team’s response was to design a range of options to suit different tastes. In a purpose-led design process aesthetics are no less important, but they should be informed by the purpose the design will serve.

Had this investigation started with a focus on assisted living (Köhler et al., 2012) or the support of children on the autistic spectrum (Biswas et al., 2018), the question of purpose for any ETS that resulted could in part have been answered by the context and more time devoted to aesthetics, as was the case of Kuusk (2016). In ten Bhömer's (2016) research, part of the Dutch Creative Industry Scientific Programme's Smart Textile Services project, they developed the purpose of the designs through collaborative HCD research studying individuals and stakeholders, including sufferers of dementia. Instead, the starting point for the *Design Situations* was, except for *Design Situation 3*, more open and not framed by a broader program. Had I been designing in a context where stakeholder concerns formed the basis of a design problem and a valid purpose appeared obvious, I might not have noticed the more general question of the absence of the user as a source of inspiration for many textile designers. The value of this investigation lies in this observation. The observation has guided the cycles of action in search of an alternative approach to textile design that could be used to educate textile designers and for industry practice.

8.2 Electronic and Textile Systems

Giving priority leads this thesis to advocate a change in thinking from E-textiles, a term which assumes progression towards ever more seamless integration between electronic and textile elements (Marculescu et al., 2003; Hughes-Riley, Dias and Cork, 2018), to Electronic and Textile Systems (ETSs). ETS are systems at object level, they consist of both textile and electronic elements functioning in unity but without emphasis on physical integration between the textiles and electronics. The linguistic separation of electronics from textiles serves to de-emphasise integration between the textile and electronic elements. Kuusk's (2016) research and the interactive media installation *Firewall* by Sherwood and Allison (Sherwood, 2012) are representative of what the concept of ETSs allows. Firewall was made using a high stretch fabric that served as an interface and display. The electronic components of the system, including the depth sensors that registered when the fabric was distorted, processor that changed the image and projector that generated the image, were not integrated into the textile. A broader definition for this category of technology goes someway to addressing the tension between a technology-led and a purpose-led approach, as it encourages that we integrate technology only when it best serves the design's purpose. The rest of this chapter refers to ETSs, unless specifying E-textiles as they were considered at an earlier point in the investigation or as others have referred to them.

The desire to promote E-textiles through what can be described as a technology push model of innovation (Rothwell, 1994) is of concern because of the social and environmental issues E-textiles present. These include the consumption of critical raw materials (Köhler, 2013c), extreme difficulty of recycling these hybrid products to recoup materials and embodied energy (Köhler, Hilty and Bakker, 2011) or of repairing them (Hardy, Wickenden and McLaren, 2020), which closer integration only makes more difficult. The concept of ETSs offers an alternative to designers, allowing them to weigh up the pros and cons of integration.

Electronic technology, like fashion, brings obsolescence (Pan et al., 2015) as advances in technology make what was once cutting edge old hat. Integrating electronics into textiles risks exacerbating the problems already associated with the overwhelming increase in the global production of textiles and electronics. In the 10-years between 2008 and 2018, global production of textile fibres has nearly doubled, reaching 110 million tons (Townsend, 2019). The story for electronics is similar, with rapidly increasing consumption leading to 53.6 million tons of electronic and electrical waste generated in 2019 (Forti et al., 2020).

Where using a material has inherent benefits because its use diverts a waste stream or reduces impact on human health and the environment, a technology or material-centred approach to increase its adoption is appropriate. Karana et al.’s (2015) examination of the use of waste coffee grounds or the Trash2Cash project (Niinimäki, 2018) to increase textile industry circularity are examples where a material centred approach could be beneficial. By contrast, there are no inherent environmental benefits to using E-textiles or ETSs, so an ethical and sustainable approach to their use requires as a minimum that we identify a valid purpose that can lead the design process and justify their use.

Electronic and electrical equipment is closely associated with rising living standards, making life easier and often safer (Forti et al., 2020), therefore it would be unwise to dismiss E-textiles a priori. This investigation trod the difficult ground between interest in emerging hybrids of electronic and textile technology, which for some purposes could be beneficial, and concern about the consequences of their adoption.

8.3 Role and strategies for the purpose-led design of ETSs

The following section addresses the sub questions regarding the role and strategies textile designers can adopt to lead the ETS design process by purpose. Following *Design Situation 1*, which motivated the research question, the investigation approached a purpose-led textile design process by looking to people and place. The process the thesis advocates starts with the potential users and moves down through the layers of design to materials and technology. This flow, from the user to the elements that make-up ETSs, has at times left the designers that took part struggling, including myself. Therefore, considering the challenges and opportunities, I will now advance my interpretation of the role of the textile designer and strategies in a purpose-led design process for ETS.

8.3.1 The role of the textile designer in the purpose-led design of ETSs

The role of designers creating conventional textiles has been described as multidisciplinary (Moxey, 1999; Glazzard, 2014, p.8), but the hybrid nature of ETSs requires new boundaries to be crossed. Discussed in Chapter 2, the design of ETS has previously focused on textile designers moving into the areas of electronic engineering and material science, creating a hybrid textile craft-science approach (Townsend et al., 2017; Veja, 2014; Robertson, 2011; Orth, 2001). As a result of her research into competition and innovation in the textile industry, Lottersberger (2012, p.109) suggests extending textile design practice to the chemical composition of fibres. An example in education of this extension is the CHEMARTS collaboration between the School of Chemical Engineering and the School of Arts, Design and Architecture at AALTO University (Aalto University, 2021; Niinimäki, Salolainen and Kääriäinen, 2018). This strategy is not, however, purpose-led because its focus is on materials and technology rather than their purpose. A purpose-led process does not exclude and can complement a craft-science approach by guiding it and providing a rational.

What this thesis proposes is a hybrid textile-product designer role that combines aspects of interaction and product design with those of textile design. By expanding the role of the textile designer we arrive at Choi and Pak's (2006) definition of a transdisciplinary practice which transcends disciplinary boundaries to look at the broader system. It is textile designers who know how to manipulate fibres to make textiles with diverse properties that can be tailored to suit the design's purpose, but it has not been our role to envisage their purpose. The product designers in *Design Situation 3* explained that prior to taking part purpose and function were central to their process, but they were unfamiliar with and less likely to consider textiles than they were resistant materials. The collaboration, they said, had opened their eyes to the use of pattern, colour, texture and the physical limitations and opportunities of textiles. To better fulfil the potential of ETS, individuals or teams might well look to adopt a transdisciplinary textile-product design approach.

Even without considering electronics, textiles are complex and varied, arguably a system in their own right (Tandler, 2016). When product designers use textiles, as with the selection of other materials (van Bezooyen, 2013), they are more likely to specify them in the later stages when the concept is mature. Textile designers bring an understanding of textile properties and are sensitive to the affective and sensory qualities of texture, pattern and colour. As Nilsson (2015, pp.16–17) moots and this investigation has trialled, greater integration between textile and product design could aid the creation of textile products that are more appealing and fit for purpose. Creating longer lasting outcomes with better physical and emotional durability could slow the rate of consumption, therefore reducing the environmental impact of textile products (Chapman, 2009; Cooper et al., 2016).

Textile designers throughout this investigation have adapted their role to include the design of the end-product and have looked not to trends but experiences as their inspiration. In the collaboration between product and textile design students, there was consensus from the product designers that working with the textile design students was “like working with a normal product designer” (PD 4 closing interview). However, in becoming “like product designers”, particularly evident in *Design Situation 3*, but also in *Design Situations 2* and *4*, the textile designers made fewer textiles. To design both the material and product, a designer moves through multiple layers of design. In *Design Situation 3,* this brought the textile design students closer to the individuals for whom they were designing, while it brought the product design students closer to the materials out of which their product would be made. Precisely because this shift represents an expansion of practice, the design process requires more time.

Because of the increased time spent exploring the purpose of a design, the textile designers dedicated less time in this investigation to their conventional role, focused on pattern, colour, texture, materiality, tactility, and sensory engagement. In *Design Situation 1,* customers suggested that an E-textile’s appearance would help “sell the idea” (Research Diary, p. 18), but the point in this investigation has been that textile designers do not currently know how to find the idea. Participants could only develop the aesthetic of their textiles once they had an overall direction, because an ETSs design is entwined with the object it will become.

In *Design Situation 3*, most of the textile students did not start creating textiles until the project had almost ended, leaving much about their design unresolved. Team B was an exception, coming closer to a transdisciplinary approach by rapidly envisaging a purpose, generating textiles early in the project and using material experiments to inspire the product’s form. They arguably achieved this by bringing the exploratory phase, focused on envisaging a purpose, to a close prematurely, but their speed was also a measure of their motivation and quantity of work they produced. Their choice to focus on designing a space divider was a reaction to the problems of micro-living they had identified through experience mapping. The team’s close collaboration illustrated the role textile designers can have in inspiring product concepts when balancing the needs of people and place with materials and technology.

Townsend (2003, p.10) highlighted that “textile and garment design are generally taught and practiced as separate disciplines”. This is also the case between interior design and textile design (Fislage, 2012). However, bringing the design of the product into the textile design process is not unheard of. Academic institutions are seeking to embrace new hybrid approaches (Dumitrescu et al., 2018) and companies to combine the design of textiles and products, referring to these as applied textiles (Bang, 2011). Designing knitted textiles, from hand knitted socks to sophisticated seamlessly knitted medical devices (Liberski et al., 2016) and garments (Taylor, 2015), is often a combination of product and textile design and Townsend and Goulding (2011) discuss the interaction between the design of textiles and clothing in three ways: textile-led (2D-led), garment-led (3D-led) and simultaneous. In clarifying the purpose of ETSs, the role of textile designers must extend beyond creating 2D samples to imagining and creating 3D products, interiors, and prototypes.

Even when there is interaction between the layers of design, users have remained largely absent from the textile design process, other than through the archetypal body form of the mannequin, standardised measurements (Townsend and Goulding, 2011) or, as found in *Design Situation 4,* ergonomic data. The creation of textiles, for both interiors and clothing, is dominated by a designer-led model in which designers, together with trend prediction agencies such as WGSN, are the cultural barometers and style makers, heavily influencing what is 'in fashion' and undervaluing wearers (von Busch, 2009) and users. It is therefore unsurprising that user needs are a less familiar starting point for the textile design process.

There are examples where textile designers have been interpreters of user needs in the textile design process for medical products (McLaren, Stevenson and Valentine, 2017), clothing for mature women (Townsend and Sadkowska, 2016), clothing for hidden disabilities (Shawgi, Townsend and Hardy, 2019) and hospital environments (Mogensen, 2018). In these examples, the research started with a clear user group and therefore who should be involved in the design process could be easily identified. These examples and my investigation suggest that for a human-centring of the textile design process, we cannot design the textile without consideration of what it will become, whether that be a garment, product or part of an interior.

As introduced in Chapter 2, this research did not start with a user need or a problem defined by a broader research program. Except for *Design Situation 3*, there were no pre-determined users at the start of the process. This reflects the context of many textile designers, who do not create their textiles with a problem or experience in mind. The lack of clarity as to the user and problem is a difficulty designers encounter when working with emerging technology. As was the case for the designed material system of the LTM project (Dell'Era et al., 2016), designers and technologists are not sure what purposes these technologies could or should serve. Involving users when there is so little clarity as to who they are, represents a challenge which this investigation has examined. Section 8.3.2 discusses the strategies used to overcome the barriers to the role of the textile designer as an interpreter of user needs.

Textile companies and designers respond to the wants of their clients, meaning companies and brands that manufacture the end product, and these clients have previously been considered the 'users' of textiles (Niinimäki, 2018). It is a challenge to shift from responding to a brief and designing for a known application to identifying a problem and therefore a purpose for which to design an ETS. A challenge first demonstrated by my difficulties in *Design Situation 1* and then by the students in *Design Situation 3.* In *Design Situation 3* many of the teams also presented product concepts with no electronic or textile element, despite the stipulation that their proposals contain E-textiles. Bringing the user into the textile design process was initially disorientating for the participants in this investigation, but eventually brought a greater sense of purpose to their designs.

The role of the textile designer in the purpose-led design of ETSs is to research areas where ETSs could have a positive impact on the potential recipients of the design. They also need to move from the creating samples to creating product proposals and prototypes. Textile designers can highlight the possibilities of pattern, colour and texture, and the physical limitations and opportunities of materials and processes, to serve a purpose. They need to envisage a purpose for which to design and being willing to question the validity of that purpose. Designers need to scrutinize the question of purpose when they are working with novel smart materials to avoid, as expressed by Karana *et al.* (2015), mistaking any transformation of their functional attributes for a valuable outcome.

8.3.2 Strategies for a purpose-led textile design process of ETSs

My experience in *Design Situation 1* led me to conclude that to design ETSs textile designers need to envisage their purpose because, unlike conventional textiles, the roles ETSs may play are uncertain. This requires that textile designers consider the object and space the ETS will become part of and with which people will interact. Following *Design Situation 1*, my choice of strategies has focused on ways purpose can lead the ETS design process, developed by researching people and place, working from this point back to materials and technology.

The five techniques trialled across the *Design Situations*, indicated in Figure 8-3, were bootlegging, material exploration, personas, experience mapping and theme generation. When searching for suitable techniques, I looked to the many possibilities offered by HCD, an extensive list of which is given by Giacomin (2014, p.616), but many of these techniques assume there is a defined problem area and that the designer knows for whom the outcome is intended, which was not the case in this investigation. Participants had to conceive potential scenarios and research human needs and aspirations to understand and envisage the purpose of their design. Holmquist's (2012a) concept of 'grounded innovation', which promotes balancing research into user needs and understanding the potential of an emerging technology with blue sky thinking and invention, informed my choice. The following section assesses the five techniques used in the four *Situations*, highlighting what was effective and what could be improved.

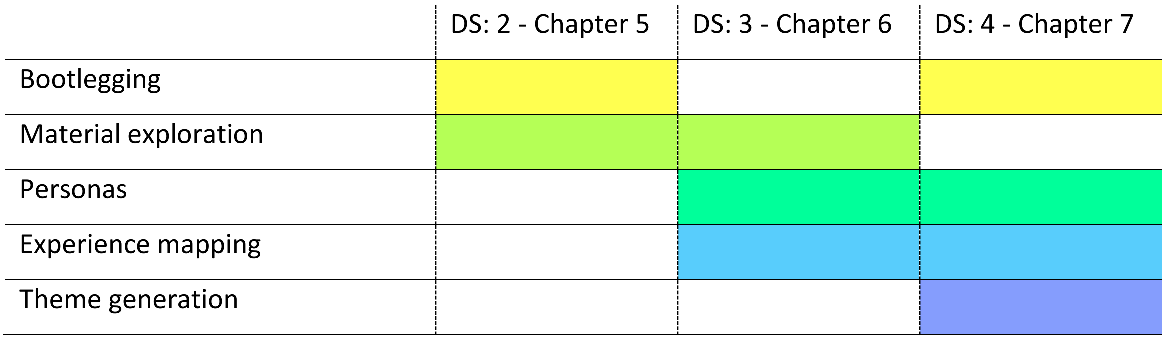


Figure 8-3 Design techniques used in the Situations

A challenge in this thesis has been to understand why E-textiles should be developed, as their functionality can often also be achieved by other means. The categories of the technique bootlegging, created by Holmquist (2012b), encouraged participants to explore why and how the characteristics and functionality that differentiate E-textiles from other material configurations could be beneficial. Bootlegging, first trialled in *Design Situation 2*, is a technique that aims to balance participants' knowledge of a technology's capabilities with creative probing of use scenarios, and originated in the domain of digital product design. Future research could further explore the prompts used for word generation and how these could be tailored to different design contexts, as discussed in Section 5.2. Most importantly for a purpose-led approach, when in *Design Situation 2* it was not supplemented by other techniques, it did not promote deeper inquiry into user needs. The ideas generated through bootlegging alone were inventive but their link to a purpose was more tenuous.

On the flip side bootlegging encouraged creativity, allowing the designers in *Situations 2* and *4* to invent novel proposals for how E-textiles or ETSs could be used in interior spaces. From a psychological perspective, Paulus and Brown (2007) explain that the juxtaposition of ideas, which occurs using techniques like bootlegging, facilitates creative idea generation. In *Design Situation 3*, the collaboration between product and textile design students, experience mapping and personas, techniques taken from HCD, were used to investigate the needs of people living in small spaces. The other tutors and I also aided the students' inquiry into technical aspects of E-textiles through presentations, workshops, and tutorials, but did not explicitly support creative idea generation. With hindsight, carrying out a bootlegging exercise could have helped the students in *Design Situation 3* when they struggled to link E-textiles to the experiences they had mapped, aiding the difficult process of navigating from contextual data to design proposals.

Reflection on the four techniques used across *Design Situations 2* and *3* led me in *Design Situation 4* to combine bootlegging, experience mapping and personas to generate contextual data and then develop themes to frame a purpose for ETS design proposals. In *Design Situation 2,* the teams used ideas about the qualities of textiles and functionality of E-textiles, generated during bootlegging, to create their designs, but there were no steps, such as experience mapping, to provide insights into user needs. Both teams experienced the user as an impediment and chose instead to superficially design for ‘everyone’. By contrast, the students in *Design Situation 3* designed for a clearly defined persona but struggled to connect the persona’s experience to the qualities and functionality of E-textiles. Hence, in *Design Situation 4,* I used bootlegging and experience mapping to complement each other. Company Y appreciated this novel way of conducting textile design, inspired by people and place as opposed to visual trends and technology. The combination of techniques used in *Design Situation 4* enabled me to create a series of design proposals with a purpose, one of which the company expressed an interest in carrying forward.

In *Design Situation 4*, as advocated by IDEO (Acumen Academy, 2020) and van der Bijl-Brouwer and Dorst (2017), I generated themes from the data created during the workshop. A criticism levelled at HCD is that it promotes incremental rather than radical innovation (Norman and Verganti, 2014). The opposing view is that themes help uncover deeper needs and aspirations, clarifying the purpose of a design and allowing HCD techniques to be used for strategic innovation (van der Bijl-Brouwer and Dorst, 2017; Acumen Academy, 2020). *Design Situation 4* provides an example of how a textile designer can use the data from mapping imagined experiences to create themes which support the generation of purpose-led ETS design proposals. Generating themes could also have helped students in *Design Situation 3* navigate from contextual data to design proposals.

In an article provocatively titled “Human-centered design considered harmful”, Norman (2005, p.14) poses the question, “If it is so critical to understand the particular users of a product, then what happens when a product is designed to be used by almost anyone in the world?”. The value of designing for specific users has been a conundrum in all but *Design Situation 1,* which highlighted the absence of the user from the textile design process. In *Design Situation 3*, where the outcome was for a domestic space, the students designed for specific users by creating detailed personas. They gave these imagined individuals names, professions, hobbies, likes and dislikes, going into far greater detail than the customer profiles commonly used in textile design. Personas, as discussed in Section 5.2, can act as a priming device, facilitating idea generation (So and Joo, 2017), but in *Design Situation 2*, rather than flesh out a persona for the user group in their scenario, the teams experienced the user as a restriction and instead designed for ‘everyone’.

In *Design Situation 2*, the participants were designing for a non-domestic interior space, which they described in the closing discussion as “architecture” rather than a “product”. They felt that doing so “opened it up”, made it “broader” and about “community” and so they incorrectly described what they were doing as designing for ‘all’ or ‘everyone’. Design for All (DfA) is a principle defined in relation to the information society to ward against the marginalisation of the unskilled, disabled, and elderly (Klironomos et al., 2006). Universal Design is a similar concept first developed in relation to architecture (Arenghi, Garofolo and Laurìa, 2016). Both DfA and Universal Design can be grouped under the umbrella of Inclusive Design pioneered by the likes of the Helen Hamlyn Centre for Design (Coleman, Clarkson and Cassim, 2016). What the teams in *Design Situation 2* were doing was not inclusive, they did not account for whom they were implicitly designing, which was informed by their perspective as able-bodied citizens of high-income countries. In noting the similarities between the designs created by each team, during the closing session, one participant noted,

> *People with differences of backgrounds […], they would have come up with something totally different. Between us we had a lot of common ground’.*
>
> *(Participant A, Team A - group reflection)*

In a two-day exploratory workshop, not aimed at DfA, I had not given the participants techniques that would have supported a truly inclusive approach. Their choice illustrates that superficially designing for ‘everyone’ and so not accounting for differences, risks being anything but inclusive.

Writing in 2005, Norman gave the automobile as an example of successful design used by many people around the world created without systematic study of users, however this comment is now outdated. The nature of driving is being radically reimagined as autonomously driven and electrically powered vehicles render past design constraints irrelevant (Stuart, 2015). The automotive industry is changing and designers working in this field are now carrying out in-depth studies of how different users interact with vehicle systems (Nash, 2020). However, this does not remove the question of how to design for many users with possibly conflicting needs. Norman put forward Activity-Centred Design as the answer, the aim of which is to understand the underlying activity rather than individual user needs. The deep understanding of activities that would be part of this approach is arguably not so far from the human-centred strategic innovation advanced by van der Bijl-Brouwer and Dorst (2017) or HCD strategies taught by IDEO (Acumen Academy, 2020), as all aim to draw together different perspectives. Additionally, creating themes allows designers to condense large amounts of data and make considering multiple perspectives a manageable task. Focusing on purpose can aid the creation of designs that balance the needs of multiple users.

Reflection on the *Design Situations* has led me to conclude that in this investigation, exploratory making with the rudimentary ETS elements available, did not help to envisage the purpose. If anything, the textile design focus on realising ideas in physical form, meant introducing ETS elements created perceived constraints which limited ideation. The exploratory nature of this investigation and the methods it employed mean I cannot make quantifiable claims as to the efficacy of any strategy, but my experience of *Design Situation 4* was a radical improvement on *Design Situation 1*, in which I had struggled to envisage a purpose for my designs and had encountered design fixation, both personally and during my interaction with others.

This thesis positions the search for the role of ETSs as a speculative enterprise requiring imagination to envisage future possibilities and purposes. In doing so, as found in *Design Situation 1* and outlined in Section 5.1, designers are likely to encounter design fixation. To counter this difficulty, I used techniques involving provocative stimuli, reframing activities and incubation, meaning time away from a task (Moon and Han, 2016). The stimuli trialled were personas, videos such as the fly-through of the ISS (NASA, 2016) and theoretical notions such as Heinzel's (2018) framing of home and homing. The reframing activities were bootlegging in *Situations 2* and *4*, experience mapping in S*ituations 3*, and *4* and theme generation in *Design Situation 4*. The use of these techniques meant that the outcomes of *Situations 2,3* and *4* were more novel and as the investigation progressed the design process became increasingly purpose-led.

This thesis argues in favour of using context-rich data created via HCD techniques and trialled experience mapping and personas in the ETS design process, going beyond the customer profiles currently used in textile design. Designers can sort the data created by experience mapping and similar research into themes, allowing them to see patterns and group the perspective of different users. We can combine these research strategies with methods, such as bootlegging, to juxtapose information aiding creative idea generation. The absence from the *Situations* of actual users or user observation activities means the design proposals were potentially built on incorrect assumptions, meaning the purposes envisaged could be misguided. That said, there is no reason using context-rich data to reach an ETS design proposal could not be extended to include actual users. Despite never previously having considered the user as a source of inspiration, the textile designers that took part in *Situations 3* and *4* saw the benefits of taking the user into account to envisage the purpose of their designs.

