F.Kane, D Vardy, A Shakoor, N.Thomas

The significance of craft in the development of sustainable materials design: localisation, technology and emotional durability

Abstract:
This paper presents a current practice-led research project that investigates the use of flax fibre, cultivated in Leicestershire, in combination with recycled polyester fibres, a bio-polymer called poly(lactic acid) (PLA) and digital surface patterning techniques to create sustainable sheet materials for potential use in a range of design-led applications. In doing so the project ultimately aims to foster connections between the creative industries and local material manufacturers encourage sustainable development from a socio-economic perspective. The approach to the work is collaborative and interdisciplinary bringing together textile design and materials science. The results to date include technical data relating to material properties and material samples that explore surface design possibilities. The discussion of the project within this paper focuses on the significance of 'craft' within the work in relation to sustainable design thinking; focusing on notions of localisation, emotional durability and the use of technology. In doing so the work it situates the work in an expanded craft field.

1 Introduction

Current sustainability agendas in regard to textile design and production include an increased focus on local resource flows (Fletcher 2008), fibre diversification, biodegradability (Blackburn 2005) and the use of alternative surface patterning and colouration techniques as strategies for moving forward. Within this framework there has been a renewed interest in bast fibres, such as flax, which can be cultivated in the UK. (Anon 2011) These fibres provide an alternative to cotton and are biodegradable. This paper presents a current practice-led research project that investigates the use of flax fibre, cultivated in Leicestershire, in combination with recycled polyester fibres, a bio-polymer called poly(lactic acid) (PLA) and digital surface patterning techniques, specifically laser processing, to create sustainable sheet materials for potential use in a range of design-led applications. In doing so the project ultimately hopes to foster connections between the creative industries and local material manufacturers to encourage sustainable development from a socio-economic perspective. The project has arisen out of research into nonwoven materials and processes (Kane 2008) and in response to current sustainability agendas. It has evolved into a collaborative venture between the School of the Arts and Department of Materials at Loughborough University which has to date been funded by the university's Materials Research School (MRS). As such the project has expanded beyond textiles to sit more broadly with the field of 'materials design'.

The focus of this paper is to draw out the significance of craft in the work. The first part of the paper is descriptive, giving some background on the materials and processes employed, the current aims and objectives of the project, the methodological approach taken and the results of the work to date. The second part aims to be more discursive, exploring notions of localisation, emotional durability and technology to explore the significance of craft within the project and more broadly within sustainable materials design. In doing so the work it situates the work in an expanded craft field.

2 Project background

The project presented has arisen out of recent work into nonwoven processes and materials and in response to continually evolving sustainability agendas. (Kane 2008) The work, centring on the design potential of nonwovens, highlighted the ability to construct nonwovens specifically for surface patterning techniques resulting in unique design effects (Kane 2009) and in addition identified the growing application of nonwovens in design-led products. (Kane 2010) It focused on the use of a bi-component polyester fibre in combination with a range of natural and manmade fibres to produce thermally bonded nonwoven fabrics that were subsequently etched using traditional devoré printing techniques. In evaluating this work questions were raised in regard to the sustainability of the materials and processes employed, in terms of; material origin, processing, application and end of life considerations. As a result, the materials and processes employed in this current project have been adapted in response to sustainability agenda's and design theory. Diagram 1 maps the choices made against sustainability agenda's and sustainable design thinking.

Design Choices	Sustainability Agenda	Sustainable Design Thinking
Materials: flax	Fibre diversity Renewable resources	Localisation (Fletcher 2008)
Materials: PLA	Renewable resources Biodegradability	Technology (as facilitator) (Sacturro 2008)
Processes: laser	Alternative surface patterning processes (To reduce chemical and water use)	Technology (as facilitator) (Sacturro 2008)
Surface design: lace	Increased lifespan of products through added value	Emotional durability (Chapman 2005)

Figure 1: Development of nonwovens design research: choices made mapped against sustainability agenda's and sustainable design thinking.

In order to explore the potential of PLA as a binder fibre, collaboration with the Department of Materials at Loughborough University was established. As a result, the project has expanded to include compression-moulded materials composed of PLA and flax in addition to nonwovens. In moving into this area the project has become located within what has been termed 'materials design', an emerging field that marries functional requirements of materials and design sensibility (Ballard Bell and Rand 2006, Brownell 2006).

2.1 Current project aims and objectives

The aim of the project is to create sustainable sheet materials for potential use in a range of design-led applications. The objectives of the initial work are to:

- establish nonwoven and compression-moulded sampling procedures for flax/PLA composites
- test the resulting samples mechanically to identify material properties (leading to application potential)
- test the suitability of the materials for digital surface patterning (laser cutting)
- explore digital surface design potential

These objectives have been approached through five parallel work areas as described below and summarised in Figure 2.

3 Methodology

The work is rooted in notions of practice-led research within art and design disciplines. Central to the methodology employed has been what could be described as a 'craft approach' to textile and materials design. Key aspects of this approach include: the recognition of making as the fundamental driver within the work; valuing the intimate knowledge of materials, tools and processes gained through practical interaction and; consideration of application. Collaboration with materials scientists (Thomas, Vardy and Shakoor) has been critical working with PLA and has enabled: the exploration of new processes (compression moulding); materials testing and analysis from a scientific perspective. Articulated reflection on periods of practical work, predominantly through discussion, alongside continued theoretical investigation of sustainable design, has helped to direct and develop the work. Figure 2 gives an overview of the work areas through which the project has progressed to date and the specific methods employed at each stage.

Work Phase	Methods Employed	Additional Information
1.Sample production	Nonwoven processing (Weight % of Flax/PLA fibres prepared; 100/0, 90/10, 80/20 and 70/30)	*Carding, needle-punching, thermal bonding *Based on previous research (Kane 2008) * Undertaken by Nonwovens Research Group, Leeds University
	Compression moulding (Weight % of PLA/Flax fibres prepared; 100/0, 90/10, 80/20 and 70/30)	* Melt blending, compression moulding Based on current research into PLA processing (Thomas, Shakoor)
2. Mechanical testing	Tensile testing	Lloyd 50K tensile testing machine Standard test procedures
3. Materials analysis	Scanning electron microscopy (SEM) Dynamic mechanical thermal analysis (DMTA)	Standard test procedures
4. Surface design trials	Laser cutting	120 watt CO_2 laser
5. Design sample development and works for exhibition	Drawing Digital interpretation Laser cutting	Emerging from on going practice-led research (Kane 2010, 2011)

Collaborative discussion and reflection on practical work Theoretical connections identified

Figure 2 Overview of methodological approach

4 Overview of work conducted

Within this section; the processes used to produce material samples are described, some brief background on nonwovens and compression moulding is given, and the sampling procedure is summarised. A minimal level of technical information is provided due to the focus of the paper.

4.1 Sample Production

4.1.1 Nonwovens

The British Standards definition states that a nonwoven is: " A manufactured sheet, web or batt of directionally or randomly orientated fibres, bonded by friction, and/or cohesion and/or adhesion…" (BSI 1992) The processes, materials and qualities of nonwovens, link them to the plastics, felt and papermaking industries. The production of nonwovens can be described in three main stages; web formation, web bonding and finishing. There are a variety of manufacturing processes and technologies used at each of these stages and as such nonwovens are often classified by production process. The samples for this work were produced using carding, needle punching and thermal bonding. Two types of thermal bonding were trialled, firstly using a heat transfer press and secondly using compression moulding. Flax was used as the main fibre and PLA as a bonding fibre. The following weight percentages of Flax/PLA fibres were prepared; 90/10, 80/20 and 70/30. The aim was to subjectively assess the performance of the PLA as a binder fibre alongside the aesthetic qualities of the resulting materials and to consider the response of the materials to laser cutting.

Heat pressing at a range of temperatures between 130°C -170°C resulted in materials taking on the natural colour and visual quality of flax and tactile qualities sitting between felt, paper and plastic. The compression moulded samples had qualities similar to cardboard. The plastic like quality of the heat pressed samples and rigidity of the compression mould samples increased in parallel with the greater proportions of PLA and higher temperatures.