Textile design, practiced and taught in its traditional arts-based form, cannot answer the questions pertinent to designing ETSs, which require a fuller understanding of the design's purpose. Envisaging a purpose to lead the design of an ETS requires an additional phase with respect to the conventional textile design process. This additional phase is an expansion of textile design practice to encompasses additional layers of design and include considerations from product and interaction design. This thesis recommends textile designers adopt strategies which consider problems and opportunities by researching people's experience of a given context to identify where ETSs might have value. From that point they can fill in the details of how the ETS would function and therefore how it would need to be designed. In this investigation designers trialled a range of techniques to link the material layer of design to a purpose. The insights from this research have implications for the design of E-textiles. They highlight the question of purpose and invite systems thinking. These insights also have relevance for other designed materials, including conventional textiles, which are discussed in the following section.

8.4 Positioning a purpose-led ETS design process

When outlining the context of this thesis, I discussed two models of innovation, market pull, where market requests start the process, and technology push, where technological innovation is the starting point. I then examined three design orientations: human-centred design, design driven innovation and material driven design. Rothwell found that the two opposing models of innovation were “extreme and atypical”, according to empirical research (Rothwell, 1994, p.9). Similarly, I identified inconsistencies in the way proponents of design driven innovation have labelled human centred approaches as capable only of incremental innovation, when in fact there is significant overlap between the two.

I also showed limitations of the various orientations when designing E-textiles. For example, although Karana *et al.* (2015) created the MDD method to connect materials with human experience, for smart materials it risks promoting any transformation that exploits the material’s functional capabilities. This investigation highlighted that in a design process that starts with a material or technology, rather than a ‘problem’ or ‘need’, there is little clarity about who the beneficiaries of a design could be, making it difficult to use HCD techniques. Despite the desire to be purpose-led, the prescription in this research that any outcomes involved textiles and electronics gave technology an unavoidable prominence that risked obscuring or obstructing purpose.

This thesis concludes that a purpose-led design process should prioritise scoping activities to identify suitable directions and possible beneficiaries. Although no users were involved in the *Design Situations,* autobiographical reflection and empathetic projection by the designers that took part lend the *Situations* a human centred perspective. The techniques used for scoping were bootlegging, experience mapping and personas which provided insights into positive and negative influences on a variety of experiences. The idea of scoping is also informed by design driven innovation. At the start of a design process for ETS the designer may not know who the beneficiaries might be. Therefore, in a nod to design driven innovation, it is the designer who moves the process forward. Speculative experience mapping creates a record of a design team’s assumptions about an experience. Assumptions that they can test against evidence gathered from the intended beneficiaries through interviews, observation and other HCD techniques.

When designing with ETSs in mind, experience mapping also exposes problem areas the technology cannot address, as highlighted by

. *Design Situations 3* and *4* used experience mapping to imagine the experiences of living in small spaces and of travel. The resulting maps present the designer with a variety of positive and negative experiences, many of which ETS cannot influence or would be better addressed by other means. For example, the various space dividers created by the students in *Design Situation 3*, listed in Figure 6-13, could have been made either without electronics or textiles and still have been beautiful, functional objects. In the HCD process taught by IDEO, after research and analysis is the creation of How Might We…? questions (Acumen Academy, 2020). Requiring, in this investigation that the solution be an ETS represented a narrowing of the question the designers were asking. I highlight this issue to advocate that textile designers, whether developing ETS or another form of textile, be aware of the potential blinkering of their perspective caused by their discipline.

For some design problems, such as Shawgi's investigation of garments for Raynaud's phenomenon (Shawgi, Townsend and Hardy, 2019), the prescription of the category of solution is less problematic, as it is a primary element of the situation. In Shawgi's case that element was suitable clothing to mitigate the discomfort caused by heat or cold at the body's extremities caused by Raynaud's phenomenon. If in place of *garments* the question were narrowed to 'how might we design *E-textile garments* to improve the experience of living with Raynaud's phenomenon?', from a human centred perspective it arguably becomes too narrow, as it excludes potentially superior solutions that do not require the integration of electronics.

For the textile designers that took part in this research, looking to the needs of individuals for inspiration was novel. For both the students in *Design Situation 3* and industry representatives in *Design Situation 4,* it offered a fresh way of thinking. It introduced the industry representatives to an alternative to basing design activities either on the requests of business customers or the possibilities of new technologies and materials offered by suppliers. Exposure to this way of working could be the first step to a greater human centring of the design process for ETS and conventional textiles.

To balance the tensions between human centred, design driven and material driven approaches, I created the term purpose-led textile design. The position of textiles as materials, and the discipline's tactile engagement with them, lend a material driven character. If we accept textiles as one of the first human technologies (Burke, 2010; St Clair, 2018), then textile design will always have an element that is technology centred. This investigation is a starting point showing through its action research *Design Situations* how the textile design process can be enhanced and balanced by taking inspiration from contextualised experiences in a purpose-led process. It explored a range of techniques, but time and context posed limitations, calling for further research to refine the process and its use for ETS, conventional textiles and other designed materials.

8.5 Purpose as a means of critique

Purpose is a means to critique an ETS design's "instrumental goodness", meaning whether the design "serves its purpose well" (Ylirisku and Arvola, 2018, p. 54). Considering purpose highlights the benefits of thinking of ETSs instead of E-textiles, both for interior spaces and as wearable technology. I can provide two examples for this argument both based, coincidentally, on jackets intended for cycling. I am deliberately choosing examples that do not come from this thesis to demonstrate the concept's broad applicability. In October 2018, a team at NTU started work on an illuminated cycling jacket designed to make the rider more visible in low light (Hardy et al., 2019). However, by integrating the electronics into the fabric the solution did not serve its purpose of illuminating the cyclist well. The team concluded that further iterations would be needed to enhance "the visibility of the illuminated jacket elbows" (ibid. p.9). Using E-yarns complicated the design of the jacket and the aim of designing for disassembly. It also limited ways the woven fabric of the jacket's sleeves could be made. Considering the jacket as an ETS, to which they could affix lights and other features rather than integrated them into the textile, could have resulted in a design that was more fit for purpose.

A similar critique can be aimed at the Levi's® Commuter™ trucker jacket. The insistence on integrating electronics has created a product that does not well serve its purpose as a cycling jacket. This is because the wearer would have to take a hand off the handlebars to operate it and be wearing headphones, both likely to increase the risk of accidents (De Waard et al., 2014). We can view this insistence, and that of other teams developing E-textiles, in terms of path dependency, the idea that the history of an innovation sets a path that becomes difficult to escape (Håkansson and Waluszewski, 2002). On a personal level, it may also be explained in terms of the sunk cost fallacy, a theory which describes our tendency as individuals to continue in a direction because we have already invested money, effort and time, independent of whether rational assessment would validate the decision (Arkes and Blumer, 1985). In the pockets of academia and industry where E-textiles are being developed, money has been invested, skills developed and reputations staked on the hope that at some point they will be adopted. In a crowded material marketplace, even when the purpose is of great value to society it is important to ask what material configuration best serves that purpose, but it is difficult for research groups and companies working on specific technologies to be sufficiently objective.

Seamless integration may also be an example of over-specification by technical researchers which designers can guard against (Tempelman, 2016). On the LTM project, the material scientists focused on performance elements, one of which was reducing the composite material's thickness, but none of the applications envisaged by the designers required an extremely thin version (ibid.). Seamless integration may also appeal because hidden technology allows otherwise ordinary items to appear magical. Leading the design process by purpose allows designers and scientists to step away from technical goals and the appeal of seamless integration – reinforced by the mystique of electronics the size of a grain of sand – because it offers a means of critique.

8.6 Limitations

This investigation examined the process by which a designer might envisage purposes for E-textiles in interior spaces. Although E-textiles for interiors are considered an important area of commercial and academic research, it is as a wearable technology that E-textiles are predicted to have the most impact. In wearable applications, comfort becomes a more important factor as the E-textile is likely to be in direct contact with the skin. Although comfort factors could make the integration of electronic components necessary, the arguments made in this thesis against E-textiles due to their environmental impact and the focus on purpose remain valid.

A further limitation of this research is that it did not focus on one context and instead the *Design Situations* moved from industry to academia and back to industry. This gives the study breadth, but it could be criticised as a lack of depth. I argue that by moving between contexts the findings have been shown to be relevant and applicable across education and professional practice. Had the study remained one of industry practice, it would likely have lacked the space and freedom that was necessary to find fresh but relevant ideas for this emerging field.

8.7 Future directions

The notion of systems is increasingly used in connection to textiles. Tandler (2016, p.188) defined conventional textiles as "material systems governed by principles of structural hierarchy". Kuusk (2016) investigated smart textiles as part of 'product-service systems'[9]. As textile design diversifies and expands into the realms of digital design, material and systems innovation and electronics an increasing number of textile practitioners are referring to themselves as "material designers" (Igoe, 2018, p.1797). The Royal College of Art's latest MA textiles specialism (RCA, 2018) and research network 'Soft Systems' is recognition of the expansion of textiles into material and systems design. Its title is a nod to Checkland's (2000) Soft Systems methodology and reflects

[9] Product-service systems are advocated to slow the consumption of raw materials as product lifetimes are extended through the provision repair, rental, personalisation and well-being services (Kuusk, 2016; ten Bhömer, 2016).

the need for more joined up and holistic thinking to accommodate the real world complexity with which design engages and for which Soft Systems methodology was created.

Systems thinking is better able to accommodate the scale, scope and complexity of humans' ability to act on other people and our environment introduced by modern technology, an ability that reaches across space and time. Jonas (1984) argued that due to modern technology ethics is no longer a question merely of 'thy neighbour'. Humans have come to exert such influence over nature that in 2019 an influential panel of scientists voted 30-4 in favour of designating the modern age the Anthropocene, a new geological epoch (Subramanian, 2019). It is an epoch shaped and defined by human activity, which started in the mid-twentieth century. Jonas (1984) argued that the ability of humans' through modern technology to affect the whole biosphere brings with it responsibility towards other humans and non-human nature both now and for their future. This notion of responsibility links to the UN definition of sustainable development, which is to meet "the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). This responsibility extends to designers, but we stand accused of having an underdeveloped discourse of ethics (Dilnot, 2019; Chan, 2018; Fry, 2009) and equating well-being simply with more products (Manzini and Vezzoli, 2008).

Modern technology is the main driver of social and ecological change and yet most technologies are adopted with little study, analysis or critical evaluation of their value and impact or other ethical considerations (Sandler, 2013). In the field of E-textiles there are a few voices raising their concerns. Köhler (2013a) offers a variety of perspectives on environmental risk prevention and critical reflection on this emerging technology, added to by a handful of other works (Sametinger et al., 2019; Goncu-Berk, 2019; Hardy, Wickenden and McLaren, 2020; Schischke, Nissen and Schneider-Ramelow, 2020). Köhler (2013a, p.211) concluded that smart textiles, including E-textiles, "have the potential to jeopardise the objectives of sustainable innovation policies that aim at a greener and more resource efficient economy."

Given Köhler's (2013a) conclusion, and in addition to the recommendations he makes, this thesis proposes the design of ETSs to create longer lasting, more repairable and easier to recycle products than would be possible through the seamless integration of electronics. To take this logic a step further, if in the future we consider Textile Systems or Soft Systems, electronics could be omitted entirely, as suggested in Section 8.4 based on the proposals from *Design Situation 3*. Furthermore, the purpose-value-impact relational model discussed in Chapter 3 is a starting point for a more developed account of ethics of emerging E-textile technology in relation to sustainability and design responsibility.

Referring to the domain of organisational management and corporate social responsibility, Karns (2011) asserts that, for business, purpose should be about human flourishing which he connects to the Millennium Development Goals (United Nations, n.d.). As a consequence of business increasingly focusing on purpose, a trend accelerated by the Covid-19 pandemic (KPMG Global, 2021), the term purpose-led is appearing elsewhere in the field of design (Nile, 2021).

In this investigation I advocated a focus on people and place associated with HCD, but I have also frequently referred to the environmental issues linked to textiles, electronics, and their hybridization. Thomas, Remy and Bates (2017, p.85) criticise HCD precisely because it is *human* centred, offering “incremental improvements to the living standards of the already privileged” at the expense of the environment and with disregard for broader socio-political concerns. I am all too aware of the limitations of the problem setting of this research given the context of the Design Situations, leading me not to advocate that any of the E-textile concepts envisaged in this thesis ever be commercially realised. Living at a point when the UN has declared an international “climate emergency” caused by human activity requires that we question the anthropocentricity of HCD, because the human driven loss of biodiversity presents a direct threat to livelihoods, food security, health and the quality of human life (IPBES, 2019). This research is only the starting point. A purpose-led approach to textile design offers a path to navigate between people and the broader life system to which we belong.

8.8 Wrapping up

As called for by Valentine *et al.* (2017), I have provided roles and strategies for design thinking that textile designers can adopt. The textile design students and professionals involved in this investigation were unaccustomed to looking to individuals - users - as a source of inspiration in their design process. Their inclusion broadens the textile design horizon, allowing designers to envisage and critique the purpose of their designs.

This investigation has taken a critical approach to designing E-textiles for interior spaces because of the environmental and social impact of their adoption and cynical of the textile industry’s motivations which relate to increasing the value of the product they sell (Schwarz et al., 2010; Weizhen, Nagai and Yuan, 2017), while acknowledging the role of technological development in raising living standards. The insights that have emerged have implications not only for the design of hybrids of electronics and textiles, but for other designed materials, including conventional textiles.

1. Textile designers have historically been separated from the individuals that will encounter their textile once it has been transformed into a product or interior through one or more layers of design. This presents a barrier to a purpose-led ETS design process. This thesis has presented cases of action, through which textile designers, in collaboration with other areas

of design and engineering, have trialled techniques starting with the people and their context to scope the purposes ETS might serve in interior spaces.

2. A purpose-led ETS design process requires an expanded textile design practice that looks to people and place for inspiration and stretches to encompass the end-product the textile will become.
3. Looking to the people that might use an ETS and speculating as to the role it could have in their lives gives textile designers the ability to critique an ETS's suitability for purpose. It also allows us to weigh the value of that purpose against possible negative environmental and social impacts.
4. To allow the design process to be purpose-led, prioritizing people and place over materials and technology, the hybridisation of electronics and textiles this thesis advocates conceptualises E-textiles as Electronic and Textile Systems (ETS) which, unlike the former, require no physical integration, unless integration offers the best way for an ETS to serve a valid purpose.

This investigation has shown the value of reorientating the textile design process, in education and industry, to envisaging a purpose through consideration of product, people and place.

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LIST OF APPENDICES

Please note: the volume of data produced over the *Design Situations* has been condensed here into a representative sample.

BLANK

Dan Flavin @ IKON GALLERY, BIRMINGHAM
18th June 2016

post-war American artist who worked with fluorescent lamps.

Reflections

- light gives a feeling of calm, soothing wellness
- The colours can blend and edges blur. Some colours are stronger than others
- light is fluid, can travel, be layered but also broken, covered and cut through
  ↳ reading about Dan Flavin's work he was well aware of this potential
  · the actual space of a room, could be played with by careful, thorough composition of the illuminating equipment
- It reflects off and creates shapes and spaces
- It changes perception and can create optical illusions - harmony, contrast, depth and shadows
- light hides and reveals

The blending of colours makes me think about how in an illuminated textile the colour of the light source, the colour of the LED yarn and the pattern and colour of the textile interact.

Dan Flavin's work illustrates the power of blending colours of light.

3

Illegible text: *reading about Dan Flavin's work, he was well aware of this potential, 'the actual space of a room, could be played with by careful, thorough composition of the illuminating equipment.'*

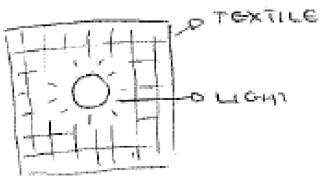
Diary page 6

DESIGNING AROUND → MATERIALS

USING MATERIAL PROPERTIES AS TRIGGER FOR DESIGN

• SURFACE LIGHTING → OLED, EL TENDS TO BE RIGID → BRITTLE? ? IS

• OLED / EL LIGHTING & LIGHTING IN GENERAL NEEDS TO BE ATTACHED TO A POWER SOURCE



: WHERE TO PUT THE CONNECTION TO THE POWER SUPPLY

CAN THE CONNECTION COME FROM BEHIND AND BE HIDDEN?

OR DOES IT HAVE TO GO OUT TO THE SEAMS AND BE CONNECTE AT THE EDGE?

A DESIGN PROBLEM WITH E-TEXTILES IS THAT BECAUSE TEXTILE DESIGNERS, INCLUDING MYSELF, DON'T UNDERSTAND THE MATERIAL PROPERTIES FROM AN ELECTRONIC POINT OF VIEW IT'S VERY DIFFICULT TO DESIGN WITH THEM.

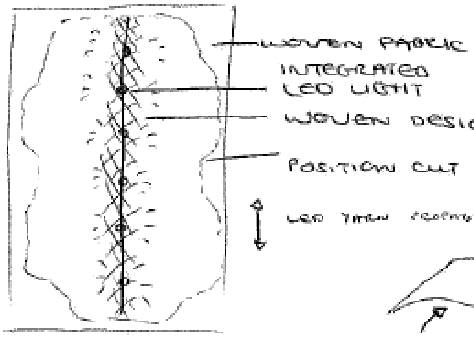
* MAYBE PRODUCT DESIGNERS ARE USED TO THIS 'INCOMPLETE' UNDERSTAND. AND HAVE FOUND WAYS AROUND IT.

6

Thoughts on weaving and integrating light

=> If what the customer is looking for is a replacement for leather in headliner we should be able to offer them a material that has to be hand wrapped. It'd be far easier to implement an e-textile in this way than if it has to go through the moulding process.

=> leather is probably a type of 'positioned cut - so why not offer a woven headliner with a position cut design.

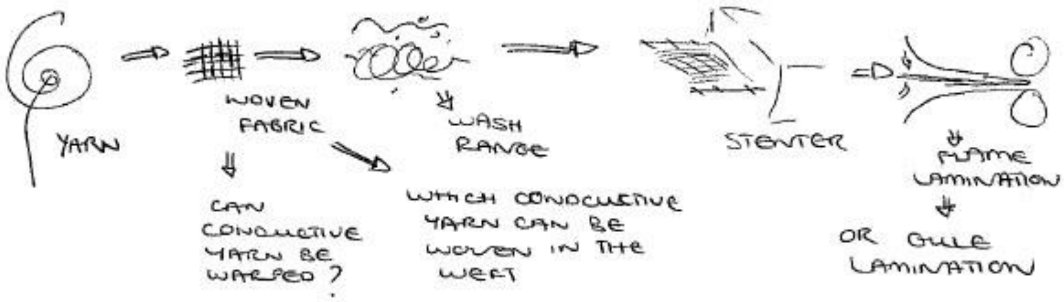


• HOW ARE DRAWSTRINGS PUT INTO CLOTHING?

12

Conversation with [redacted] 18/08/16

A useful part of the investigation could be to weave various types of conductive yarn and process the fabrics along a normal production route checking their conductivity at each stage.



- DECIDE ON A LENGTH TO MEASURE ⇒ 1 mt ?
- DOES THE YARN & FABRIC NEED TO BE CONDITIONED TO GET REPRESENTATIVE RESULTS ?

⇒ WIRE – BEKAERT – STEEL COATED WITH COPPER
YARN – ELITEX® – POLYAMIDE COATED WITH SILVER (GALVANIC)
– POLYESTER COATED WITH COPPER (under research)

'The main important step is to develop high conducting textile structure to be used in a first step for 'wire-up' classic electronic components on and inside the structure of a fabric.'

"TEXTILE ELECTROCHEMISTRY – from the conducting yarn via sensoric and interactive structures to robust and flexible textile micro-systems and technical applications"

(brainstorming)

Helen's question about leather – 'what is it about leather that makes you go 'oooo' ?

⇒ What is it about an e-textile that makes you go 'ahh! that's interesting' ? BRAINSTORM

15

TOUCH - HANDLE

Something that has purpose

The experience of novelty

RESPONSE

Beauty

TRANSFORMATION

appearance

exciting....

what is it about e-textiles that makes you go ahh!? — unexpected functionality

.... 'wow' factor ✓ cool.

DESIRE & MEANING

cutecircuit NY catwalk Collection 2015

looks good — NY catwalk Collection

has functionality

✓

The idea that you can change the lit up pattern is the key to making the stuff cool and not just pretty

Converse ⇒ opinion influenced by the brand? All-Wah Trainer acts as a wah pedal (Guitar playing)

functionality that isn't a poor ~~imitation of~~ substitute for another material ie. where there function can only be carried out by an e-textile

INSTRUMENTALITY - ease of use

AESTHETICS - sensory reactions (PRIMARY)

SYMBOLISM - associations elicited (SECONDARY)

RAFAELI and VILNAI-YAVETZ, 2004

DRIVER

see the road

Advanced warning - How can the car make you aware of situations without causing alarm and without you taking your eyes of the road?

control the car

Speed

direction

Find the controls you need

aid concentration / prevent distraction

Help in difficult driving situations

when you're tired / bored

When you're stressed / sad / angry

PASSENGER

Comfortable

sleep

Pleasurable - listen to music

play games

talk

read

feel safe

what do passengers like to do on car journey

adults vs children

NEEDS FOR VEHICLE DRIVERS & PASSENGERS ⟶ FUNCTIONS THAT SATISFY THESE NEEDS

compromise between spacious interior and ease of reaching control / field of vision

15/09/16

[redacted]

Key area of research 'a new concept of interaction' - what could replace switches?

What should an e-textile look and feel like to make it clear that its a new kind of surface material?

lighting wasn't discussed - e-textile lighting didn't seem to be on their radar.

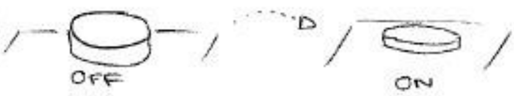
Concerns - • joining e-textiles to the rest of the electronic system

• replacement / repair of e-textiles

They are unclear about what they want. Creating functional prototypes and story boards could help development.

NOTES FROM TILAK ABOUT SWITCHES & REFLECTIONS 30/09/16

TRADITIONAL SWITCHES



↳ visually
- the change of position tells you that the switch is on or off

↳ audio
- you hear a click when its pushed

↳ tactile
- when you use the switch you can feel that the position has changed or that the attivation contact has been made.

– – – –→ GO TO P 23

20

... From P 20

Methods of creating textile switches or alternative gesture controls

⇒ SKIN RESISTIVITY - GALVANIC SKIN RESPONSE (GSR)
- ELECTRODERMAL ACTIVITY (EDA)

— SKIN RESISTIVITY BETWEEN 2 POINTS

⇒ IMPEDANCE MEASUREMENT (CAPACITIVE?)
(CAPACITIVE SENSORS)

→ DC > IMPEDANCE & RESISTANCE = THE SAME THING
A C > COMPLEX RATIO OF VOLTAGE TO CURRENT IN AN AC CIRCUIT (BOTH MAGNITUDE & PHASE)

x SURFACE CAPACITANCE

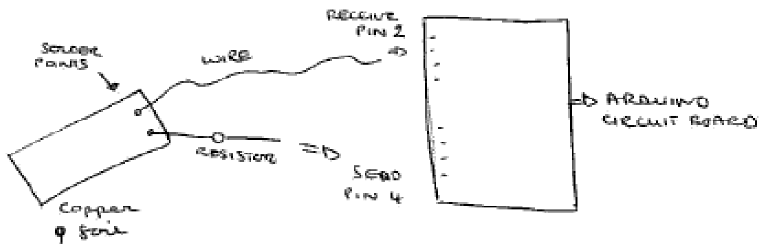
x PROJECTED CAPACITANCE

- SELF CAPACITANCE — X-Y TOGETHER
→ ALLOWS FOR MULTIPLE TOUCH POINTS

- MUTUAL CAPACITANCE — X-Y SEPERATE
→ ONLY ALLOWS FOR 1 TOUCH POINT AT A TIME BUT GIVES A STRONGER SIGNAL

CAPSENSE - Capacitive switch

21/10/16



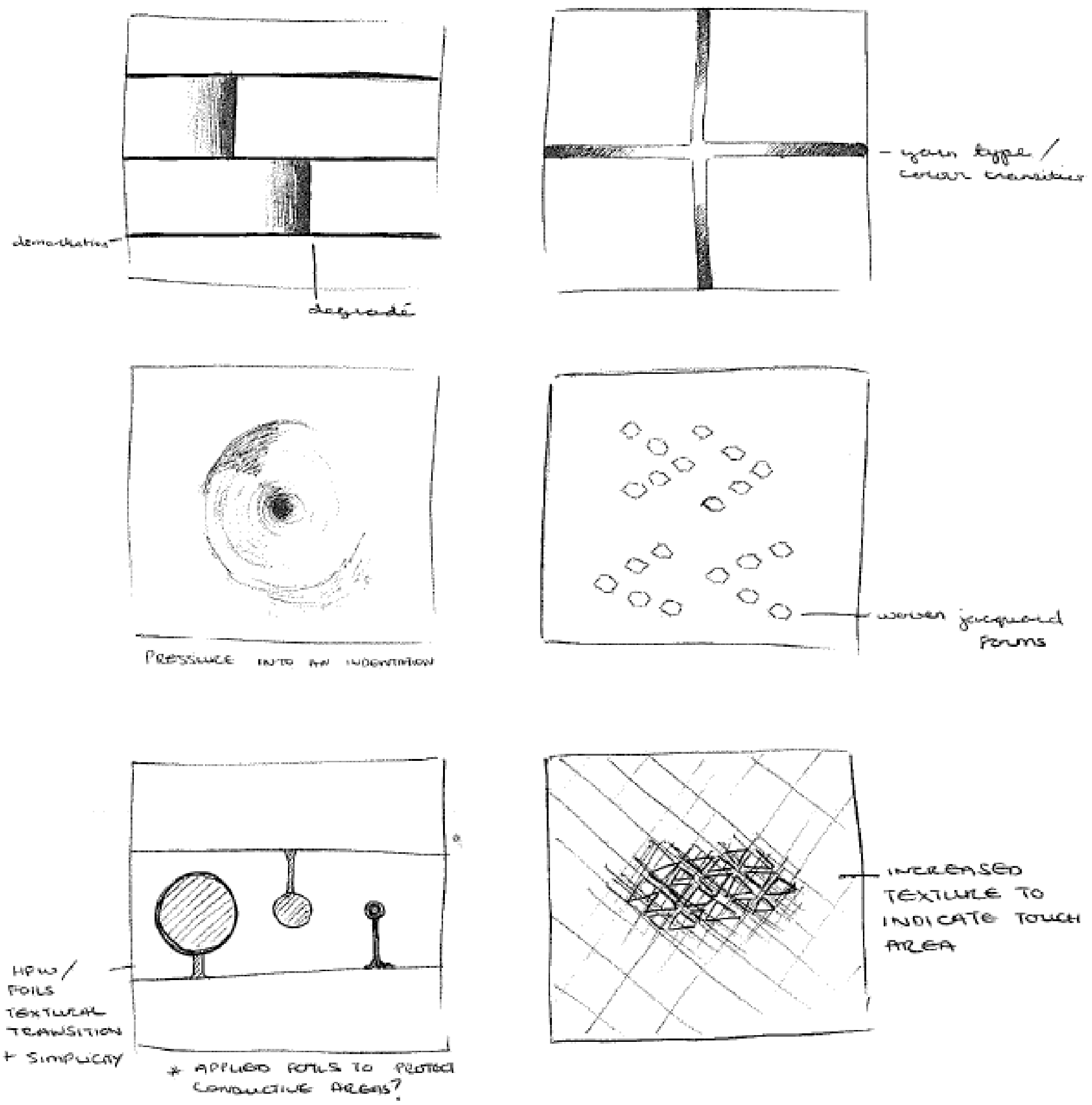
→ Could that be a conductive textile?

→ What thickness of material can be placed over the top of the sheet without stopping the sensor from functioning?

Tracker pads and touch control are now a part of everyday life.

P23

VISUAL COMMUNICATION OF SWITCHES



* For the design collection a video could show the function of the prototype - the physical prototype could tour.

* The heating prototype could also work on a gesture basis.

P24

leather not as popular in India

cultural/tradition

my thoughts

Why are textiles used in vehicle interiors ?

- COMFORT
- ACOUSTIC PROPERTIE
- HOMELY
- WARMTH
- APPEARANCE
- CHEAP WAY OF COVERING LARGE SURFACES
- TRADITION

IF SAFETY IS A PRIORITY WHAT ARE THE MAJOR CAUSES OF ROAD ACCIDENTS ?

- SOFT
- DON'T GET AS HOT / COLD AS SOME OTHER MATERIALS
- HAVE 'GIVE'
- NOT STICKY / SHARP
- we're used to feeling textiles next to our skin

P 26

17 / 10 / 16

☹ my own negative bias towards 'smart textills'

- The applications in automotive aren't important enough for science to find the solution
- There are few really clever products out there
- It's a 'gimick'
- They go against simplicity and sustainability
- It was invented by textile companies trying not to loose production in developed countries
  - ↳ [redacted] main interest is to gain competitive advantage & increase profit
- For most of the applications its used for other materials can do the job better
- Medical applications are one of the few truely relevant / ground breaking / necessary areas, where e-textiles can make a real difference to peoples lives
- They're really difficult to produce
  - ↳ I mustn't let my bias dictate the outcome of my project
- At the end of the day the market will be limited because they'll be to expensive

'If I find myself believing a certain thing to be "good" or "bad" or "not for me" I instinctively take the opposing position. Play devil's advocate.'

Design research - methods and Perspectives chapter - Living Proof - Tracey Moon P 227
HINT 4 - GET OVER YOURSELF
P 29

AUTOMOTIVE

21/10/16

:) Smart Textiles are GREAT!
flipping my bias on its head

- E-textiles could provide us with improvements in terms of function, performance and aethetics that we can't even imagine

- They bring together the worlds of textiles, engineering, product design and interaction to create solutions for today's problems:

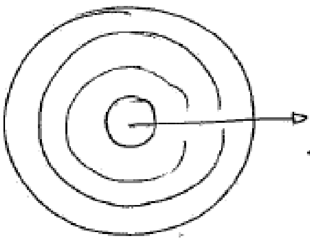
AUTOMOTIVE INDUSTRY PROBLEMS -

- Sustainability
- Envriomental impact of use
- Safety
- Efficiency
- Comfort - Ergenomics
- Ease of use
- Well-being - Health

- Novelty
- Beauty / appeal

P30

Apple example of product development



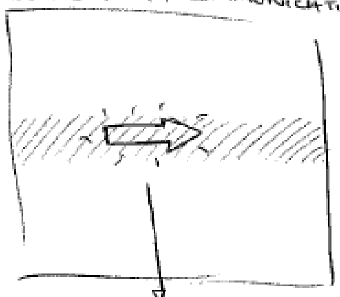
DESIGN TARGET !

TIME BASED INTERFACE

OTHER IDEAS FOR E-TEXTILE LIGHTING OR TEXTILE / LIGHTING / INTERFACE

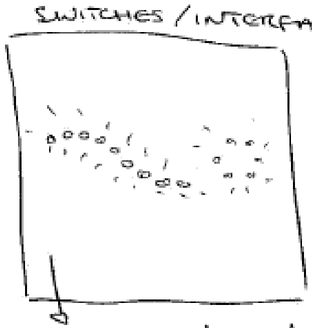
HIDDEN DISPLAYS

WARNING / COMMUNICATION



light from behind to make symbols or messages appear

SWITCHES / INTERFACE



As your hand approaches the surface lights up either to show you the switch is on or to indicate the required gesture

35

Electronics day! 15/01/17

Touch board - micro-controller - electrodes for touch or proximity

reset button for calibration - wait for the red light to stop flashing

Touchboard code can be replaced
↳ Distance sensors => CAPACITIVE SENSING

=> can trigger other outputs - sound / movement / light

(=>) Surface resistivity of conductive paint => 55 Ω/sq @ 50 microns
Drying time 10-15 mins

● LiPo battery to power - 3.7V connected to: 2-way JST PH series connector
↳ Lithium Polymer battery : rechargable by USB when battery & USB are connected

Datastream can be access but requires a program (=>) max / MSP - visual programming language

(=>) GRAPHER - processing sketch
↳ visualisation of raw proximity data
↳ Debugging
↳ Observing range of signal variation

=> Conductive paint sealant - clear coat spray
- mod Podge

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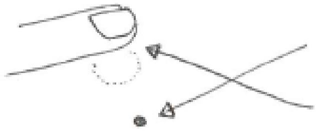
Designing touch/proximity sensors

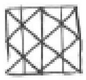
1st Atempts



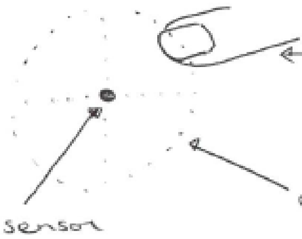
sensor should be smaller* than trigger => Theo says this isn't right

=> BIGGER THE BETTER

* amount of conductive material can be kept low by cross hatching
↳ woven fabric structure?

ie  or  => TEST TO FIND CORRELATION
↳ How does it translate in a textile?

TOUCH BOARD has a capacitive touch chip



disturbance - (Difference in PERMITTIVITY - ability of a substance to store electrical energy in an electric field)

electric field

* SENSOR - an object whose purpose is to detect changes in its environment

FIRST SET-UP

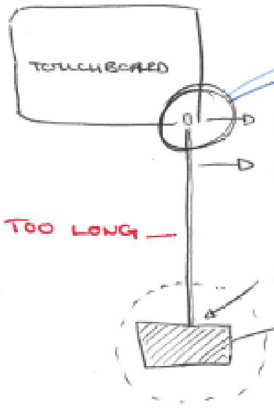
- copper tape to test ✓

PROGRAMMING TOUCH BOARD

- ARDUINO IDE (Integrated Development Environment)

p40

Proximity sensor trial



1st – SEMI SUCCESSFUL LAYOUT

PROBABLE REASON : glue on copper tape probable not conductive so was acting as an insulator

→ electrode 0

→ function point from 1cm away (in height)

TOO LONG –

copper tape

→ solid – not an outline

⇒ INTENDED ELECTRODE AREA DOESN'T WORK ... WHY?

└ RESISTANCE OF MATERIAL ?
OR DESIGN

PRINCIPALS

- Baseline capacitance

PARALLEL PLATE CAPACITOR

Property of dialetric ⟵ AIR

Size of plates – person & conductive

└→ bigger the better

distance

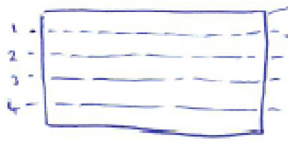
└→ lower resistance better

⇒ glue on copper tape could disturb because its not conductive

10/02/17

SUCCESSFUL TOUCH SENSOR with copperwire 'yarn' that could be used for 'E-textile' gesture sensor. Experiments with sensitivity threshold easy and successful.

IDEA FOR TEXTILE



– mesh fabric

– copper yarn

⇒ LOOK AT PRODUCT DESIGN + WGSN FOR AESTHETIC INSPIRATION

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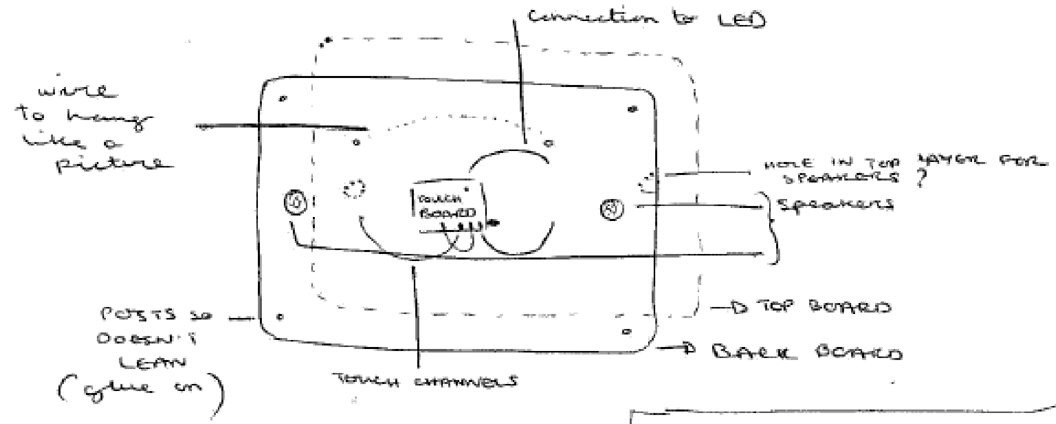
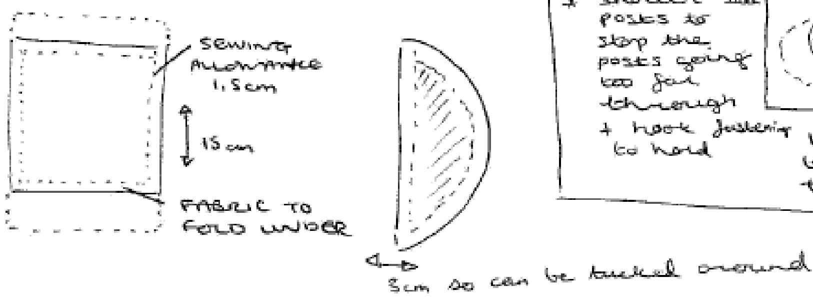
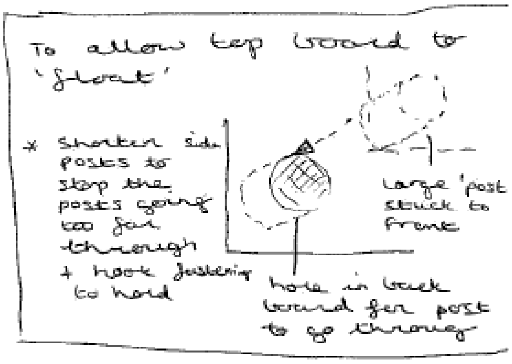
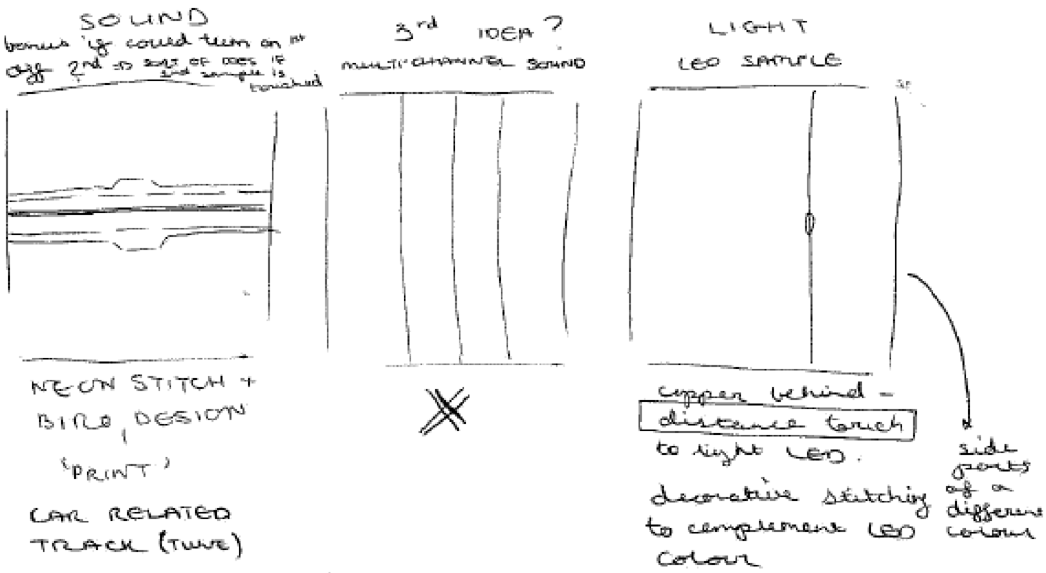
Reverse of samples (Behind) 15/06/17



FABRIC PATTERN PIECES







P85.

Hand Weaving - design session 19/01/18

Creating a fabric suitable for an automotive seat containing thermistor yarns

Challenges:

1 - Suitable structure to hold and protect thermistor yarn.

2 - Structure that allows thermistor to be positioned at specific points both horizontally & vertically

3 - How to make a hand woven fabric look suitable for an automotive project

Solutions

1 - Double cloth allows thermistor yarn to be 'hidden' in back layer
↳ designs with double cloth only where thermistor is to be inserted - speed of weaving, performance

2a -  current pattern mean ~~scale~~ repeat needs to fit positioning requirements

2b - Alternative patterns that offer more flexibility

3a - Enhance / use 'natural' / artisanal appearance
↳ more yarn
↳ other yarn / pattern choices

3b - Technical / geometric weave design may not help give a suitable appearance

P.106

Automotive design considerations

- Look - sporty, youthful/fresh/trendy, comfortable, dynamic
- touch - soft, grippy, smooth
- cost - will this meet the target?
- performance - is this likely to pass the spec?
- manufacturing - can this be made consistently?
  - will it cause a problem during any process?

Interior E-textile consideration

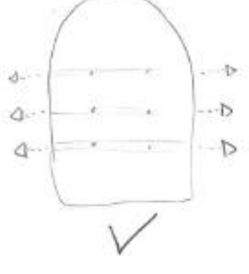
- look - Does this convey its function? ⇒ help me understand what it does/how I should interact with it?
  - Does it show that it is 'special'?
- touch - can I feel that it is different (functional)?
  - does its touch help me understand its function/use it? (interact with it?)
- function - what is its function?

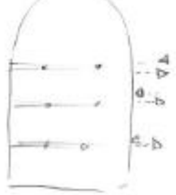
NTU WEAVING - 90epinch jacquard 16/03/18

cotton warp (ecru)

twill structure of triangle design had to be modified to a 2-6 twill ⇒ 16 ppcm

On the jacquard the ends will have to be cut so the connections to the thermistor will have to be on either side of the fabric





✗ NOT POSSIBLE ON AN INDUSTRIAL LOOM because of cutting scissors

NTU weaving 23/03/18

Full length prototype - changing pick colour to an 'empty pick' to stop the loom means pick density was not what it should have been in the double cloth area.

- lack of experience with software made designing more challenging.

?107

18/04/18

weave at random

What applications wouldn't need the sensors to be placed? → INVESTIGATE

'Design' Problem
ie sensors at specific points in yarn

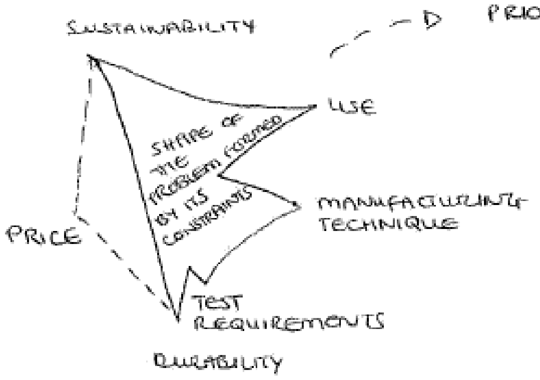
Engineer machine solution to allow for placement

continuous sensor → would be a more useful e-textile component

fibre optics

Wefts - specific discontinuous lengths

PRIORITIES WITHIN THAT SHAPE



20/04/18

SHAPE OF MY DESIGN PROBLEM COMPARED TO OTHER E-TEXTILE RESEARCHERS ? → ORTH, VEJA

DRAW ...

→ Problem framing - The problem frame

P110

The letter R identifies me, and other speakers are identified by their team letter and their participant identifier, listed in Figure 5-2.

R: The first question to each group is about the functionality of your concept. Could one of you or together, could you talk us through what the concept was?

Team A-B: We were going to make some sort of tent structure or a structure to go inside a building. It had a focus on thermoregulation. Heat and cold and then responding to the environment. The… one thing would be it would have thermos-chromatic ink used so that you've got this sort of passive visual response so that coloured blocks of thermo-chromatic inks with bookish sayings just so that they would appear and depending on whether it's hot or cold they would react to that. It would have temperature sensors built into it and so then that would respond to either when it was too cold they would respond by heating or triggering these responses to heating or if it was too hot triggering these responses to cool. So the heating responses one of them would use highly resistive materials to create heating elements. We did a test with one of the samples from the advanced textiles lab that shows how that would work and that would be a pattern round on the bottom. We did do a prototype that will, even though it was using conductive film, shows how things would work within a temperature range. So that was one of our little prototypes. The second one was a prototype for the heating of the fabric. We didn't do anything with thermos chromatics because we didn't have access to them. And then the other aspect of the heating using servo motors or something the structure would breath, move up and down. So we didn't really get that happening we just sort of did it as sort of an approximation, it looks like an ice-cream, but it would raise up and down and the movement of that would create currents, air-currents to cool . Or, if it was cold, to heat it, it would pull down and wrap over it. We didn't really do any prototyping for those mechanisms because we just didn't have time. And then we put some lights inside it that you could read the bookish sayings.

R: Did you think about a specific user group when you were you were developing it? Do you imagine that certain people would use it more?

Team A-B: We had three different user groups, exhausted parents, elderly and travellers but we sort of decided and a certain point that we were sort of more interested in just trying to see how we could think about structure rather than a specific group.

Team A-A: I think its fit for all considering that it's a library

Team A-B: Possibly a library, we had a few possible areas, but we sort of worked on the library

R: Can you, I'm not so much talking about the prototype, but the concept. Can you think of any problems that, that concept might have and would need to overcome, if it was to be considered for a space?

Team A-E: Size of the structure and size of the space, yeah, a little bit, would be something to think about. It needs to be a certain height that people could walk in and for the whole mechanism to rise up and down, it would need a certain space.

Team A-B: I think you'd have to do a lot of testing too, just in terms of how the vents would work on it to heat or to cool and um I mean the prototype is very tall for its floor area which I think is just necessity but all of those things would be important. And I mean we also thought it could have a whole lot of other uses. So we thought library, public space [inaudible section] but there are lots of houses that are not properly insulated so the idea of creating a structure within another structure that was better insulated and able to be warmed better could be great for elderly people for example or a domestic context rather than a public one. So it was really just like a concept that could be taken in different ways. I think also yeah the mechanisms for how things open and close, and the sort of combination of mechanical and this sort of electronic response and to sensors where sensors were placed. How far up the heating elements went, you know there's a whole lot of spatial things that would really make a big difference to how properly it worked.

R: Can you imagine, I mean how fundamental do you see E-textiles to the realisation of a concept like this? Do you think it could be realised with the use of textile or E-textile materials?