4.1.2 Compression moulding

Compression moulding is a process used within the manufacturing industries to make flat and curved parts via the application of heat and pressure. A range of samples were produced using compression moulding including: small tiles which were used for Dynamic Mechanical Thermal Analysis (DMTA) and laser cutting; larger tiles used for laser cutting and; small samples used for tensile tests. PLA /Flax fibre composites were prepared by melt blending using the Haake Polylab Torque Rheometer. The following weight percentages of PLA/ Flax were prepared; 100/0, 90/10, 80/20 and 70/30. The composites were compression moulded at
180^0C.

The samples produced had qualities similar to thick Perspex. Visually, the colour of the samples was surprising, a deep dark brown tone, possibly resulting from residual moisture in the flax. These samples provided the focus of mechanical testing.

4.2 Mechanical Testing

4.2.1 Tensile Testing

Tensile testing of the PLA/Flax compression moulded materials was performed on a Lloyd 50K tensile testing machine to see if the addition of flax fibres had any effect on the mechanical properties of PLA. The tensile test is carried out by stretching the sample at a constant rate until it breaks. The machine is linked to a computer which records all the data from the test, allowing for comparisons with 100% PLA. Figure 3 provides an overview of the mechanical findings which show a significant drop in the modulus of the PLA/Flax material compared to 100% PLA, but also a significant increase in the

elongation at break. The addition of the flax, therefore makes this composite more ductile than 100% PLA.

PLA / Flax	Tensile Strength	Tensile Modulus	Elongation to break
100 / 0 (pure PLA)	**43.8 ± 3.1**	**1.6 ± 0.14**	**4.1 ± 0.59**
90/10	24 ± 2.28	0.35 ± 0.03	25 ± 4.5
80/20	26 ± 0.71	0.36 ±0.02	27 ± 5.5
70/30	38 ± 3.4	0.44 ± 0.02	29 ± 4.0

Figure 3. Summary of mechanical findings relating to compression moulded PLA/flax

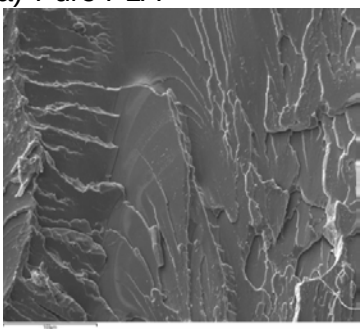
4.3 Materials Analysis

4.3.1.Scanning Electron Microscopy

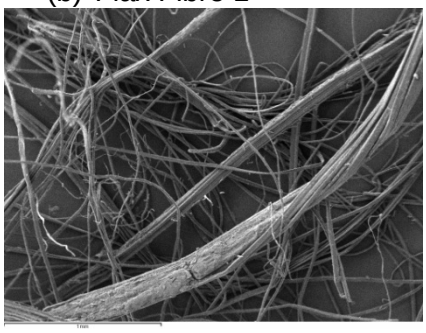
A scanning electron microscope (SEM), LEO 1530 VP, was used to investigate the morphology of PLA and PLA –flax composites. Small amounts of flax and PLA fibre were coated with gold to make them electrically conductive, thus preventing charging up and allowing it to be imaged. In addition small pieces of fractured samples, resulting from the tensile testing, were coated with gold and then imaged and analysed using the SEM to check the fracture surface morphology. Figure 4 shows the fracture surface analysis of PLA, flax and PLA-flax composites. SEM images of flax fibres and PLA- flax composites were recorded at different locations and magnifications. Figure 4(a) shows the fracture surface of pure PLA. 4(b) and 4(c) shows the rough surface of flax fibres during morphological analysis. 4(d), 4(e) and 4(f) shows the fracture surface analysis PLA –flax composites.

The images show that fibres that have been pulled out from the sample. This suggesting that the bonding of the fibres isn't as strong as 100% PLA bonding hence the reduction in modulus, but that the fibres are bonded strong enough to account for the increase in extension at break.