Team A-A: Not really, we wouldn't have the heating system.

R: Well, you can have heating elements, heating elements

Team A-A: No but the purpose, because it's part of the material, it's part of the integrated system, so this is kind of like a pop up that is put up straight, very quickly and then taken out very quickly. It's just more like a balloon, it's like an inflatable castle if I'm just ignoring the structure itself because it could be everything automated […inaudible section…]. So, considering this, those would be really in, within the fabric so that would be straight away, we don't need radiators, that could be considered as a hazard as well, sorry I'm just the optimistic part.

Team A-B: But I think, one of the things was to try and create so it was integrated and that it was light and that it was flexible. So you could make much more permanent structures, and you've got heaters and things like that, but the idea that of something that was able to be, everything is integrated into it was quite… sort of part of it and also that it was more sensory and a bit poetic rather than…

Team A-A: I saw these interchangeable colours as very sensorial as well. It could be considered as an aspect of calming effect or you know part of the feature you know … if it's just a pop up. It's a little bit of an 'Illuminarium' but not necessarily using the lights as such. It's more like a library should be, calming, encouraging and all the positive aspects where you could encourage people to go so for them coming back to read or pick up books it has to be that kind of specific environment

R: So, for your group you feel that the fact that it is textile is inherently important for the structure to maintain its… For the structure to communicate what you were trying to in terms of its… that's very fundamental to the design concept, the fact of textile and the various properties. So, what specific textile properties do you think make…, you know why is the textile nature and not for example a plastic or a paper or a glass or any other form of material?

Team A-B: Partly sensory and partly just the… I mean if it was just a space in the library for story telling it's got something magical about it, it is like a tent but also its comfortable and its soft and its warm and the outsides cold. Acoustically it would be really nice because you could be really near but if you had the right textile it could be quite absorbent, so I think it's that sort of, those. I mean there are functional aspects to that but there are also sensory aspects that would be really nice.

Team A-E: We wanted it to flow as it moved.

Team A-B: We said breath.

Team A-E: To kind of replicate an organic system, just kind of…

Team A-A: Kind of like the breathable aspect I think is part of what we need in any building so it's kind of like important. It's not necessarily […inaudible section…]. It is important for anywhere.

Team A-B: It becomes more like a living thing rather than just a geometric space

Team A-E: But in a way I think it's more to provide a great experiential experience from a sensorial point of view as well as environmentally.

Team A-B: And we didn't get, I mean we just used bit of indications for the graphics side of it but being able to work with that linear sort of heating elements and then depending a little bit on how it worked with the thermos-chromatics you could work with other, you know, more organic shaped forms or text so actually graphically that could be quite beautiful and the fact that the graphics could change, especially with the thermos-chromatics, disappear or appear could be quite magical in that sort of sense so it's an imaginative as well as a functional space.

R: Okay, thank you very much. Now same sort of questions to the other group if you can talk me a little bit through your concept.

Team B-H: So, what we kind of came up with was a space where you can alter your surroundings. Cause, for example travelling around you get interrupted a lot of the time you have to put your headphones in because people are too loud. It can get too hot, you either feel sad because you're travelling from somewhere. The idea of having a portable isolation booth was what we thought about. Umm, so kind of similar to yours in a sense like the idea of having well-being and something that you can carry around with you wherever you go. So, a space that can alter the sound, the feel and light basically. And it is shape changing so we thought of the idea of origami and breathing and yoga so kind of being a bit zen. So, whether this space is like flat pack and so origami and then it opens out and it has all these aspects that you can activate if you want if you want them to. It's a bit more of a conceptual idea not totally practical maybe but the whole idea that normally we can't control anything around us, like life is so unpredictable, but what if could control the unpredictable. So, what we kind of created if you want to plug it in… demo… so this is just a little slight prototype of maybe origami that maybe breathes but it is activated by doing zen fingers together. It had more…

R: It was moving more.

Team B-H: It had more movement

R: But that's the nature of prototyping

Team B-H: And initially we started off with paper and paper is a bit more rigid but the whole idea was seeing how the textile and origami aspect could be integrated together. So we thought about doing fabric so we did fabric on its own and then that didn't really work very well so then we put cardboard underneath it and then it work a little bit better but now it's not as good, but then we also did a bit of weaving. One of our team members who is not here unfortunately she just wanted to do some weaving and put some lights in it. Because obviously the aspect of light so we had the idea of that because the whole idea is to have an environment that is comfortable but also create an environment around you which is different to the environment that you're in . So being able to make something that's not calm, calm all of a sudden by just activating it in a sense. And then a bit lower we've also got some conductive thread that I accidentally plugged to a battery and warmed up. So, we've kind of got the warming aspect as well.

Team A-B: You could fuse these two projects.

Team B-H: Yeah literally.

Team A-B: It's interesting because we didn't really discuss them together at all.

Team B-H: It seems that both of us have looked at the idea of well-being and that's a really big thing. Especially with E-textiles. It is good for our well-being and to have it integrated because we are in a sense becoming less detached from our environment. We are seeking for something that is not what we normally have, but yeah...

Team A-A: I think we have this thirst of moving fast, getting there fast and stress levels go up higher and higher and now we get to the point where we realise that actually we are so stretched we need spaces where you could actually be induced in a way that you could actually calm down . Not necessarily by just telling yourself but visually, emotionally, spiritually directly speaking. So, we need all, in some respects, technology will help us get there as we no longer know what it's like.

Team B-H: Yeah, one of our, I can't remember her name, a team member that is not here. She basically said that in some airports and hospitals they have these, like showers, which you're fully clothed in but it's like an installation that you stand in and the water moves so fast that it blocks you out from everything around you and you can't hear anything which I thought was really interesting like. We have nothing like that here, but she said it's just like a zone which you walk into and the water just goes down and you can't hear anything, see anything…

Team A-B: Washes off all of the radiation.

R: It's also interest. I suppose in the end we did an exercise that was looking at different users but actually both groups, the user has very much ended up being everyman, everybody situation. Do you think… I mean, did the fact that process, how did that influence the development of the concepts. Like, did the thoughts about a user…

Team B-H: We definitely spoke about a user but I think with E-textiles, there's so much around that isn't actually accessible to people, that's only accessible to people with lots of money or they're all prototypes or things that people talk about, what if it could be something that is accessible to everyone? How would normal everyday people use it and what would they need. And not categorising a particular group of people, just saying, right anyone can use it. Not just say travellers or…

Team A-B: I think also if you said we were working on a product I think it would have been easier to sort of work to a specific user, demographic but thinking about it as architecture I think opens it up. That doesn't mean to say that, you know I mean architecture like a childcare centre, there's adults in a childcare centre so it's not just about only for the children so maybe that's one. I don't know… it's just a thought that has come into my mind that architecture tends to be a bit more…

Team A-E: Community.

Team A-B: Broader in its user group so maybe that's why it wasn't quite so critical. We started off talking about a user group but in the end, we decided…

Team A-E: We started off with travellers didn't we.

Team A-B: That's right.

Team A-E: And I think that's where the tent came from.

Team B-H: Yeah, we were a similar thing, we were travelling as well. Not that we had a travelling thing because thermo.

Team A-A: I really think as well because all of us we have something in common, and I think it's also commonality a problem because if you think of people with differences of backgrounds and sort of areas they would have come up with something totally different. Between us we had a lot of common ground, so I was really surprised to see that the themes were pretty much the same. We had about three or four elderly stickers so there was a lot of, coincidence I don't think it was, but we had a lot of common ground.

Only participants A, D, E, F and H completed the questionnaire.

1. What are your feelings about the use of ‘bootlegging’ as part of the E-textile design process?

Team A-A: I personally think this is a very good technique.

Team A-D: I really enjoyed the bootlegging process it allows you to experiment with lots of ideas and gives you freedom to play with different electronics. Sometimes it was hard to understand what each component could do though. It was my first time seeing some of this technology so it was great to be introduced to it.

Team A-E: Loved it. I will use it in my workshops + lectures in the future.

Team B-F: Wasn't afraid to explain my "crazy" ideas, because I couldn’t fulfil them by my own anyways.

Team B-H: It made people really consider the purpose and the problem of a product. In a way it made people stuck as they became a bit too considerate and less playful.

2. Briefly describe your group’s concept generation phase of the ‘bootlegging’ process

Team A-A: Our bootlegging was - a library tent - for elderly, children with special needs and parents. It had a breathable roof, with insulated - heated walls, colour changing materials, and self-activated vents.

Team A-D: For - Libraries, Music events, Children, Old buildings protection
Technology would include temperature control, ventilation, thermos-chromic ink, sensory lighting
We would need to consider - how it would piece together, what the user needs, cool and hot temperate control, coding and sensors

Library Tent would create an enclosed area for children to read. This would be a more engaging and fun space for them. Using sensory lights and temperature control to create a calm environment. Ventilation could be controlled through shape memory alloys. Or breathable materials.

Music events attract lots of people and cause cramped hot environments. Some people suffer from anxiety in crowded places. Tents made out of E-textiles could help this. The tent could respond to the temperature through data from sensors. This could open up more ventilation when the tent gets busy and hotter. On the other hand, it could warm up if to cold. LEDS and other decorative lights could be threaded into the fabric for lights effects. The tent material could be made with thermos-chromic pigment, this would act as an indicator for people outside on whether it will be to hot and cramped inside before they go inside. They could have a colour scale on their wristband to compare the colour to so they can work out the conditions.

Team A-E: First selected: travellers, thermochromic, regulating but struggled with the restrictivity of the user group. The concept evolved to remove the restricted user group but use the other categories.

Team B-F: We weren't afraid of failing, made a lot samples that leads to next step.

Team B-H: We spoke about each concept page with the post-its and combined similar ideas on each. We then created a final concept through this process of whittling down.

3. How did you feel about the experimental making phase of the workshop?

Team A-A: I believe it was very useful, considering the amount of time we had available, we spent sufficient time in discussing the initial plan, but the outcome was different, and we had to amend some of initial ideas. I really enjoyed the process of making the tent.

Team A-D: I liked the making phase of the workshop. I'm quite a practical person and like learning about new things so I had great fun exploring these new textiles and electronics.

Team A-E: It was exciting and enlightening to work with other discipline professionals + work around linguistic challenges.

Team B-F: At first workshop day we, our team was a bit depressed, we failed many times, figures out that need extra equipment that will come next day, but continued to try again and again.

Team B-H: It was exciting, but also quite daunting. As I was unsure how to even start using E-textiles.

4. What aspect of the experimental making did you focus on?

Team A-A: We all join different aspect as for example: cutting the fabric, gluing, helping with the structure for the tent.

Team A-D: I tried to go around the group and see how other people were getting on as well as helping Kerry who was also assisting. I had a look though most the materials and played around with a lot of them. I also helped make the fabric that moved in a fan action with the switch being controlled though finger mittens.

Team A-E: Construction.

Team B-F: I tried out all except making mechanisms.

Team B-H: I focused on ensuring that my group were working okay and that they knew what they were doing. I also helped create the origami in fabric and the woven sample.

5. Is there another aspect of the experimental making that you would have like to engage with?

Team A-A: I would like to have more experience in helping to prepare the E-textile mechanism (to make the heated elements!)

Team A-D: I would like to have seen and maybe experimented with some of the sensors that can be use in E- textiles.

Team A-E: I would have like to experiment/ investigate more the Picaxe/Arduino boards.

Team B-F:

Team B-H: I would have like to be more engaged with coding. Maybe there could have been an aspect of the workshop which taught everyone basic coding.

6. Any comments about your group's concept and making process?

Team A-A: I think it was very good and we had a good outcome too.

Team A-D:

Team A-E: Extremely impressive how the idea was generated from such vague beginnings.

Team B-F: We were responsive to each other and tried to fulfil all ideas

Team B-H: It took a while for the group to agree on an idea. A group member was more concerned by the "why" rather than just creating and playing around with materials.

7. Any other comments about the workshop

Team A-A: I really enjoyed it!

Team A-D:

Team A-E: Very well constructed and implemented.

Team B-F: It was really inspiring.

Team B-H: It was fun and free, and it made people think of products which could exist and what would benefit our well-being.

BLANK

Living well in small spaces

BA Product Design year 2 in collaboration with Pearson Lloyd

Context

Prime Central London is seeing the rise of the micro-apartment, according to new research, squeezed accommodation budgets have seen singles and couples opting for location and convenience over size.

Although living spaces are getting smaller the basic housing needs for these living environment are staying constant. With a recent report from the British Property Federation highlighting the following facilities/amenities should be available in all homes, no matter the size

Basic housing requirements - Bed, Washing machine, Toilet, Shower, Sink, Storage, Sofa/ arm chair, Cooking facilities, Fridge, Table

Living well in small spaces

BA Product Design year 2 in collaboration with Pearson Lloyd

The Brief

To design a living space / products for the young, mobile, urban dweller of the 21st century. Your living space is limited to 18 sq meters and must incorporate all of the basic housing products listed below.

You must also select a specific design challenge and develop a innovative product / solution in response to this need.

Basic housing requirements

Bed, Washing machine, Toilet, Shower, Sink, Storage, Sofa/ arm chair, Cooking facilities, Fridge, Table

You may or may not need to redesign products from the basic housing requirements listed above. Any product that you do not need to develop can be specified however these must be visualised and documented within your work / final presentation.

Design challenges

Privacy - Users are parent and child and often have conflicting needs

Entertainment - User lives alone and enjoys hosting gatherings of 4 - 6 people within their home

Work - User lives with partner. They work from home and need a space that feels like a workplace

https://www.samjacob.com/portfolio/thestack/

Living well in small spaces

BA Product Design year 2 in collaboration with Pearson Lloyd

http://www.heatherwick.com/studio/news/fiction-table-launches-at-daniel-katz-gallery/

http://studiomama.com/

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https://www.corridorsociety.com/

https://www.devorm.nl/products/ak-2-pet-felt-workplace-divider-lamp

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https://myheatworks.com/pages/tetra-specs

http://www.abrogers.com/portfolio/compact-living/

Living well in small spaces

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Project deliverables / Final submission

This is an individual project. You are each required to produce and deliver the following for this project:

Project deliverables / Final submission
This is an individual project. You are each required to produce and deliver the following for this project:

1 x Well presented critical consumer journey of your chosen design challenge (Privacy, Entertainment, Work) highlighting several potential opportunities for design interventions

A3 'Development Work' Document which must include all sketches, drawings and photographic evidence of consumer insights, prototyping and feedback.

4 - 6 x A3 Presentation Boards, which clearly illustrate and describe your concept and space. Please make sure that you include full colour visuals of your final design proposal a storyboard explaining user experience and a clear example of scale

1 x Visual consumer journey highlighting how your solution to the design challenge is used by your target consumer this could be delivered as a film/animation or as part of your presentation boards

Professional Practice deliverables

Using Issuu.com create an online portfolio of work. This document must include:

- Title page
- 6 x design practice projects 2 - 4 pages each presented to a professional standard (2 projects from your first year work and 4 projects from your second year)

Living well in small spaces

BA Product Design year 2 in collaboration with Pearson Lloyd

Project Assessment

Assessment is based on the learning outcomes of the module, as detailed in the module guide, using the following assessment criteria:

- Time Management/Professionalism
- Design Process
- Design Suitability/Sensitivity
- Presentation & Communication
- Professional Practice deliverable

Feedback

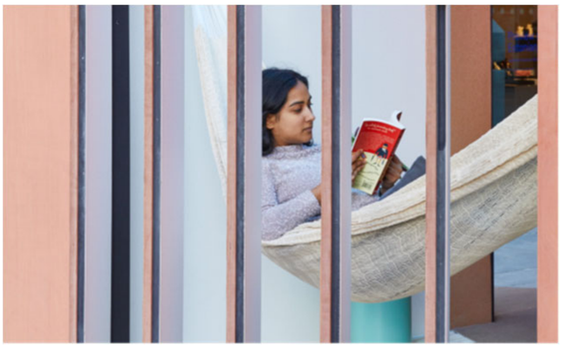
During the course of the project, you will receive verbal and written feedback from academic staff and your peers at timetabled project tutorial sessions.

Project Deadline/submission

You are required to submit and present all work on the following submission deadlines:

26.03.19 Tuesday groups at 10.00	Location to be confirmed
28.03.19 Thursday groups at 10.00	Location to be confirmed

DROPBOX: You are required to submit all deliverables to specified DROPBOX folders by 10.30am on your deadline date



Living Well in Small Spaces

A micro-living and E-textiles cross-disciplinary collaboration between Product Design and Textile Design

Industry set micro-living project with Pearson Lloyd Design consultancy

Project starts with life size micro-living mock up in product design studios

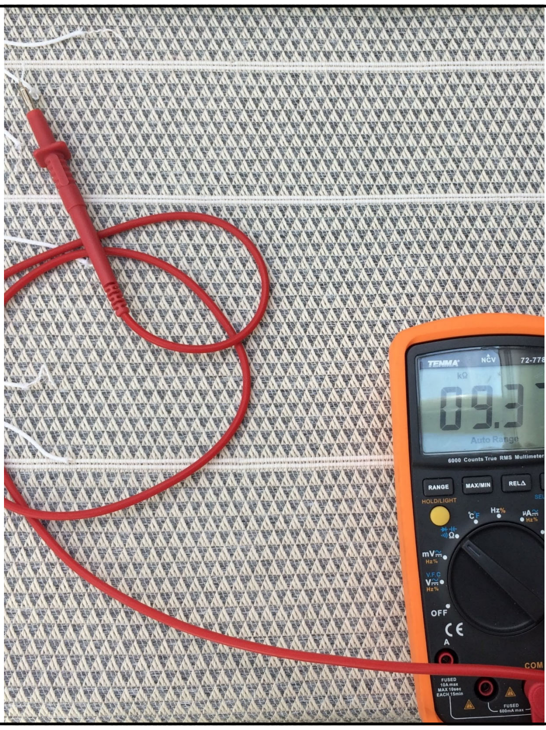
Access to series of Professional Practice lectures from exciting external design companies

Insights to latest E-Textiles sensor yarn research with the Advanced Textiles Research Group

Access to expensive E-textiles materials through a series of E-textiles workshops

Collaborative cross-disciplinary design tutorials

Extra support in a welcoming collaborative workspace from NTU Maker Club



Living Well in Small Spaces

COLLABORATIVE PROJECT : WEEK 30-35
Extensions for DCC as required to allow participation

Potential to map learning into personal project
PROJECT #3 DEVELOPMENT & SAMPLING: **WEEK 35-41**

Project learning outcomes remain the same

10 students from each course

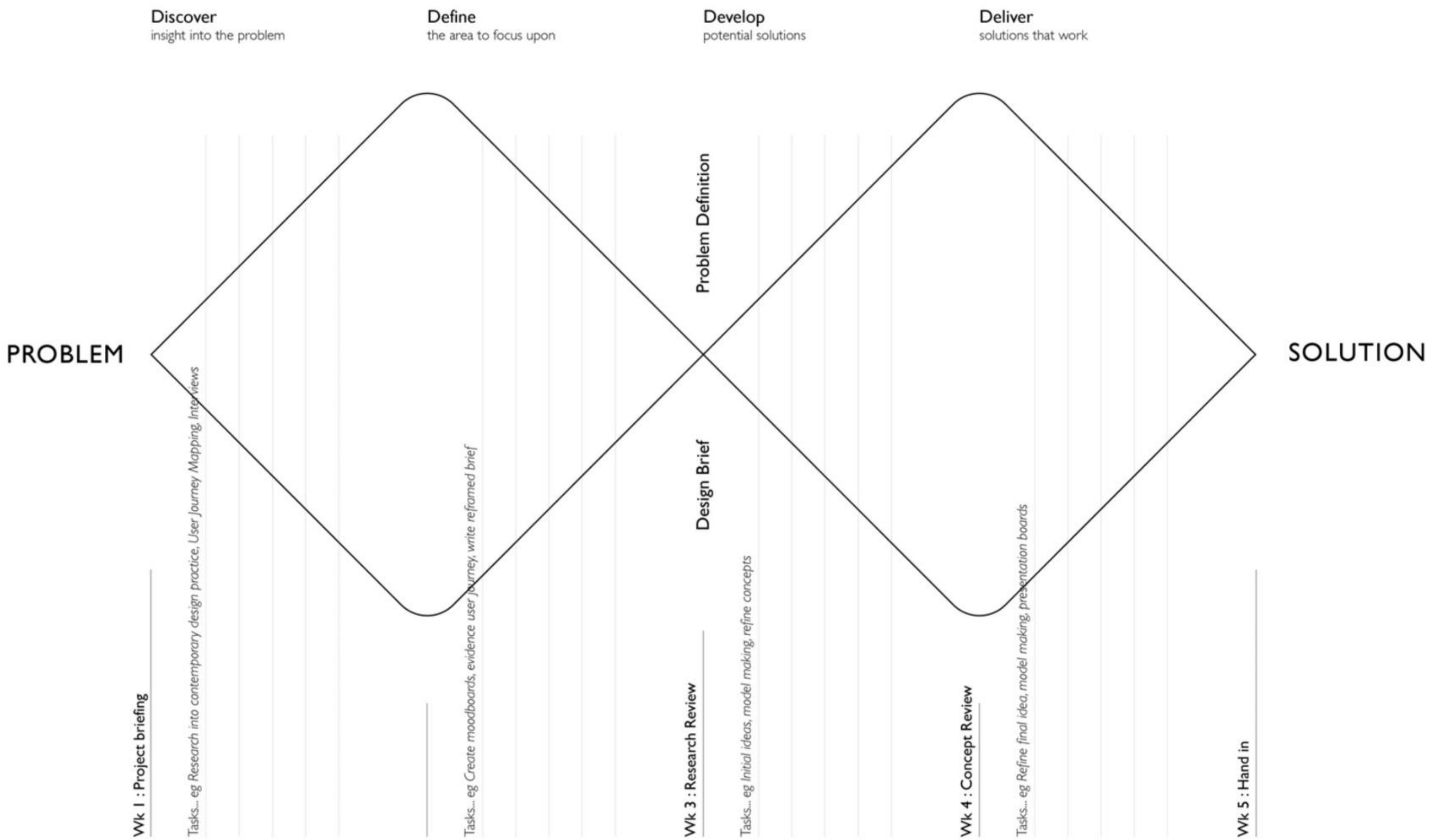
Project Benefits

- **Adventuring** beyond traditional subject boundaries.
- **Networking** between staff | students | research groups | industry partners.
- Building professional skills that make you more employable: **team-working | adaptability | confidence | collaboration | communication | project planning**
- Access to e-textile materials and world-leading research
- **The project aims to build strong working relationships that may lead to future self-initiated creative projects in final year**
- The project will be empowering; feedback from student experience will directly inform future cross-disciplinary collaborative scenarios.

Why plan creative, collaborative, cross-disciplinary scenarios?

- The future of textile design and the potential of smart textile applications in architecture / product / fashion requires opening up to knowledge beyond our discipline and working with different design methodologies more akin to product designers or architects.
- This works both ways. **Textile designers have unique sensory knowledge of colour, texture, pattern, tactility to offer other disciplines**.
- The ability for designers to think flexibly and collaborate beyond their subject specialism is vital to the future of the creative industries.

This is a research project funded by the School of Art & Design. All participating students will be asked to feed back on their project experience in order to inform future collaborative projects. Research findings will be presented at conferences and may be published.



Discover
insight into the problem
Define
the area to focus upon
Develop
potential solutions
Deliver
solutions that work
PROBLEM
Problem Definition
Design Brief
SOLUTION
Wk 1 : Project briefing
Tasks... eg Research into contemporary design practice, User Journey Mapping, Interviews
Tasks... eg Create moodboards, evidence user journey, write reframed brief
Wk 3 : Research Review
Tasks... eg Initial ideas, model making, refine concepts
Wk 4 : Concept Review
Tasks... eg Refine final idea, model making, presentation boards
Wk 5 : Hand in

Student	6. What motivated you to take part in this collaborative project?
PD-A:	Wanted to improve my skills but also, I liked the idea of collaboration with E-textiles as it's something I find interesting but didn't have the opportunity to do.
TD-A:	I'm constantly inspired by the world around me, and the specialisms outside of textiles, and I wanted to use this opportunity to push myself.
PD-B:	Work with E-textiles, get to work with people from other disciplines.
TD-B:	I would like to work with E-textiles in the future in an artistic way, kind of an exhibition, and also interested in something new.
PD-C:	I like the idea of using other design disciplines to inspire a project in order to create something truly unique + different.
TD-C:	For learning new technique and knowledge.
PD-D:	- Creating something not done before - Working with other creatives
TD-D:	- Challenge of trying something very new to me. - Micro-Living - idea of sustainable living vital. - E-textiles is future of design.
PD-E:	Gain a new perspective with the way I approach design and better understand E-textiles.
TD-E:	- Being able to cross disciplines. - Seeing potential by integrating technology in textiles.
PD-F1:	I wanted to learn something new. Since design is an interdisciplinary subject I think it's important to learn about other related subjects as well.
PD-F2:	To learn a new skill and see what the textile course is about.
TD-F:	Want to learn more about E-textiles as I think it will potentially have a big future therefore may inform future careers. I think the possibilities of it are interesting too.
	7. What design skills and/or personal characteristics do you feel you have that will help you with the project?
PD-A:	Time management, my creativity, organisation and establishing a concept, developing it through to completion
TD-A:	I'm easy to get along with, I am organised and passionate. I can operate all of the textile machines with confidence and I have a good eye for colour.
PD-B:	Coding, E-textiles awareness, product design and problem-solving skills.
TD-B:	Imagination and used to working with other materials, not just textiles.

PD-C: Open minded to trying new things + using it as inspiration good understanding of layout and presentation to produce something that looks good.

TD-C: How to utilize E-textiles into space design, and consider colour match are important in this project

PD-D: - Confident prototyping ability.
- Curiosity.

TD-D: - Creative idea generating.
- Flexibility to try new approaches.

PD-E: Modelling - 2D and 3D, ability to work well in a team.

TD-E: - Being able to knit + have understanding of other textile specialisms i.e. print, weave, embroidery, multimedia.
- open-minded

PD-F1: I have good time management skills which will help me use my skills in the time I have efficiently.

PD-F2: Design skills such as developing ideas and concepts that could work well within the brief and E-textiles. Also working in teams it’s important to communicate ideas.

TD-F: Good problem solver + practical thinker as well as creative thinking.

8. What do you want to gain from being part of the project?

PD-A: Better knowledge of E-textiles/textiles in general and experience of being outside my comfort zone.

TD-A: I want to gain knowledge from another specialisation. I think this is valuable for my own practice in terms of the way I go about constructing my own design brief. This is good experience, as I may work with product designers in the future.

PD-B: More fluent use of coding and E-textiles better understanding of textiles in design contexts.

TD-B: New skills, new view on textiles, new opportunities to work with.

PD-C: Understanding another creative course and how I can use it within PD for other projects.

TD-C: Expanding my technique and knowledge.

PD-D: - Skills/knowledge of E-textiles.

TD-D: - Approaching work/projects from a different perspective will help with further projects
- Understanding of E-textiles + Micro-Living

PD-E: Same answer as question 6.

TD-E: - Better understanding of E-textiles and product design
- Friends

PD-F1: I want to learn about programming and manufacturing E-textiles! In addition to its various applications.

PD-F2: I want to gain confidence with working with new materials and prototyping products involving textiles.

TD-F: Better understanding of E-textiles + produce an interesting product that helps solve a design/living problem.

9. What challenges do you expect to encounter during the project?

PD-A: Finding unique ways to integrate E-textiles into micro-living and ideal areas of opportunity for our targeted demographic.

TD-A: Technical challenges - I know near to nothing about electrical, but I'm sure I will learn.

PD-B: Solving a real problem and creating a feasible product using E-textiles.

TD-B: Work with embroidery of knit, if our project would have need another media than print

PD-C: Learn how to create textiles and finding the right way to apply them to the project.

TD-C: Firstly, language about E-textile is totally big part to me. Second is how to attach technique to textile (about coding etc.)

PD-D: - Working together effectively
- Applying E-textiles into my way of working

TD-D: - Conceptual side of the project + high level of CAD drawings/presentation.
- Thinking about how to integrate E-textiles into work

PD-E: Ensuring that I deliver everything that I/We want to present within this time scale.

TD-E: - Things going wrong.
- Time management.
- Amount of materials you can use.

PD-F1: I've never learnt programming so it might be a bit more of a challenge for me. Another challenge would be finding a clever way to integrate E-textiles into our product design brief.

PD-F2: The biggest challenge will be incorporating technological features not only on the textiles but on the products within the tiny living space.

TD-F: Ability to apply + use E-textiles within samples successfully. Adapting to product design way of working.

10. What support do you feel you will need to complete the project?

PD-A: A few workshops in E-textiles a bit of self-learning and a reframe of the product brief every now and again so we don't lose track.

TD-A: A tutorial every week so that I know I'm working in the right direction.

PD-B: E-textiles tech classes, progress review, help with prototyping.

TD-B: Knowledge of E-textiles, connection between E-textiles and embroidery or knit.

PD-C: During the design process > coming up with concepts.

TD-C: Information about process.

PD-D: - Support from a textiles point of view to my ideas.

TD-D: -Support from tutors on deliverables + specifically what we must produce.
- Weekly tutorials with textile tutors.

PD-E: Tutorial sessions.

TD-E: -Designing with accuracy + safety.
- Reassurance of being on task + making appropriate decisions.

PD-F1: The option to spend extra time with lecturers in our groups to ask any specific questions.

PD-F2: I will need support from the textile team and also the product design tutors to help us develop the brief.

TD-F: Help with using E-textiles, especially applying it with potentially embroidery as I am not 100% confident that I could produce a woven sample

R: So how can we help you basically we are here to try and give you materials or help you with your ideas so it's up to you what you need. How can we be useful to you?

PD-F1: I think our primary idea right now is the paintable what was it called again conductive paint to create the sounds, the acoustics. So we kind of want to make essentially like a demo of that right. That's our main focus right now. Programming that and having a demo and the graphics and we don't know how else. We're kind of struggling to find other ways to incorporate E-textiles right now so that's what we're talking about.

R: Into your ideas [Group: yeah] so how about you go back then to your problem, because obviously you're going to have to show, they want you to show multiple ideas for Tuesday. So what are the problems that you've identified?

PD-F2: Well our main topics are entertainment and work .[R: Yep] So we want to like… there are people that live in the house want to have gatherings and stuff with people and have them entertained and at the same time they want a space they can comfortably work in, and have light privacy to themselves as well.

R: Yeah so I mean, certainly there are various ways that textiles can be part of that scenario, in terms of how they divide up a space, change the acoustics of a space. Did you, so… I remember you talking about sort of like the problem, when you went to your flat, and the problems that you encounter. So I mean, what you kind of need to go back to, I don't know if it's at all helpful in terms of thinking about how textiles could be part of solving your problem. Certainly focusing on breaking down small aspects of that problem, like to give a few examples, you know you've got people looking at if it's a workspace what do you need to work well? And how having a textile… because it's something that's movable, so if you want to change a space in between Entertainment and working a textile is quite an easy way, that can roll up, can fold up, can…

TD-F: Yes we think about that already. Having like a pull-down space, because the bed is going to be above, and then have that then a screen or something be able to pull that down so you can kind of close it off a bit.

R: And I mean maybe if there's other things that, that screen can do… because if that screen becomes part of that zoning of the workspace, what things in your environment do you need to control when you're working and… because that screen will be something that's nearby you so how it could contribute to helping you work well.

PD-F1: The other thing is with kind of focused on the work right now, we are still trying to think about how to solve the entertainment part of the brief, and like the seating and things like that for when people come over, because that was an issue as well, we are thinking about whether we could incorporate E-textiles in to that somehow, or in the kitchen somewhere, we are not yeah.

R: I don't know, I don't know how… let me try and find a few things.

IDT: So if you're going to do, so you're changing, so in the day it's perhaps working and in the evening you're imagining the person then changes it so it's more of a home environment.

PD-F1: Essentially we haven't any sketches yet… So essentially it's a loft bed and we just have different Layouts down here and what we want is this type of flip-able table and it saves space so then when people do come over you can flip it over, you can put it away, and then you can have people sitting here and then there is just this elongated lounging area. So we are still designing like the seats that can be moved around to facilitate that so it's more of like a Bachelor environment. We are also thinking about having this bed on this type of pulley system where you can kind of just push up even more, to have more space, more headroom. And even if one person wants to go to bed you can and you have the screens that you can pull down which are like soundproof and they're going to be sitting flush against the bathroom so you essentially have like a cubicle to yourself. So yeah we've kind of got this part nearly fixed it's just the entertainment, and like the seats.

R: Well so one way, what came to my mind in terms of them being foldable and light and portable like tensile furniture would be something that you could look up so that's very much integrating textiles with a more rigid structure.

IDT: I mean these, instead of folding up and being rigid, could do use a textile as part of the seats? So they either roll up or perhaps they fold against, into the wall.

TD-F: I said like a blow-up thing, I quite like that that's quite fun, blow up chairs.

IDT: Blow up chairs.

TD-F: Oh I thought that's what you said sorry,

IDT: No rollup.

TD-F: Oh ok.

IDT: But it could be blow up.

R: Either way yeah.

PD-F1: I think tensile furniture could be interesting because it could be easily folded.

PD-F2: Folded like.

PD-F1: Yeah I'm just trying to imagine, but that's actually pretty cool, but what would we incorporate into the fabric?

R: That that is what I'm thinking about… I mean one, I don't know if there are ways, and this is where it's maybe about thinking of the, it being an electronic textile system as opposed to it absolutely having to be the electronics into the textile. It might be that there is something about lighting with it, that… I was just trying to think out how… you know you could maybe have LEDs that serve as reading lights or something, because this is where you could like cross it over with this furniture being modular for when it's, between what do you need one it's an entertainment environment and what do you need when it's a working environment, and so it might be… that there is, I think you need to investigate that, what like, so one of the things about that tensile furniture maybe that there are different ways that it could open out. You could investigate like all different ways of folding, and according to that there might be that, when it's for entertainment, because you're talking about the conductive surfaces and things well maybe that is something that you integrate, that is in your tensile furniture, there are touch sensitive areas on the textile of the furniture.

TD-F: I think we should maybe incorporate that in the desk chairs so that it could somehow help the productivity, because we said about the light, we mentioned about trying to mimic natural lighting within that little space so that you can either then light for working, or if one of them wants to go to bed, one of them can still work underneath, and also so it doesn't feel as claustrophobic.

PD-F1: With entertainment there are issues when you're not using the chairs what do you do with them how do you store them if you have multiple sets?

IDT: Sorry if it's tensile furniture then surely they pack up quite small, so I mean you could put them in any storage spaces.

R: There can be little areas in the wall or something like that.

TD-F: We need like a little shelf underneath the bed space [Yeah] careful because of the weight/width but then things can sort of like just slide in [PD-F1: yeah okay]

R: So yeah, they would be a good way to solve that space problem. What else…

PD-F1: Are the types of textiles that filter air potentially, because we are also talking about including as many like, it's kind of like a something we considered near the end but like plants and things to filter the air, indoor plants, because when you have a lot of people it could get really stuffy so could we do that with textiles somehow, like smart textiles?

R: So air filtration, I mean if you think of a cooker hood, it's a carbon in a non-woven textile, is what it is, so that you could, like you could have some material. What you would probably want if you are wanting that sort of filter thing, sort of get filled up, like after a while it needs changing, so you would not want that itself to be the decorative part you'd want that to be something that you could just take out and dispose of and put a new one in umm. There are maybe, there's maybe something that you could think about to do with ventilation of the space, ventilation and filtration. So that's where you could be looking at sensors in the textiles that are triggered at certain temperature levels, or that sensing, you could look at like what environmental factors, like when you have a lot of people in the space what kind of thing could be the trigger for the sensor. So yeah easily for getting hot because we all produce heat and in a small space that's probably going to be something that you're going to encounter, so yeah that there is a textile that has a temperature trigger and maybe some vents within the space so that this textile opens when it gets too hot.

PD-F1: Maybe even if there is like higher carbon dioxide concentrations.

R: That's what I was thinking, I'm not quite sure if that's something that happens but have a look at, because there are sensors that are detect that absolutely you just need to know what the sensors need to be detecting so what environmental factors, even if for working or entertaining, might make somebody uncomfortable, might make somebody not so productive, and then how, so if it's fairly to connect heat with opening up textile vents but it could just be that there are panels that lead to a filtration system and that the textile, external part of the textile, it might have a pattern that if you're using it for that, temperature sensing, it might be that it itself that that part is like a beautiful wall hanging that changes colour or pattern with… and then it makes it also a feature and then you're like are we we've got a little bit hot and now we've got ventilation.

IDT: What's on the underneath of the bed?

TD-F: That bit? Or the space underneath

IDT: Well the immediate space underneath it, are you doing anything with that space?

TD-F: Yeah it's going to be the workspace, like the desk space. So you've got these desks

IDT: Yeah you've got the desks, but what the space here directly underneath the bed.

PD-F1: Right underneath. I guess just lighting [IDT: right] I think just lighting yeah

TD-F: We could incorporate some sort of storage in it maybe [PD-F1: maybe, yeah]

IDT: So it's quite a large area isn't it.

TD-F: [Team: yeah] yeah we could have something that you mentioned before about having maybe the chairs that are flat and then you can clip them on the underside, slide them.

PD-F2: We don't know how much space that we're going to have.

PD-F1: For storage, because the mattress takes up space.

IDT: But if you've got somebody sleeping up there and somebody is working down there you really want it to as much as possible be sound deadening don't you. You want it to stop, so if they're working below you want the sounds to be deadened as much as possible, so it's not being reflective surfaces. So what material is great for not reflecting sound.

R: Textiles. Textiles, to not reflect sound it's textiles. That's why you have textiles in acoustic rooms and things like that

IDT: So what would be good underneath there, the whole of that?

TD-F: A nice bit of fabric.

IDT: Textile. What also do you want underneath there, if you're working?

TD-F: Lighting.

IDT: Lighting.

R: So that could be one whole system.

IDT: So there is one whole system. So what you want is the textile that stops the sound, but you want it distributed with lights which you could control to give the correct working environment in terms of light

TD-F: And I guess then he wouldn't have space taken up by desk lamps and things.

IDT: Yeah.

R: So one of the products you know I showed the company, this company, I showed different project that they'd done but they did this rollable photographic, so for photographers, a light that they can roll out to take when they're doing photography. So obviously to make it rollable it had to be it was a textile system with embroidered conductive tracks to make the lights work.

TD-F: Can you use the conductive thread on the multi-head machine?

R: I think so yeah. I don't know if there's any pictures of… I mean this is all industrial embroidery that they do this is whole sensor units.

IDT: But if you're looking for something to incorporate both fabrics and lighting that would be something to do.

R: If you want to try something out, there's different versions.

TD-F: Because I think [TDL] said, I can't remember if she said she had used it.

R: Yeah [TDL] done a bit of embroidery. If you want to speak directly to [TDL] about what has, what she already has done, because they have done quite a bit of experimentation to support the ATRG, so yeah talk to her about that, if you want to take that away for you to try some stuff out, to try out the textile side of things.

IDT: So you could have something that's underneath which is cloth, textile sorry which would be sound absorbent with lighting built-in [TD-F: yeah), it could even change the colour and the atmosphere of the lighting.

TD-F: Yeah because I think we're on about the entertainment bit, incorporate some sort of light feature that could change colour or be quite a nice, a bit of a party.

IDT: You could have disco lights there, so you could actually have it programmed to change the, if the lighting is distributed all around this and it's multicolour, then you could do basically like a video wall but on the ceiling.

TD-F: Okay like a reverse dancefloor yeah.

IDT: So that would give you a fantastic disco lighting underneath there and then but during the day it's then just white or what colour you need, off-white perhaps, to give you enough lighting to work, and in the evening it turns blue to get you to sleep [TD-F: Yeah]

PD-F1: What if we had like a section on the wall that was textile wall and it was more like mood lighting throughout the day to help with like sleep patterns or just things, like that maybe towards the evening when you're starting to get tired it's more like warmer colours to energise you and help you work or whatever and maybe it could be thermochromic as well.

TD-F: Maybe we could like…, like a dimmer switch, maybe it could detect the level, the brightness, so sort of like as it was getting dark they would like slowly start getting brighter.

PD-F1: But also you could have like a pre-program system where like as it becomes later at night it decreases in light so then your melatonin levels are like higher.

TD-F: So I guess you could program it to kind of I don't know.

R: There are these programmable bulbs so if you want to look into what they can already do and think about what else you might want to, like that might give you some ideas of what is already available but also might trigger, because you might see some obvious things that you're like oh it doesn't do that all that's a real shame, what I would like to do is…. So in terms of, do you already, have any thoughts from the textiles side of things about any of the ideas that you have, how they're going to look like, like the actual appearance that you want out of the textile.

TD-F: Yeah I think we've started to do like a bit of a mood board of things (R: That's good) like colours, so keep it quite like, sort of quite, I'll show you. Keeping it sort of quite like, we're going to have like with the paint wall, have it quite like a natural, scene not scene, I don't know I haven't had a chance to…

PD-B1: Quite like earthy, organic type of tones. We're also looking at tactile therapy and things, how it essentially tries to transcend you into the environment that it is, so we're going to have audio like nature and maybe underwater sounds. So kind of like reflecting that in the stuff that we touch so we kind of need to explore that as well.

R: Definitely I mean with embroidery there's ways of making that a very tactile experience.

TD-F: Yep, that's sort of the colours I was thinking for the inside. That's what I was looking at for the E-textiles bit, sort of like that.

R: Yeah definitely, in terms of, I know you were talking about conductive paint but that could easily be in conductive embroidery there is no reason it has to be the paint, or it could be a combination of printed and painted and embroidered to give different textures and allow different sort of mark making into that surface. It could be something quite bespoke.

TD-F: Yeah I want to get some designs done before the end of this week. Get some ideas.

IDT: So you could have something that has a couple of those things together but see what they say on Tuesday in terms of direction. It's just then how we can help you to… but you don't have to actually create something in total for what you're doing [TD-F: Yeah] just enough to show that you've investigated it that you've got some understanding of.

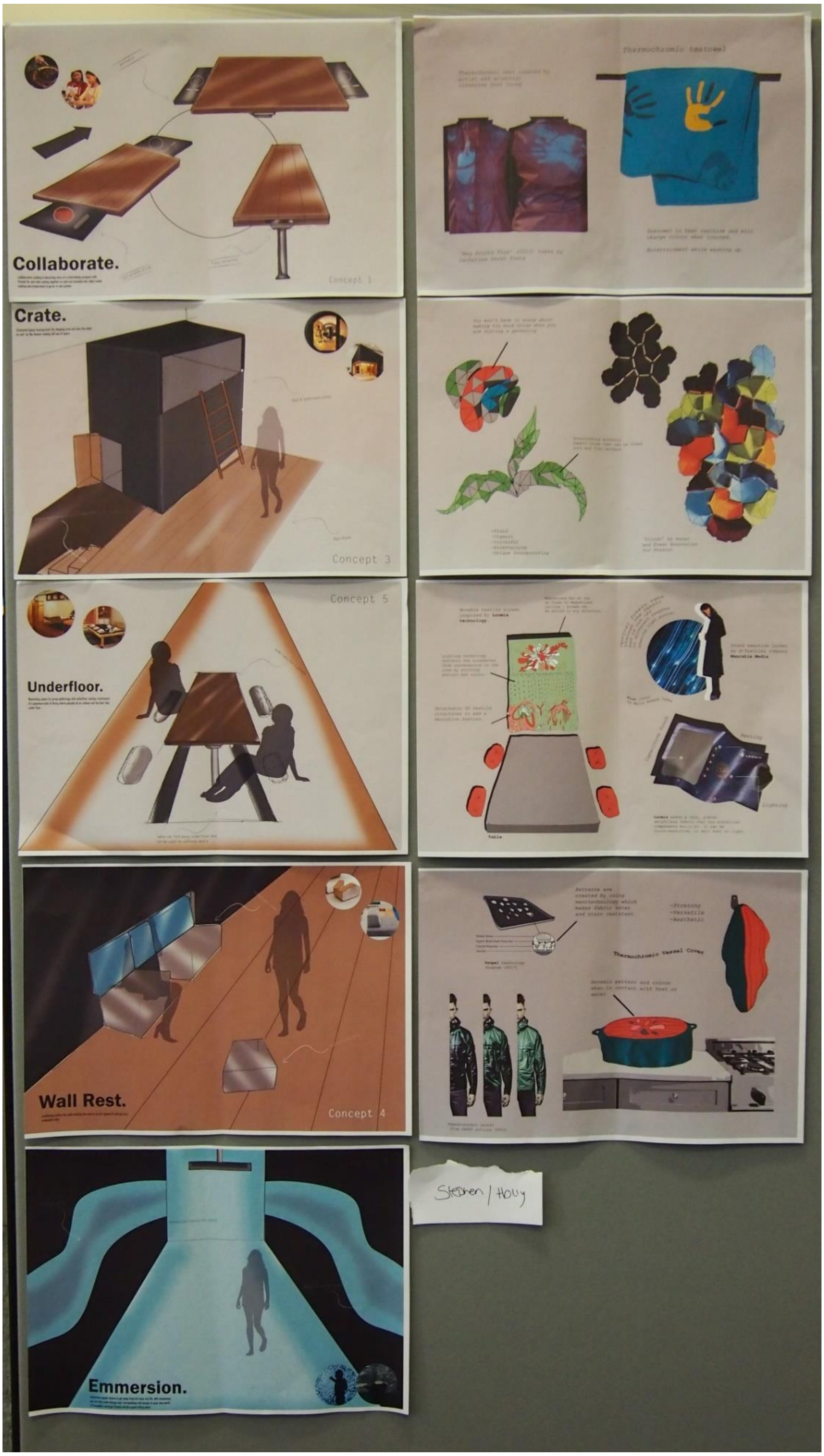
TD-F: Because I guess even if I can't embroider on our multi-head with this or there is not enough for whatever I could just do it with regular and we'd just see how it could.

R: Well apart from anything else, we are certainly not expecting like a full-scale model so it may be that you just do a [TD-F: a sample] small swatch and that's absolutely fine.

PD-F1: For the entertainment I remember that we were talking about having that paint and maybe having like a DJ deck type of set up on the wall so you could like play with that when you have friends over.