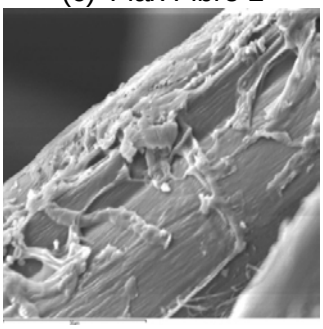
(a) Pure PLA

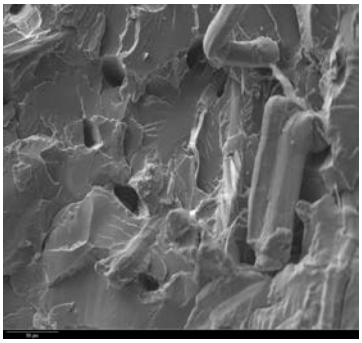


(b) Flax Fibre 1

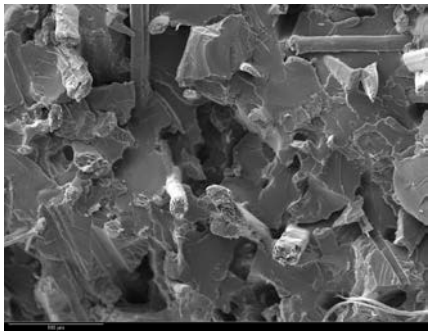


(c) Flax Fibre 2

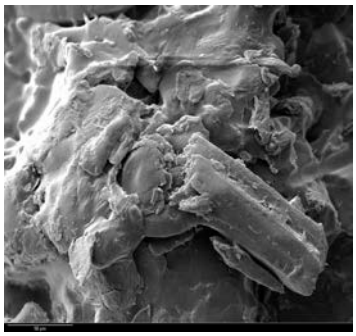




(d) 90 - 10 (PLA-Flax)



(e) 80 - 20 (PLA-Flax)



(f) 70 – 30 (PLA- Flax)

Figure 4 fracture surface analysis of PLA, flax and PLA-flax compression moulded composites.

4.4 Laser Trials

Laser cutting and marking are established and accepted methods for processing materials within both industrial manufacturing and textiles. Trials were conducted on both nonwoven and compression moulded samples to assess the efficiency of laser cutting on the various compositions of flax and PLA. A 120 watt $C0_2$ laser was used. Small tiles of each grade of composite were cut employing three different laser paths; a straight line, 90-degree zigzags, and a circle.

The trials suggested the potential to cut each of the grades of PLA/Flax nonwoven and compression moulded materials with further work. As the laser path faces a change of direction it slows down slightly resulting in an increase in energy on the surface of the material at that point. In regard to the higher concentrations of PLA this caused the material to melt and then re-weld itself making the cut incomplete or abstracted. This could be surmounted via development of specific laser processing parameters.

4.4.1 Surface Design Development

A series of surface designed samples were created to explore the potential of patterning the materials through laser cutting. Two examples are shown in Figure 6. The designs employed were drawn on visual explorations of historic textile techniques associated within the local region. The imagery used originates in images of Nottingham lace and counted-thread work. It has been developed through hand drawn and digital interpretations using Illustrator.

Figure 6. Compression moulded Flax/PLA nonwoven and Compression moulded PLA/Flax. Both laser cut employing imagery based on Nottingham lace.

In reflecting on the project, the value and significance of craft within the work from both theoretical and practical perspectives emerged throughout. From this point the paper aims to start probing this significance in relation to three strands of sustainable design thinking: localisation, technology (as facilitator for sustainability) and emotional durability.

5 Embracing localisation

Flax was selected as the central material for this project. An affinity with it was established in recent practice-led research into nonwovens. When re-evaluating the direction of the research in regard to sustainability, the credentials of flax against current sustainability agendas seemed strong. Of particular interest was the fact that it can be cultivated locally in the UK. Its use could therefore be seen to embrace notions of localisation.

Localisation | craft | materials design

Localisation is a strand of sustainable development. The term refers predominantly to a gradual transition towards more localised economies in terms of food, energy, manufacturing and so on (Hopkins 2010). In relation to fashion and textile design, Fletcher (2008 140) notes that reducing carbon emissions through reduced transportation is the most obvious advantage of a local approach but describes richer and deeper benefits in terms of economic resilience, cultural and aesthetic distinctiveness and, connectedness (ibid 140 – 149). She suggests that a local focus develops 'creativity as we inventively respond to problems with the resources and expertise that is to hand' (ibid 40), highlighting McDonough and Braungart's (2002 in Fletcher 2008 141) assertion that the 'best' products are those with a human and material engagement with place.

Notions of human and material engagement are central to articulations and discussions of craft. In exploring the distinctiveness of craft alongside industrial design, Helen Rees (1997 120), suggests that the attractiveness of craft lies in its explicit identification with values of social continuity and personal creativity. This is perhaps facilitated in part, as Rees (1997 122-123) alludes, by the transparency of the craft object's origination. Resulting, she notes in products that 'we can both admire and understand'; essentially, that we can engage with. Similarly, Howard Risatti's (2007 60 – 69), discussion of nature and the origin of craft objects implies such engagement through locating this 'understanding' in the very roots of craft practice. These roots, he suggests, lie in human responses to physiological need that prompt a certain universality to the way in which material, form and technique come together to form a craft object. Whilst we recognise and understand craft objects universally in relation to their function in meeting a (physiological) need they are often, as Risatti points out, culturally distinctive in terms of place and time of origination. Thus suggesting that a craft approach to materials design may engender a sense of place in the object within which they are applied.

Within the project discussed here, it was hoped that a craft approach to sustainable materials design would engender a sense of engagement with place (in this case locality in which the fibre has been cultivated) in designers and makers using the materials and potentially end-users of the potential product outcomes. It was hoped that this would be achieved through connecting with the origination of the materials and the surface designs employed. Whilst this element of the design process might, as Rees notes (1997 120), play only a minor role in the economic impact of the resulting materials it plays an important symbolic and rhetorical role. This possible inter-connectedness between articulations of localisation and craft, which centre on notions of human engagement place, suggest that a craft approach to materials design might be seen as a facilitator of sustainability.

6 Affirming technology

Technology has been central to the project discussed in terms of both materials and processes. The introduction of PLA to enable a potentially biodegradable material, use of laser processing enables chemical and water free surface design, and the use of established manufacturing technologies to process raw materials into samples. In terms of sustainable design, technology is perceived here as a positive and potentially facilitating factor.

Echo-tech | craft | materials design

Sarah Sacturro in 'Eco-Tech Fashion: Rationalizing Technology in Sustainable Fashion' (2007) outlines some of the tensions between technology as a positive and negative factor in the development of sustainable (fashion) design. Her discussion focuses on fashion and as such embraces textiles and could therefore be understood in relation to materials design.

Sacturro describes a pessimistic view of technology in the context of sustainable fashion as being characterised by a 'back-to nature' philosophy that is ambivalent about technology or worse, positions it as a destructive force within society. Such a view, she notes, can be termed as eco-centric. Conversely a techno-centric view holds a confident belief in the 'human ability of science and technology to manage the environment' (Madge 1997: 46 in Sacturro 2007). Balancing these two positions, Sacturro suggests eco-tech as a term that more accurately describes the complex activities and attitudes occurring at present within field of sustainable fashion. Borrowed from architecture, she explains that the term refers to the use of sophisticated technologies to promote and develop social and ecological practices and awareness (Sacturro 2007).

Such activities in the field of textiles and materials design include the development of new fibres and alternative processing techniques. PLA is one such example. Made from cornstarch the polymer offers a renewable alternative to the petroleum in the production of synthetic textiles and plastics. In addition it is industrially biodegradable and is also chemically recyclable offering sustainable 'end–of life' options. In terms of surface design, alternative processing techniques facilitated by digital technology such as laser cutting and marking similarly present opportunities to improve the environmental credentials of products. There are no chemicals or water used in this process and the composition of the material being processed is not altered, thus creating the potential for easier recyclability. (Goldsworthy 2009) Sacturro (2008: 480) suggests that, in relation to manufacturing, 'technology must be precisely applied to limit pollution and energy expenditures, while the manufacturing processes must become open source and accessible rather than remain proprietary'.