R: Yeah I mean, if you want so, I imagine you're one of the groups that talked about wanting to use the Touchboard. Between now and next week, I don't mind giving you that if you could bring back because this actually belongs to me [PD-F1: Oh thank you] I'm happy to lend it to you. Before the end of the session I'll find the cable. There's the cable and it runs with Arduino. If you're having any trouble just send me an email and we can organise to meet sometime between now and next week [PD-F1: Ok] but there you can start, just have a go, don't I think you're already trying to program your thing. Just have a play. Because you've got to work out how to make Arduino work and stuff like that, so that's enough of a challenge, just to make it do anything, so go-ahead [PD-F1: Thank you].

Team A: Concept review presentation

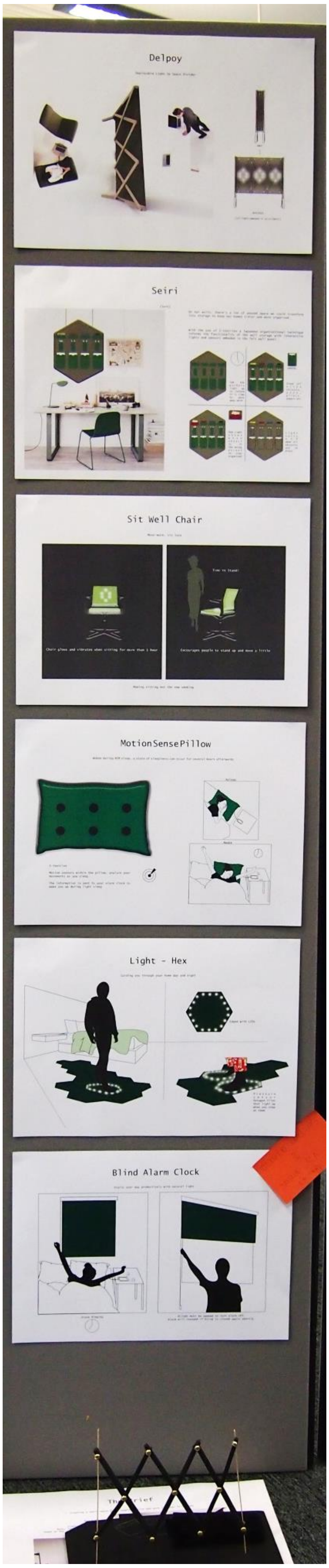



HAVEN.
Haven contains in built leds woven into the fabric as well as Motion sensors creating a entertaining sensory experience
HAVEN.
HAVEN.
Motion Sensor
Escapism
Entertainment
Immersive Space
Flowing
Interior View.
HAVEN.
HAVEN.
Escape from the busy city life and relax with freinds or family in this entertaining multisensory space


MARCO & SARAH
COEXISTING IN SMALL SPACES
BOARD(?)GAME TABLECLOTH
MUSH_ROOM
BOARD(?)GAME CHAIR
OPACITY
ZIG ZAG
PRIVACY CHAIR


REFRAMED BRIEF
USER PROFILE
Living in Lagom
not too much or too little
Geography Korean drawing
Design 1: Mountain
Design 2: Water
Design 3: Wood
Design 4: Stone
What is the "Lagom"?
LAGOM
KETACHI + SUYEON


LIVING IN THE "HEU-REUM"
FOR WORK AND RELAX.
USER PROFILE
LIVING IN THE 흐름 : HEU-REUM
: not too much or too little
Thermochromic pigment
KETACHI
SU YEON
HEU REUM 흐름
PLEASE CONNECT POWER
FINAL SAMPLE
3D RENDER OF STUDIO LAYOUT
FLOORPLAN
Studio
HOW IT WILL WORK // MATERIALS + INSTALLATION
POSSIBLE MANUFACTURER/COLLABORATOR // NIMESIS TECHNOLOGY
Shape Memory NITINOL thin wires with woven textile
PLEASE CONNECT POWER



Concept

Final

Concept Final


The Zebra Chair
The Ultimate Loft Bed
The Pop-Up Kitchen
Bathroom


Tranquility, whenever and wherever
Biombo
Fresher and cleaner air in your home.
Create your symphony, set a party mood.
Biombo
Biombo
Double sided
Set the mood
Biombo
Menu
Lights
Music
Biombo
Work
Play
Relax
Biombo

R: Did you think the constraint of material, so having to make it an E-textile rather than just any textile made your product solution better or worse?

TD-A: I think it made it better because you had to think about that element as well and kind of like, to have, it made it more interesting as well, whereas if you didn't think oh I've got to incorporate this element as well you might have gone for something a bit more basic.

TD-E: It's like for us, having just the plant pot, you could have had just a plant pot but then it's like you could have an E-textile plant pot. So, it's like pushing it to the next level so I guess it would make it better, yeah.

TD-D: I found at the very beginning I thought of it more from like the product without the E-textile part. Like my mind would automatically think of things that folded or things that just worked on their own and I thought 'how do I incorporate E-textiles?' And then as the project went on it became a bit more clear how…, like with the workshops it became more obvious how it would benefit it and then I do think it … the project a lot.

TD-A: The other thing we found it difficult at the beginning to sort of think about how we were going to incorporate it but as time went on we just sort of realised how the things that we found out about would apply. It just took time basically to figure it out.

TD-E: Yeah, I definitely think like product came first, E-textiles came second, rather than thinking of what we could do, to then apply to a product, but then I thought that might have been easier. I don't know.

TD-A: I guess we're working with people that just automatically think that way.

TD-F: We didn't go to that straight on. It kind of went round a lot just to get back kind of to square one and like figure out what to do, to catch up to where.

TDL: So how long do you think it took you to get to the stage where you could really start thinking about the E-textile?

TD-E: I would have said last week [laughter].

TD-F: I would say 3 weeks, solid 3 weeks because that's after the initial research and….

TD-D: Do you mean the idea or the actual integration and how it works put together with the textile?

TDL: Um, I don't know really.

R: I think, you were saying you were thinking of products, how long did I take you to…

TDL: Get beyond the product.

R: To see like…

TD-D: 2-3 weeks at least.

TDL: You're all nodding… you don't agree.

TD-B: No, we, I think we found first a shape with textile and then we were thinking about how we were going to use it as a product. Yeah, so for us it wasn't, I don't know, like it was fine.

TDL: You felt like you were thinking about E-textiles right from the beginning?

TD-B: Um, we were thinking of, first about textiles and then how we are going to incorporate E-textiles and we like, found out many ways but then that it's not possible to make that like we'd like to do that so we were thinking then other ways and then we find E-textiles and then we were thinking about how we are going to use it because we knew that we would like to make some kind of divider of privacy so we were thinking about this and then like in the end it was like we split both, like curtain and divider into one.

TD-F: I think it's quite hard as well because it's still quite a new thing, it's quite hard like in the research stage to think of ideas because lots when you do research it's still quite a lot just LEDs.

TDL: Yeah [laughter]

TD-F: There's not a lot of …

TD-B: Yeah, we didn't want to work with LEDs in the beginning but then we found out it was interesting because we got a shape so it was like one working with the LED, the shape, the transparency and shades.

TDL: Do any of you feel like you came up with a product idea that felt new and different to you form the research that you had done?

TD-A: Yeah, I hadn't necessarily seen anything like our final concept, because it's so concept based I guess.

TDL: So, you felt like you were thinking beyond what can really happen?

TD-A: Yeah.

TDL: At the moment.

TD-A: But also not. I think it would be very expensive. I think it's possible.

TDL: Yeah.

TD-E: I think for our group it's obviously like it has been done before and there are like things that will water itself. I think it's more like a design that I haven't seen so much like a…

TDL: So, you felt like you were really integrating the electronics with the textiles with the product.

TD-F: I think with ours, like the paint, it's a thing out there but no one's really used it commercially. Or as far as we've seen. You can buy like the paint and the circuit board, but we couldn't see any company that's really utilised it in an actual product.

TDL: And that's really interesting because I guess that's one of the things we think isn't it, that there's a load of new materials out there that no one really knows what to do with… and you were trying to bridge that gap I guess, ok.

R: So, my next question would be, did working with E-textiles change your design process, compared to how you would work on other projects?

TD-D: I think it's hard to tell because the nature of the way we worked was really different based on the whole product design element and the fact, I mean obviously our usual process is like: gather visual research, develop a concept, gather research start to make from that and then work, or that's how we've learnt to start projects and it was like we can't get to that stage until the product was finalised and I guess E-textiles came at the back because that was kind of done at the first stages with the product, or not like the first stages, the middle, the aesthetics came probably last… last stage yeah.

TDL: So, did you mind that?

TD-F: I think I didn't like it the fact that I didn't feel as like… helpful. I wanted to kind of like, because they were doing a lot of like product design online CAD. So, I wanted to like, work my fair share, but it was kind of hard to do that because I didn't want to go and just…

TDL: Do stuff for the sake of it.

TD-F: Yeah because I went in and did some embroidery and I just kind of did it and then I was like but actually it was like we've already decided that we're not going to do this anymore so…

TDL: There's a bit of nodding there, what would you… any other?

TD-A: I feel like we tried to make it so that the design grows with the technological development and other ideas but that, I think its individual to the group because everyone thinks in a different way or is like more or less open to ideas, some ideas do you know what I mean?

TDL: So, if you had had to do it by yourself, and you hadn't had the help of a product designer, what do you think your challenges would have been?

R: Or how do you think you would have done it? How would you have approached it?

TD-D: I think it would have been a lot less focus on the function and the object and what it was meant to be for, and more about the aesthetics and how it looked and so it would have been more experimental in some ways but in other ways a bit limited because I think the product…

TDL: A bit purposeless.

TD-D: Yeah, the product helped like, like a purpose, what we want to achieve and then how we could do that, so it did give it more of a substance.

TD-E: I feel like the session that we had, where it was like the day of the customer journey, user journey, I wouldn't ever have thought about doing that. I feel like it's definitely changed the way I've thought about design. I would definitely use that in my stuff again because then as you said, it's like you're designing for a purpose now instead of just the aesthetics, it looks nice, which I feel like we do.

TD-A: Same, I found that in other projects, I made something that looked really nice as a square sample but struggle then to apply it.

TD-E: We're kind of set to just interiors or fashion, and you say 'oh this is nice let's put it on a sofa' but to actually put it on something that is actually going to be used by someone that's obviously going to push our design further… [Quiet agreement].

TD-D: It encourages us to look at our projects differently and imagine things for all different outcomes because I think a lot of us will tend to focus and think this is a dress or…

TDL: You'd just focus on the materiality and the fact that it lit up, rather than thinking about why do I need it to light up? How is somebody going to make it light up? So, designing for the interaction with the textile is something that you feel it was helpful to work with other people [various yeahs] on and learn from their design purpose?

TD-E: I would say it is probably going to be vice versa… hopefully [TDL: Yeah laugh] that they would think more about the materials they use instead of just saying, oh… I feel like our just putting it on a cushion is their let's just use wood. Whereas they might now think into material awareness and stuff.

TDL: I was going to ask that question really, what do you think they got out of working with you?

TD-D: More colour [murmurs of agreement] more colour in the design [TDL: colour] experimenting that way.

TD-A: Yeah and just sort of being more open to think beyond practicality and maybe just to dip your toe in a more conceptual ideas I think… which then helps you to create something a bit more down to earth [TDL: yeah].

TD-E: With ours I see a lot of prints going on, like this a divider which could have different kinds of prints going on, but I feel like the others, it would just be a divider, and that's all you're going to get because obviously they're just thinking of that… the length that it could go to…

TD-A: And… if it has those design elements it's more interactive for the user as well, it's very beneficial for them because effects emotions and atmosphere that you wouldn't otherwise get with just a product.

TD-F: White and basic and minimal so I think they found it quite nice to actually have… justify having, not more flamboyant design but a bit…

TDL: More considered.

TD-F: Yeah, yeah and a bit more exciting than just plain

TD-D: And know what to do, what to add to their design

TDL: Yep.

R: And that relationship between aesthetics and function and interaction. How did think about function and interaction maybe change the way you were thinking about the aesthetics that you were bringing in? What did that change compared to how you normally work?

TD-A: It's very much based around a fictional character isn't it… So, they always have these character analyses… their target market. I think that's a really good thing to learn because you know exactly what you're trying to [TDL: So, something about] make them feel.

TDL: I mean you'd be quite used to doing concept boards, doing mood boards, creating colour and atmosphere and tactility in your work but I think what you're saying is that you haven't really thought so much about the engagement with it. How somebody feels or actually interacts with the product… function, functionality of what you do, stick it on a sofa [laughter] stick it in a dress, you know.

TD-D: Yeah, the user journey [TDL: yeah) I think that's a new word that we know…

TDL: Yeah that user journey really maps somebody's experience with the product.

R: I was also thinking, it's a layer past market research because don't think of it just as a market, try and think of an individual that represents that market.

TD-A: It goes so deep because where do they shop? What do they do on a day to day basis? It's so detailed…

TDL: What things get on their nerves [TD-A: Yeah exactly] and that's a potential design problem for you to solve.

TD-F: I think that was good, highlighting key problems [T: yeah] to solve.

TDL: So that could really add focus and depth into your subsequent design journeys maybe. Do you think it was useful to have that kind of a story, if you like?

TD-D: Yeah, I think it was challenging at first because to get our heads around a different way of working but it really did lend itself.

TD-E: It gave you more ideas, rather than just having nothing. It gave you something to go off.

TDL: Um ok. Have you learnt what you expected to learn on this project?

TD-F: I think I thought there would be more … because obviously we had the E-textiles workshops bringing your ideas. I think I was expecting more to be able to be able to go and see different things in use or make it to do that

TDL: More prototypes, [TD-F: yeah] more examples maybe?

TD-F: Yeah… kind of more making.

TDL: More taught.

TD-F: Yeah, more taught things.

TDL: Rather than, work out the idea and we'll help you to do it.

TD-F: Um, because you wouldn't necessarily know about some of the things, like I would never have known about your water sensor [yeahs of agreement]

R: Yeah that's what …

TDL: The product designers said similar too. They said it in a different way, but they meant the same thing I think. Sorry Janna were you going to say something? [TD-D: umm] The question was, have you learnt what you expected to learn or something different?

TD-D: Oh yeah, it was nice in a way to be left kind of independent in a way with our ideas. We were exposed to a lot of different possibilities and shown the kind of things we could do and that helped how we can generate ideas and then once we started that … obviously our ideas developed but we could explore on our own what kind of aspect we wanted … you obviously did research and found that on your own and so it was what we were interested in which was pretty cool.

TDL: Yeah so, it's trying to get the balance right between giving you enough input in the first stages to use [yeahs] whilst also noting that you are breaking new ground and trying to find new uses of things. What have been the most enjoyable parts of the project for you?

TD-F: It was nice seeing the actual product. Designing something and then those guys could then turn that into a really sophisticated CAD model and you could see it in use and in situ. That was really cool, seeing that.

TDL: Took it a stage beyond what you normally feel you could do by yourself.

TD-E: Instead of just a visualisation on Photoshop it was good to actually make it. I feel I pushed myself because I haven't done shaping, I hadn't done that before and normally I would just say this is what it could look like so then to actually have to produce it as well it was a good thing. [yeahs]

TDL: What about you [TD-C]?

TD-C: Actually, I can't really… a lot because I did it all on my own, because I did work alone because I tried to experiment and our base idea was from my research and then just tried to make like that and then just ok and then don't mention it, don't complicate. Yeah so, I just worked alone.

TDL: So, you didn't feel that it was as collaborative [TD-C: yeah] as you thought it was going to be for you?

TD-C: Yeah, actually it … to me, it was kind of stressful because she don't mention and she didn't include our work so.

TDL: Yeah so if you don't get the communication right in your team, was that a problem? [Quiet pause] depend on the team [yeahs]. You don't have to tell tales [laughter) It's always a problem isn't it, collaborating with somebody else you've got to find your working relationship and it's a challenge.

TD-A: It really helps if they're eager to want to talk to you every day or at least about..., even just checking in, 'oh how's it going', 'it's going good'. It's nice to have a little support system.

TD-E: I actually found it was nice to work with a guy [yeahs] because we have just been girl, girl, girl and it was nice to.

TD-A: Refreshing.

TD-E: Yeah refreshing and even just to have… maybe I would have done it more, I don't know… because I think flowers are feminine anyway but seeing it from a male's point of view as well just taking it different. Because it might have been different if I had a girl, I don't know.

TDL: Yeah, ok, so I think you've probably asked some of the next questions, I guess what I wanted to know was what you like the most about it but also what are the things that put you off a bit from engaging and I guess what your saying is sometimes communication was difficult [yeah] actually collaborating was difficult. Is there anything else that you felt was a barrier or a hurdle?

TD-D: The only times that I felt like the project was quite challenging was the beginning stages when, I think someone said earlier, we were a bit more like…

TDL: Spare parts?

TD-D: Yeah, obviously sharing out the work is important, so we would do, try and do as much as each other but because the CAD, as much as I like CAD that part is more challenging. They've got a lot of software and things that they can do, more 3D things and they can do things quicker and they know more techniques and stuff. So, with me I was trying to keep up and teach myself, like ok, how do I know how to do this in Photoshop and Illustrator? So, it was more challenging I found, all the CAD at the beginning.

TD-F: The design outcomes, the product design won, whereas I think it might be nice to have like a few maybe textile pointers along the way as well [TDL: yeah]

R: Yeah: We've talked about aligned deliverables, more of a balance and clearer and that you would be judged as a team at the same point probably so that there had to be textile boards and so that would have made you make it. Because the product designers had a lot to deliver quite early on.

TDL: Whereas you almost had to wait to decide what the products were before you could develop the textile and it's like, that came in the last week really didn't it and you haven't really had time to develop the textile, it like only at the starting point or the first prototype, like you said.

TD-D: The textile is usually more resolved [TDL: yeah] I find there's more time to think about the techniques the aesthetics and things like that.

TDL: Yeah you didn't really have time to… It's like you need another two weeks now to go away and really resolve the textile ideas and check that you are using the right fabric and are there any other particular techniques that would be useful to… to really, you know, make your embroidery really work. Do you want to do it digitally? Do you want to look at some different stretch structures in stitch?

TD-D: Ordering fabric and stuff as well.

TDL: So, you didn't actually get a textile design tutorial did you, you got E-textiles, but you didn't actually have like that kind of element.

TD-D: That would have been a really nice thing, just one with us.

TDL: Yeah.

TD-A: Yeah.

TD-D: All of the textiles because that's usually how big tutorials are roughly 6.

TDL: What kind of questions would you have been asking there then?

TD-E: I guess, I don't know, just see more of the textiles side of it but also, I felt like their like obviously experimentation is through product drawing, like this could be this and this but me trying to draw different knits that just doesn't work.

TDL: No, you do it through making.

TD-E: But whereas that, that didn't happen until now and then I literally had one design and that was what we were going to go with.

TDL: And that would be really interesting, sort of taking that back to the textile tutors won't it because they're going where's your loads of samples? And it's like, well there's one.

TD-E: Like my tech file is like zero.

TD-D: They'd be like, what are you doing?

TDL: So yeah, I think that's quite interesting, in terms of what the project deliverables are. It's a different way of working towards one finished result prototype rather than…

R: I'm wondering whether you could do it that in parallel whilst their doing… because… talking with the product designer seeing as it does almost seem like they have to do their first bit of the diamond, you could almost come in once the product had been decided but that seems like.

TDL: You don't have a say

R: So, maybe what you could do in parallel whilst you're working on all of that product bit would be if there was a bit more taught actually trying to develop different types of E-textiles, like circuits and systems, it would have also meant a bit more taught side of the E-textiles so you could experiment and how you could make it functional and also visual and then you'd have had more E-textile knowledge prepared for when you'd chosen your concept.

IDT: I think the problem though is that if you go in later on, then it's interesting because you guys are interested in the actual materials, experimenting, having the knowledge of the materials and experience of them which is very different to what product design. If you come in later on.

R: No but I'm saying they'd be doing it in parallel though, it's just…

TDL: I don't know whether you could have done that though because…

R: Maybe not.

IDT: Because it wouldn't inform the design then.

TDL: Because I think you almost had to, because I can see now form conversations last Thursday that I just wanted to say there were so many ideas that ok that's a great idea. For instance, let's go and have a look at a load of construction techniques and embroidery that make things expand and collapse and you need to spend a few weeks doing that [TD-D: oh yeah] and one solution [TD-D: there was no… before today], you know there's so many, yeah, options. For you with your lace knit structures, for you with how you were going to develop interactivity in the fabric, and you'd got some really good starting points hadn't you, you guys but it's just more time to develop the aesthetic of it or how the electronics actually integrate into that practically. So that you know that it will work and function and feel right, rather than just a proof of concept that, yeah, I know that I can get it to work or I can be made to work, actually making it work is different isn't it. So, I think it… I don't know that's my perception but…

IDT: How would you structure it? Have you got any ideas yourselves from the experience?

TD-D: The only thing I could say, I know it sounds pretty simple is to extend it. I know that obviously we need more time. I don't know how useful the time would be for the product designers, but I think even …like… for model making, floor plans. I think there would probably be a fair amount for them to be getting on with.

R: Yeah, adjust their deliverables, have different deliverables.

TD-F: Yeah, because it was like we were spending time helping out with that, whereas actually if we'd spent time in workshops.

TDL: Developing your fabrics.

TD-F: Yeah. Because I think if we had, so if they had a sort of like a group outcome but we each had separate things that we each had to deliver and not… because then yesterday, 'we've got to print out all our research' and I was like 'oh, ok, well mine's all on like a file' so I think, yeah…

TDL: Yeah, formats for the project is different as well because it wasn't… They were already doing it in their module. We're doing something different in our module so yeah obviously that doesn't function as well as it would if we'd written the project together from scratch and made sure that you'd got all the right constituent parts.

TD-F: I think like obviously because we're not each aware of the differences as well which makes it difficult then in having all the stuff in…

TDL: Yeah, and I think we weren't sure what the difference was going to be either, in terms of what we asked you to do and that's why we've been flexible with that. I gather you will need a technical file to map all your processes that you've done but yeah, I do acknowledge that you haven't had as much time to develop fabric swatches as we thought. So is it one or is a series of different things… but yeah, the user journey, great [yeah], that kind of stuff, that's a really new thing that I think will really enhance learning from what I can sort of see and from what you're saying and that something you…

R: So, I had another question. At what point, and this both in terms of weeks and terms of where you were at in the design process. At what point in the design process did you start to make textile samples?

TD-E: Mine was last week.

TD-D: About a week ago... a week and a couple of days.

TD-A: Yeah definitely a week and a couple of days ago.

R: Because I know you guys maybe had it a bit earlier on.

TD-B: Yeah we made first those small samples because it was to find that [PD-B] had the 3D printer, so she knew the knowledge. If I got the idea she told me that it's possible to make it. Like in our collaboration it was really fine because it goes like… maybe at least we somehow imagine it was fine then. So those were like first samples were small and then I think previous week we, no two weeks ago we made the bigger samples and then the final samples arrived previous week, but we got many troubles with doing it so its yeah…

TDL: Yeah, timelines, material ordering, knowing you've got the right materials, not knowing what materials you want until you've solved what the actual problem is going to be that you're going to solve [TD-B: yeah, yeah]. So, there's lots of practical problems there that mean it would be very hard to do it as a short sharp project in a week if you're genuinely going to come up with your own design problems and ways forward. Yeah... Any other top tips if we did it again? What would you say?