Discussions of craft provide an alternative perspective on technology within the design, making and manufacturing processes. Perspectives that could perhaps, very broadly speaking, lead to technology being made more accessible (in the broadest sense of the term), through notions human-engagement. A craft approach to design necessitates personal interaction with processes and materials, potentially resulting in a resonance between product, object and user. Risatti (2007: 109 and 195) discusses that through handwork, a physical and emotional resonance between hand, as an extension of the mind and body, and object is realized. The transparency resulting from such a sense of praxis imbues the resulting objects, he suggests with 'meaning and emotional power' (ibid: 194-195). Technology, usually manifested in a 'machine', is often understood within such perspectives to cut this sense of praxis from the autonomous hand, resulting in a loss of meaning (Ibid: 195). It can be argued, however, that this is not always the reality if 'personal interaction with materials and processes' is perceived beyond handwork to embrace concepts of personal know-how. Interpreting David Pye's (1968) discussion of the workmanship of certainty and the workmanship of risk, Dormer's (1994: 138 - 157) argument can be understood as affirming 'personal-know how' as the key factor in underpinning the meaning in craft objects. He asserts that personal know-how, as apposed to the distributed-knowledge often associated with technology used within the context of mass manufacture, is very much evident in the use of technology within the context of craft, thus the resulting objects retain a sense of personal or human-engagement.

Within the project in question, personal know-how gained through a craft approach to the project, has been employed in connection with technology in terms of; establishing material composition, nonwoven and compression moulding sampling parameters, surface design development, laser parameters and the identification of application possibilities. Integral to this has been collaboration with materials scientists enabling personal know-how from a scientific perspective to inform the work hopefully leading to precision and details, as Sacturro (2008) encourages, in the deployment of technology. It is suggested, therefore, that a craft approach to materials design, that embraces collaboration, could engender accessibility to technology and precision in its use. Possibly positioning craft as a facilitator of 'eco-tech materials design'.

7 Acknowledging emotion

Emotional durability alongside physical durability has been acknowledged as a potentially significant factor in developing sustainable products (Chapman 2005). The materials under development in this project maybe suitable for industrial composting at the end of their life but a consideration of the lifespan of a product, with the intention of extending it is an important strand of thinking within sustainable design thinking. Emotional durability can be perceived as a key factor within this.

Emotionally durable design | craft | materials

In his argument for emotionally durable design Jonathan Chapman (2005 24: 16 – 17) highlights the techno-centricity of mainstream contemporary industrial design in which technological currency is the sole product value indicator. He suggests that this both serves and perpetuates cycles of desire and disappointment. This disappointment, he argues, arises through failed relationships with products due in part to a loss of meaning when new products arrive on the shelf, but perhaps more significantly a lack of empathy between user and product. Symptomatic to failed relationships, suggests Chapman, is waste; which ultimately contributes to an unsustainable consumer society (ibid: 16).

Empathy between product and user, Chapman suggests, is derived through meaningful embraces with objects (2005:18). Unearthing the meaningful content in objects, he summarises, happens as users 'steadily excavate into the semiotic core of an object'. One could perceive Chapman's ensuing discussion of narrative and storytelling within design as tools for this slow unearthing. He discusses the importance of narrative, including the notion of storytelling, in provoking meaningful subject-object relationships. Historically, storytelling, folklore and legend have cultivated mutual understanding and cohesion within social groups informing social interaction (Chapman 2005: 121 -122). The decline of such practices, he notes makes way for material engagement in which anonymous narrative experiences that tell homogenized tales of technological genius and human accomplishment which fail to sustain interest (ibid). He suggests that designers must enable the users of objects, through design, to form narratives that map subject-object relationships over time.