TD-F: I really enjoyed doing the collaboration, I think it would be a really nice thing to have permanently even if it's..., like you could pick the different collaborations because I think it was kind of a shame that we've missed out on the workshops that have been going on [TDL: yep] because they sounded quite interesting. I think it would be something to still do but…

TDL: Try not to do it instead of what you're supposed to be doing, yep we can do that.

TD-D: I would say because we were mainly based in here [product design studio] for lesson stuff which was fine because I actually really enjoyed the guest lectures and stuff they were really. I thought they were really appropriate, I don't know if they…

TDL: Yeah, they were brilliant, weren't they?

TD-D: Yeah really interesting. But, it would be nice to have had a couple more sessions in based in textiles or for them to come into our…

R: Like a textiles guest lecture, type?

TD-D: Or just a session like we came into a session, it was really interesting, we came into sessions of them learning about user journeys and things like that and had a day there so maybe if they had come and into our course and learnt some things about ours…

TD-F: Yeah more of like a 2-way thing as opposed to like us just doing theirs.

TDL: Yeah, it's quite interesting because we thought that the E-textiles workshops were those things, but I completely get what you're saying actually, yeah.

TD-E: Because I feel like maybe they didn't know really what textiles are because I thought I knew what product design was, but I actually thought it was furniture design and I didn't realise there was a separate one for furniture design. So, then I kind of knew and I took him into knit and made him knit, like to understand it because I feel like he didn't really know the potential that you could do so I feel like them having the hands-on experience might like even have led them to more design ideas or something. [yeahs] Just to experiment a little bit…

TD-D: Did he actually knit?

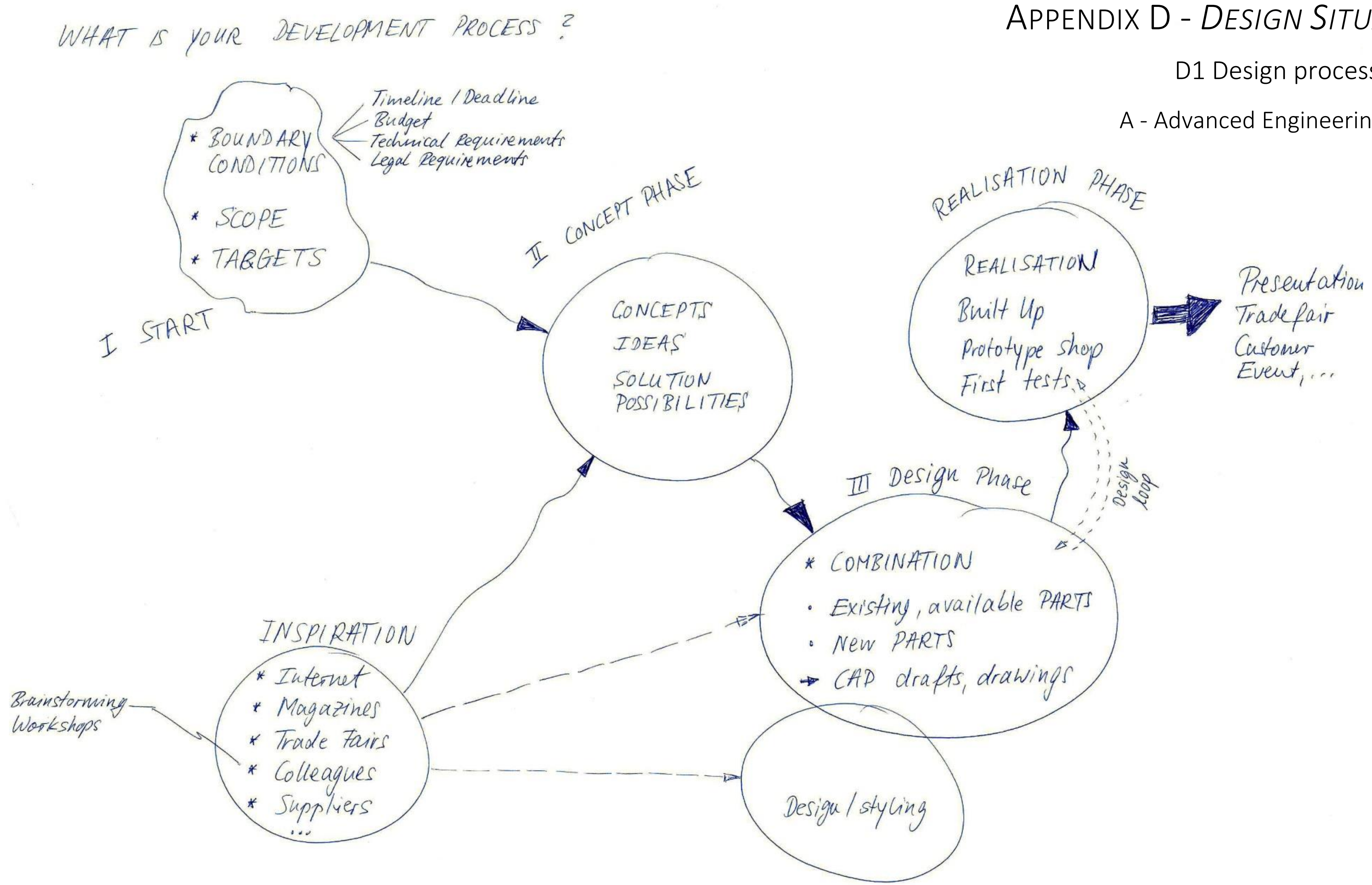
TD-E Yeah, he was so proud of himself. He took it to the tutorial, like chucked it on the table like 'look what I've done' [laughter]…

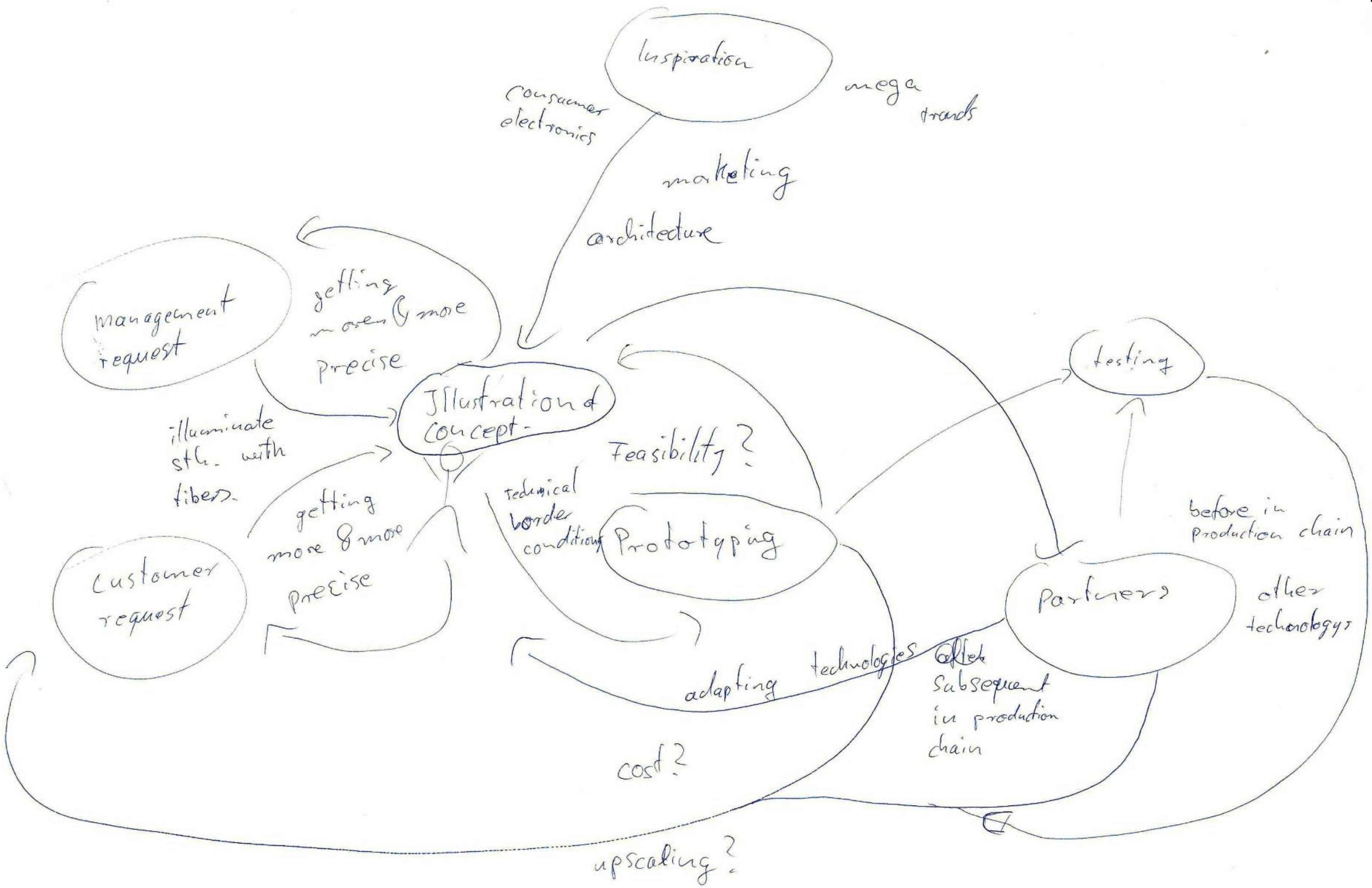
TDL: Anything else… no.

APPENDIX D - *DESIGN SITUATION 4*

D1 Design process sketches

A - Advanced Engineering Manager




Inspiration
consumer electronics
mega trends
marketing
architecture
management request
getting more & more precise
Illustration of concept
illuminate sth. with fibers
Feasibility?
technical border conditions
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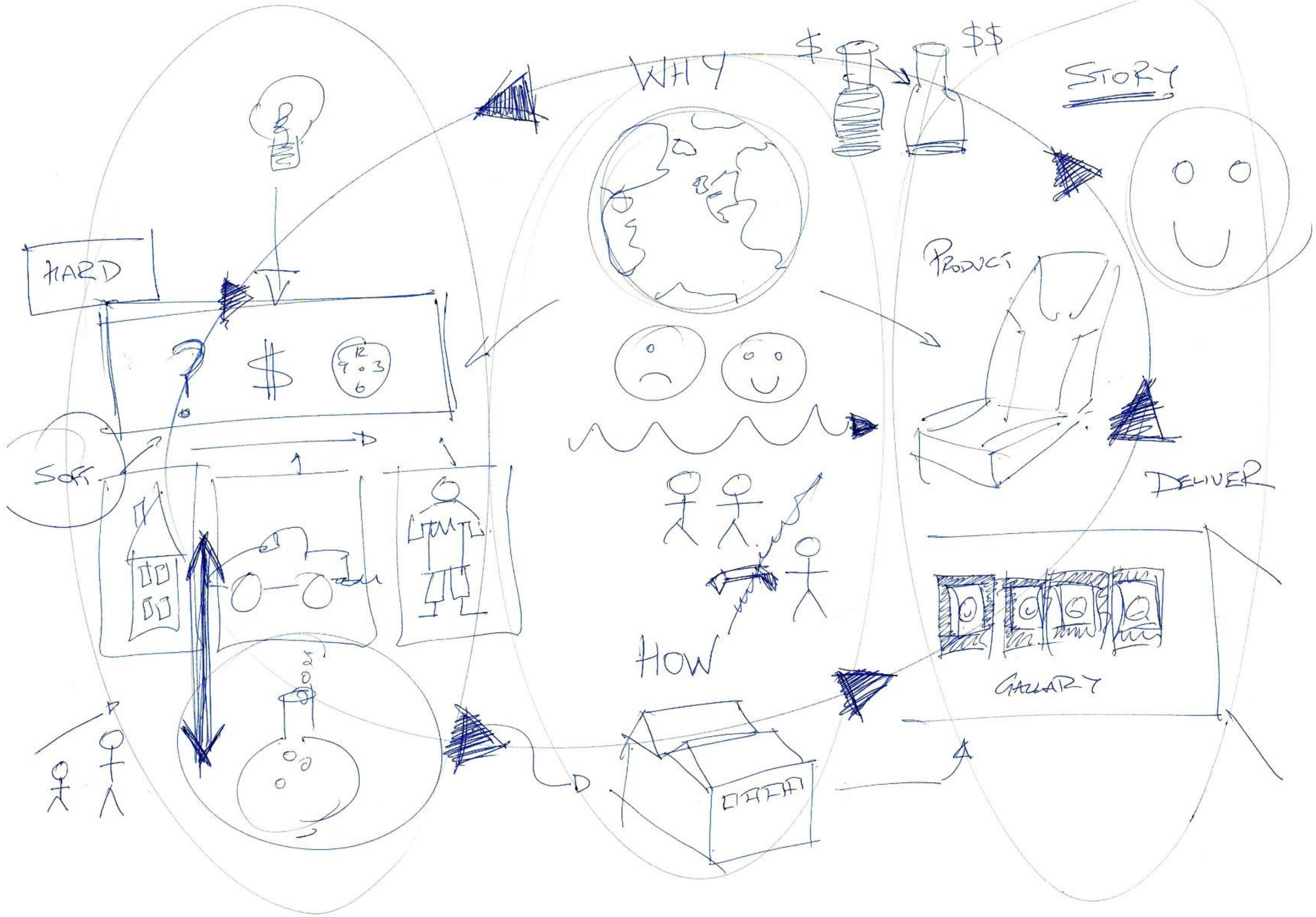
subsequent in production chain
cost?
upscaling?


WHY
$
$$
STORY
HARD
$
SOFT
PRODUCT
DELIVER
HOW
GALLARY

focus

problems

functions

product

evaluate

optimize interaction

how to use the seat?

long term sitting

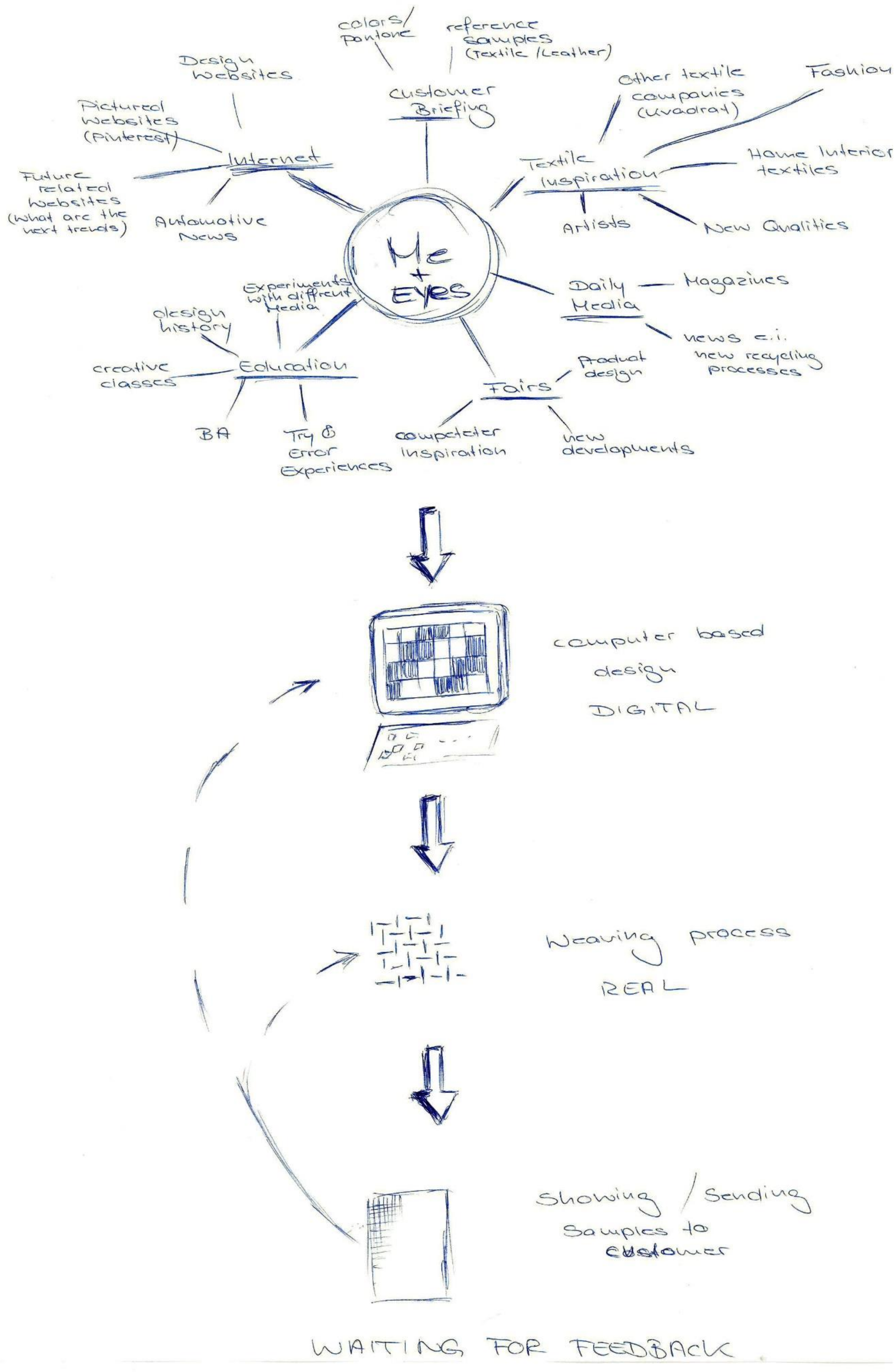
user

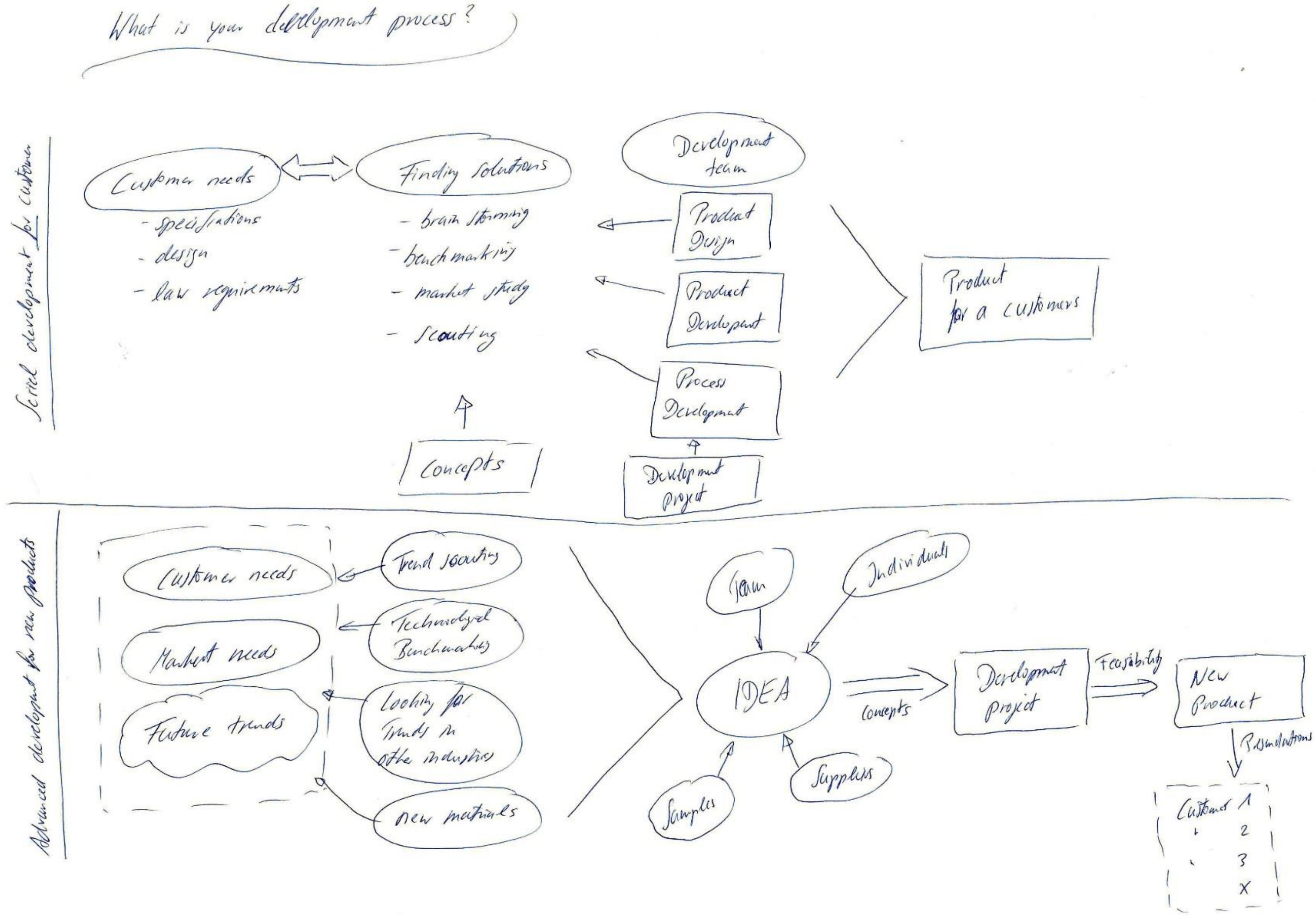
what the user needs?

human factors

health

wellbeing


colors/
pantone
reference
samples
(Textile /Leather)
Design
websites
Customer
Briefing
Other textile
companies
(Kvadrat)
Fashion
Pictured
websites
(Pinterest)
Internet
Textile
inspiration
Home Interior
textiles
Future
related
websites
(what are the
next trends)
Automotive
News
Me
+
Eyes
Artists
New Qualities
Experiments
with diffrent
Media
design
history
Daily
Media
Magazines
news e.i.
new recycling
processes
creative
classes
Education
Product
design
Fairs
BA
Try &
Error
Experiences
competeter
inspiration
new
developments
computer based
design
DIGITAL
Weaving process
REAL
Showing / Sending
Samples to
customer
WAITING FOR FEEDBACK


What is your development process?
Serial development for customer
Customer needs
- specifications
- design
- law requirements
Finding solutions
- brain storming
- benchmarking
- market study
- scouting
Development team
Product Design
Product Development
Process Development
Development project
Concepts
Product for a customers
Advanced development for new products
Customer needs
Market needs
Future trends
Trend scouting
Technological Benchmarking
Looking for Trends in other industries
new materials
Team
Individuals
IDEA
Samples
Suppliers
concepts
Development project
Feasibility
New Product
Presentations
Customer 1
2
3
X

A → B → C → D
← ←

A) Input

- Briefings (lissen to the costumer)
- Knowledgs of yarns and materials
- Knowledgs of properties and behavior of materials
- Knowledgs and global experience

} BLOCKING CREATIVITY !

- Color and material fairs like: Premier vision Paris
  ↳ TRENDS
- Tech textile innovation fairs
- Internal sharing of ideas and innovations. DesignLAB
- Specifications from the OEM.
- Try to think out of the box
- Open for new technologies

↕

B) Start making first development / in group < Design development

- Weaving dobby / Jacquard
- Knitting.
- Knowledge of weaving and knitting. finishing
  ↳ experience
- integrate advance technologies as appetizer
- Sometimes trial and error
- Knowledge of new applications
  ↳ added value technologies

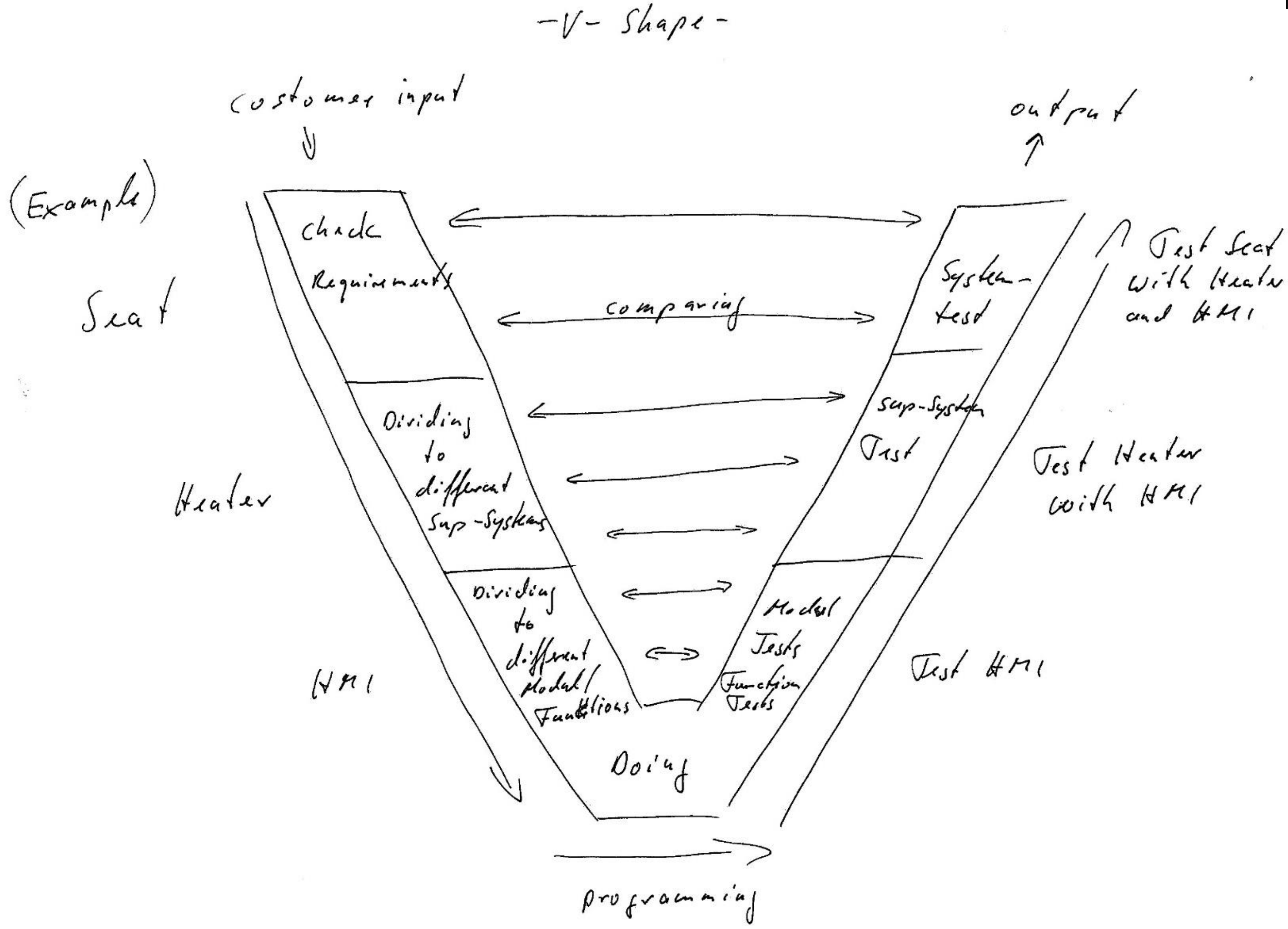
{ It can not work
{ does exist

↕

C) Improve the first trial

to better performance / right color development
better spec's
better price
better appearence
following info from the costumer.

D) Final product


-V- Shape-
customer input
output
(Example)
Seat
Heater
HMI
check Requirements
Dividing to different Sup-Systems
Dividing to different Modul/Funktions
comparing
Doing
programming
System-test
Sup-System Test
Modul Tests
Function Tests
Test Seat with Heater and HMI
Test Heater with HMI
Test HMI

The letter R identifies me, and other speakers are identified by the initials of their role:

Group Design Manager (GDM), Electronics Developer (ED), Engineering Manager (EM), Ergonomics Specialist (ES), Textile Designer (TD), Textile Engineer (TE), Development Manager (DM), Fibre Optics Engineer (FOE)

Team B - Phase 8 description

R: So this last bit is to try and boil like, put together the ideas that you've all discussed and hopefully it will give me something that I can work with, but I'm not too worried about it. I think what I'll do after today is kind of filter down. Because I think there's some interesting things that came out of earlier things as well that maybe one of the ideas that you brought through. So I want to give a kind of package with all the things that I thought were interesting that came out of this. That might be things that you can do whatever you want to do with them, or they might be things that we then talk about and you go actually that that's little thing. Although this that we did was interesting, that thing there we like. We like something about that. So don't worry too much at the moment about what this actual thing that my second part of that diamond, let's not worry about it too much. And I think it's more interesting the research part, the insights. So somebody from, or the two groups can you tell each other what your thoughts are? And then there's maybe some discussion amongst the group about in general things, like there's things that cross over or in general things that are interesting

GDM: About the scenarios we created from the journey with the textile and electronic?

R: Yeah, so about that. But then there may be just another discussion we want some closing bits about in general when the company wants to go that might be relevant. And last little bit I've got a couple of videos from the university and some stuff, some materials, so I'll just hand things round so you can have a look at that. So the last bit won't be too stretching, just this bit and then you're done.

GDM: [DM], do you want to explain what we're doing on one of those?

DM: I hope I can read what you…

GDM: Ah.

DM: OK, OK. This was, make it for single person and long distance. So first of all, we we looked about the…

GDM: The journey?

DM: No the … Post-its

R: It's been a long day.

DM: And we we make a decision that this kind of post-its with this words are… depends to… is good for the single person long distance journey [sigh]. So we make it a little bit better. So we decided that for this scenario, the single person long distance, this was not self-driving car. It's a self-driver… the car is driving by a driver, by himself or herself. And this was the first thing to do. And then the other thing was the, yeah, the interaction between traffic.

GDM: Oh, god, this is my writing. I wasn't expecting anyone to have to read it. OK, so as [TD] has just said we were talking about this sort of like… you driving yourself and you want sort of features and options which can stimulate you or calm you, but don't interrupt or affect your driving. So I mean, you don't want something which is going to bother you. And so we divided into physical and emotional areas. On the physical areas, as you can see here, we have certain things like this morphing and morphing would be driver… if you are on the motorway or you're in the city because you have a different environment, you need a different experience. And that means the textile has to be flexible to stretch into different things. So that's more the physical side. And then the lighting, unbeknown to me, actually is both physical and emotional. So you have light which can wake you or light which can calm you and make you go to sleep. More on the emotional side, we said you have smell. So as [ED] said you have coffee beans which can wake you up and stimulate you, that smell or menthol or whatever. And you also have different smells, which like lavender, which you perhaps calm you. And then we were also looking at this humidity sensor. So the more you sweat perhaps, it can actually help to interact and actually intuitively turn on or turn off these features.

?: Air conditioning or something.

GDM: Yeah. [silent pause]

R: Was there something from the other one?

GDM: Yeah, that one was a bit more difficult I found.

TD/EM: The students.

GDM: This was for the… we said because we said there are 20 passengers on this bus and it could be a group of students going on this sort like a one-hour journey, or it could be in an urban environment for a city tour. And here we were saying certain things like the temperature, whether it's crowded, hot or cold, internal external temperatures. So the materials themselves, if it were sustainable, such as wool, could help you to absorb moisture, but also they would be self-cleaning, like antibacterial, because you've got a very diverse group within that space. And also, unbeknown to me, I didn't realize that UV light can kill bacteria. So light sources within the cab can actually help to do this, but of course, easy clean finishes. And then we said about the space itself, if you want to larger space or a smaller space, depending on the occupants and if you want privacy or communication, you would have morphing space, which is easy to use because that's to be intuitive, because you've only got one hour to experience the whole thing. So it's not a matter of learning over a period of time. It has to be immediate. And this has to be artificial intelligence so it can actually pre-empt what you'd like it to do. And it could also be supported by colour changing to make it more open or more enclosed. And then, ahh, we were talking about when you're in a bus with a group and also a particular customer group. Electronics and communication is probably very important. So you need electronic communication, but also you'll need to charge your device wirelessly.

Team A - Phase 8 description

TD: I start with the doctor.

GDM: Yeah.

TD: We had the doctor's journey mapping and we decided that our vehicle, however it will look like, is divided into two parts because we have the part for the doctor himself in the early morning, Monday morning, when he starts his work, he maybe needs his room with coffee smell, for example, or he's ready to go music and or a little bit of bluish light to wake up. And then we have the part where the patient comes in. And we thought that those two parts has different needs. For example, the part for the patient. Um, how does it start?

EM: Advanced information about the patient.

TD: At the beginning when he drives to his patient, he gets some information about his next patient, for example, in a heads up display so that he can read it, for example, in an autonomous car, that he can get the next information he needs and or if he has to drive by himself, that it's voice controlled and maybe he can hear the information he needs.

EM: And also during the surgery. So the doctor needs some tool so you can say it by voice control. So voice recognition, I need a scissor for example and then the place where the scissor is located.

DM: I need a saw [laughter].

EM: The light turns on and the doctor knows where the tools that he needs right now are located and can fetch them.

Yeah. And then you don't always have the same patient in this part. So it has to change due to the patient's needs and it also has to be self-cleaning antibacterial if we talk about blood and something else and easy to clean or maybe also odour absorbing. And we thought of that the textile on the seat or on the table could also give some information when the patient sits or lays on it, for example, the heartbeat, stress level and temperature. And so and then it's also should be flexible due to heating and ventilation and also the colour. Because when we think of a clinical area then most of the time it's clean, white, and not every person feels comfortable with this surrounding. And so maybe that at the beginning the doctor gets the information what his next patient feels comfortable with, special light or special music, sound, smell or whatever. And for the doctor himself, he needs also a little bit intelligence surrounding because you had to here two different scenarios and it would not be perfect to play the party music if he loses his patient. [laughter] So would also be good that his surroundings depend on the situation he had before. And then we thought sometimes it takes a bit of time to get his next patient and then he needs a place where he can relax or even sleep. And this should be more the comfortable, soft textile and soft form area instead of the clinical part. Because if you if he needs to use the defibrillator, then he needs a very hard underground because if he has a soft underground, he pushes the patient into the seat. And yeah. So we thought of that. Those two parts in one pod, whatever it is, both has to change and be intelligent due to the situation what happens in the car.

DM: I read a word, flashing seat, what do you mean flashing seat?

TD: That was your idea, [TE], the flashing seats.

TE: Flashing seats, yes when when the doctors get out of the of the car instead of having the flashing lights on the top of the on the roof of the ambulance, it could be also that the seats are flashing.

DM: Ok.

TE: In different colours depending on what use.

?: Level of urgency.

TE: Yeah, but that's blue for the ambulance and a red or yellow for a car who is doing some… roadwork or something like that.

TD: Yes, almost there.

ED: And he told us.

EM: Protection, yeah.

ED: Contamination of the [inaudible] also, so it is flashing, so now I have to decontaminate myself, then I can go to drive.

EM: And also the seat.

ED: Yeah. you don't want to contaminate the seat.

EM: And the second one we chose was the retired persons who wanted to go to [place name omitted] from [place name omitted], to go shopping or something else, and therefore we gathered some ideas so we can have a kind of visual app, so a very simplified app so that the people can choose the vehicle that they would like to have for the transport. So on one hand, the simple, cheap one and on the other hand are more sophisticated and more expensive one. And yeah, this app can run on a television by pressing just one button. You can choose your your favourite transport vehicle. So maybe also diverted by by colours. So colour red is the one vehicle which has two seats. Colour blue is another one with four seats or whatever. And you know, when when the vehicle reaches your home, it has the right ambience and and light for… depending on your favourite adjustments. And the low cost vehicle, you cannot decide who else enters the vehicle, the car. And if you want to have some private privacy, you can do it with textiles like a 'Gardine' - curtain.

TD: I wrote the German word.

And this curtain just to to shut your your privacy space. And if you have people with different favourite surroundings and ambiences, you can also use a quiet, neutral background music and also the ambient light could be neutral. And in case of the background music, it cannot, it can turn on after some time of silence. So if no one is talking, so the mood gets maybe a little bit special, or stressed, and then the background music can turn on and the stress is gone away. And with the high cost car, then you can have… you can choose the group of people that you would like to have within you, traveling with with you, traveling in the car. You can have a thicker textile curtain possibilities. So if you find out that the other person is not as pleasant as you would like to have it you can use the curtain as well. And the music.

GDM: Acoustic.

EM: Acoustic curtain as well. Yeah, that's and that's for the music you can hear just only in your little space when you use the curtain. And on longer trips, you can also do some some video games with the other person. So just for shortening the time of travel and… Well, that were the main thoughts that we had on that topic.

R: On the point that you said about games with the other person, when I did the student project, one of the projects that one of the groups, their product concept that was for a textile space that would kind of drop down from the ceiling, and so you could change the interior with this kind of textile tensile structure that you could hook to a few points. And then it would work with and something like Google Home, and because the girl that was in the group. She and her housemates had Google Home, and so the idea would be that the textile just had some quite simple light integration, so… but it made it so that the game became not only audio, but you would have some visual feedback of like, right answers and things like that. So maybe that you're talking about entertainment, there is some simple features that could could be in the textile, that allow that experience to be more immersive.

TD: I also was I was on a fair once and there was a company. They were thinking about how to integrate music without having a huge heavy box and they integrated into the wall. And that was also cool because in my bachelor's thesis. I integrated this in my one-person vehicle. It was a bit rounder. And so it's behind to seat but in the wall. So you don't need a special or a lot of place for your music device and could use this safe place for something else. And that was also really cool.

Closing reflection

R: That's interesting. So I'm absolutely happy with everything that has been done. Are there any other ideas, like is there anything else I should know about maybe the companies are interested in, or was there anything from today that you are thinking that you want me to know about? Because what I would do now is when I recover from today, take a look at everything, and as I said, I come up with some proposals of sort of how one might transform it into something that maybe you guys will on reflection have some ideas about how you want me to transform it into something. Like don't know if there's something…

GDM: For me what I really like is, on our design lab, and, like we always do a lot of things we've been doing in the design lab, or the next design lab is we've got a profile map, like we always do, and we have a profile for the four major trends of mobility, whether it's mobility sharing, self-driving, environmental - electronic vehicles or E-vehicles, but sometimes when we… we just would say, OK, here's a seat, or a console with a textile on it, it's good. But we're not telling a story. We're telling a story because of the experience. But I thought this, this…

R: The journey?

GDM: The journey was really cool. I've not seen that before, and that helps you to tell, actually, and think about how the end user would experience this product during the life cycle. And I found that really useful.

R: You can, you can do it even more detail, because the way the students had to do it, they also had to create an actual, it wasn't a generic user. They had to have names, the age, what they did [GDM: Yeah] They to go down really into the detail of who was this person and and what they.

GDM: The experience that they would go through.

R: The actual experiences that an individual, not an overall, more or less, this is what what people, like in this vague category feel like but that individual, and imagine a day. Because they had a specific small space than they were doing it on E-textiles for micro living, which is a little bit like apartments now in London or Shanghai, If you're unlucky. it's so expensive that you might not be able to get much more than… I think their space was 15 metres square and they had to create a space which had washing, eating and cooking, entertainment, sleeping all within that space. And how they would use E-textiles to make that a more pleasant space to actually live in and use them to change the environment, so this immersive space was one of the ideas that was an idea for entertainment and could make it not feel like, oh God, we were stuck in this tiny apartment but how you could actually make it something fun to be in that small space doing something together.

GDM: It also helps to consider features you might not have considered to add features to it, make it even more added value. So I thought that was really interesting.

R: Is there anything else?

What about the ergonomics? [pause] Because in a way, I think when you said about your working day, and you considered the the biology of the human form and the… the seat itself, this thing helps you to consider how you would actually… because nearly all of the workshops in some way, we considered the movement, the interaction, the whatever. [R: I mean…].

TE: Especially on long distance. So when I will driving home, at the end, you. Yeah, even when it is comfortable seating, to sit in that seat, at the end. So something is happening with your body that you don't want to be in it anymore. [GDM: Yeah]. So why is that coming or where is that coming from.

TD: And most of the time you're talking about the let's say ideal sitting position, but in reality it's different. It's the same when you're working at your desk, the idea sitting position, but if you're honest, sometimes you sit like this [demonstrates a slouched position] this is different [group agreement], and it's more and more during the day. So. And yeah…

GDM: Yeah because in the morning I can see [EM’s] head and by lunchtime [physical demonstration and laughter].

TE: Yeah. But it's a very good system, but with that system, do you not have the problem that you're specifying? I had that on the table also that your specifying, now you're looking how can you make an ambulance better than than she is today? Sometimes I have that feeling because…

DM: No, I think it's a method to find new ideas and make one scenario, you could make it from this.

TE: It could be that we are not the specialists. Then we have also that discussion that we are not, we are not ambulance people. We are not doctors. We are textile people or other. So it could be that that there is some new things out of it that they never think about.

R: Absolutely.

TE: This is the only. Yeah, this is… otherwise you're looking to make another or a better.

DM: Or maybe you find an idea or an idea for for a new fabric that you can use, not in an ambulance, you can use in other areas.

R: Because I mean, there's something and I think all of these scenarios about changing in the space and how the how the textiles could work in changing the space so, you might it might be a kind of macro level idea that you end up seeing, oh, wow, that's across all scenarios. Yeah. Or it might be that a particular point is interesting and then you want to get some people in and actually investigate that, like interview some truck drivers or and get a real user journey.

GDM: Because I don't know if it's more difficult or made it easier, easy or difficult, because I think if we'd talked about our core business areas, we would have gone into more things, which we already know.

R: That's why I…

GDM: By looking at an ambulance, it's something we don't know so we question things a bit more, even though we're probably not the experts. But also one could take that information and take it back into your core business now and probably would have taken a few steps forward.

R: That if that is the idea, [yeah] that that's why we're putting together ideas that are not just comfortable like, because you could just automatically have gone right we for E-textiles I think we need this this and this [group agreement] and that wouldn't have…

TE: Then again you will have all the same stuff. Yeah.

GDM: And then you'd have gone back to the little core on your development spectrum or barometer. We would have been back in the middle rather than thinking at the beginning and the end.

The project was approved by Nottingham Trent University Joint Inter College Ethics Committee on 22nd August 2016 and updated approval was confirmed on 7th November 2018. Each Design Situation had its own consent form - the example provided is for Design Situation 3.

NOTTINGHAM TRENT UNIVERSITY
Proforma: Research Consent Information Sheet

Protocol Title
A PRACTICE-LED DESIGN APPROACH TO THE DEVELOPMENT OF E-TEXTILES FOR INTERIOR SPACES
Principal Investigator
Rachael Wickenden
Project Group:
Advanced Textiles Research Group
Supported By:
M3C

What is the purpose of this study?
To investigate the role of the textile designer in the development of electronic or E-textiles for interior spaces

What are we asking you?
The questions will investigate perception of E-textiles, designing with them and their potential uses to inform research.

How we would like to use the information provided
To aid the creation of tools and insights for academia and industry that will facilitate textile designers working with E-textiles in the development of meaningful products.

Compliance with the Research Data Management Policy

Nottingham Trent University is committed to respecting the ethical code of conducts of the United KingdomResearch Councils. Thus, in accordance with procedures for transparency and scientific verification, the University will conserve all information and data collected during your interview in line with the University Policy and RCUK Common Principles on Data Policy (http://www.rcuk.ac.uk/research/datapolicy/) and the relevant legislative frameworks. The final data will be retained in accordance with the Retention Policy. All data will be anonymised and made available to be re-used in this form where appropriate and under appropriate safeguards.

What are the possible risks or discomforts?
Your participation does not involve any risks other than what you would encounter in daily life. If you are uncomfortable with any of the questions and topics, you are free not to answer.

What are my rights as a research participant?

- You have the right to withdraw your consent and participation at any moment: before, during, or after. If you do wish to withdraw your consent please contact me using my contact details as above within 2 weeks of participation.

- You have the right to remain anonymous in any write-up (published or not) of the information generated.

- You have the right to refuse to answer to any or all of the questions you may be asked.

- You also have the right to specify the terms and limits of use (i.e. full or partial) of the information generated.

- You have the opportunity to ask questions about this research and these should be answered to your satisfaction.

If you want to speak with someone who is not directly involved in this research, or if you have questions about your rights as a research subject, contact Professor Michael White, Chair for the Joint Inter-College Ethics Committee (JICEC) at Nottingham Trent University. You can call him at 0115 848 2069 or send an e-mail to michael.white@ntu.ac.uk.

What about my Confidentiality and Privacy Rights?

Participation in this research study may result in a loss of privacy, since persons other than the investigator(s) might view your study records. Unless required by law, only the study investigator, members of NTU staff have the authority to review your records. They are required to maintain confidentiality regarding your identity.

Results of this study may be used for teaching, research, publications and presentations at professional meetings. If your individual results are discussed, then a code number or a pseudonym will be used to protect your identity.

Audio/visual recordings

Permission to use audio or visual recordings of your participation, for presentations in the classroom, at professional meetings or in publications, is requested below, as this may be necessary to understand and communicate the results.

Any recorded data will be kept confidential and in a secure place in line with the Research Data Management Policy and destroyed in line with the current RCUK/University Guidelines.

Who should I call if I have questions or concerns about this research study?

Rachael Wickenden

Email: rachael.wickenden2015@my.ntu.ac.uk Phone: +44(0)7809 157978

CONSENT FORM PROFORMA

Dear Research Participant

All participation in the project is voluntary. If do you agree to be part of the project, we would like to use the information to develop a report; but your name and identity will remain anonymous. If you decide at any stage, you no longer want to be part of the project, just let us know and we will make sure any information you have given us is destroyed.

This project has been reviewed by, and received ethics clearance through, the Nottingham Trent University Joint Inter College Ethics Committee.

Please read the following statements:

I have read the above project description, and had an opportunity to ask questions about the research and received satisfactory answers to any questions.
I have had sufficient information to decide whether or not you wish to take part in the study.
I understand that I am free to withdraw from the research at any time by informing the researcher of this decision.
I understand that the information I give will be treated in the strictest confidence.
I agree to take part in the study.
I agree that my participation in workshops and tutorials can be audio and video recorded.
I understand that quotations, which will be made anonymous, from workshops or tutorials may be included in material published from this research.
I am willing to participate in workshops and tutorials as part of this research project.
I understand that anonymized data may be used in other studies in line with the University Research Data Management Policy

I confirm that data obtained from the study can be used in the final research report. I understand that the data will be used anonymously: names, places and identifying details will be changed.

Full Name ____

Date ____

If you have any questions please contact …… Rachael Wickenden

Email: Rachael.wickenden2015@my.ntu.ac.uk Phone: +44(0)7809 157978

In line with the Research Data Management Policy, requests may be made to use data from this study for other projects. If you do not wish your anonymized data to be used for future studies, please tick here ☐