Craft can be seen to deliver meaningful experiences through many of the ideas already touched upon; association with a creative individual, recognisable origination of product in terms of process, materials, place and time, and universality of function leading to a sense of human engagement. Each of these could be seen to provide points of departure for the development of narrative strands within the deign process. The intention within the project described in this paper has been to develop a narrative around notions of local textile history and resources. This has been approached, as discussed, through the use of a local resource, but also in referencing local textile traditions and industry within the imagery employed for surface design. Thus, taking advantage of the ability of communicate meaning through their materiality.

The imagery within the work originates from drawings and photographs of textiles contained in Nottingham Trent University's lace archive and other documentations of Nottingham lace. Through its universality, the selection of lace as a starting point for surface design is intended to visually prompt association with traditional process, skill and history. Communicating the specificities of material origin is more of a challenge but it is hoped that the initial work will, to use Chapman's phraseology, prompt the beginnings of semiotic excavation and hopefully leading to meaningful embraces.

3 Conclusion

In conclusion this paper has described the initial stages of project that explore the development of sustainable sheet materials for design applications: more specially the

development of flax/PLA composites. It discusses the project within the framework of three strands of sustainable design thinking: localisation, technology and emotional durability. By exploring the interconnectedness between such thinking and craft theory the paper begins to suggest that a craft approach to materials design is relevant to sustainable development in this area. In particular, the discussion underlines the ability of craft approaches to embrace localisation, affirm technology and acknowledge emotion. And, in doing so craft engenders the kind of human engagement with materials and processes that leads the meaningful embraces which objects required for sustainable design, production and consumption.

References

Anon. 2011. *Teflax project*, http://www.dmu.ac.uk/faculties/art_and_design/research/team/texflax/index.jsp , accessed May 2011

Ballard Bell, V and Rand P. 2006. *Materials for Architectural Design*, Laurence King Publishing, London.

Blackburn, R S. 2005. *Biodegradable and Sustainable Fibres*, Woodhead Publishing. Cambridge.

Bronwell, B. 2006. *Transmaterial: A catalogue of Materials that Re-define our Physical Environment*, Princeton Architectural Press, New York.

BSI. 1992. 'Textiles – Nonwovens – Definitions', *BS EN 29092: 1992, ISO 9092:1988*, London.

Chapman J. 2005. *Emotionally Durable Design: Objects, Experiences & Empathy*, Earthscan, London.

Dormer, p. 1994. *The Art of the Maker, Skill and its Meaning in Art, Craft and Design*, Thames and Hudson, London.

Fletcher, K. 2008. *Sustainable Fashion and Textiles; Design Journeys*, Earthscan, London.

Forum for the Future. 2007. *Fashioning sustainability; a review of the sustainability impacts of the clothing industry*, http://www.forumforthefuture.org/files/Fashionsustain.pdf, accessed May 2011.

Goldsworthy, K. 2009. RESURFACED: An exploration of 'design for up-cycling' through laser finishing for textiles. *Cutting Edge; Lasers and Creativity Symposium*, November 2009, Loughborough University. http://www.cuttingedgesymposium.com/20-minute-papers/ accessed December 2011

Hopkins, R. 2010. Localism or Localisation? Defining our Terms, *Tranistion Culture*, http://transitionculture.org/2010/07/30/localism-or-localisation-defining-our-terms/ , accessed September 2011.

Kane, F.E. 2008. Designing Nonwovens: Industrial and Craft Perspectives, *unpublished PhD thesis*, Loughborough University.

Kane, F.E. 2009. Laser Patterned Nonwovens , 102, *Laser Institute of America, 28th International Congress on Applications on Lasers and Electro-Optics*, Orlando, FL, USA, 5th November ISBN 9780912035598.

Kane, F.E. 2010. Nonwoven textiles for residential and commercial interiors in *Applications for nonwovens in technical textiles*, Ed. R A Chapman, Woodhead Publishing, Cambridge.

Sacturro, S. 2008. 'Eco-tech Fashion: Rationalizing Technology in Sustainable Fashion', *Fashion Theory*, Volume 12, Issue 4, pp.469-488, Berg.