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TEXTILE DESIGN RESEARCH: FROM CHEMISTRY TO CRAFT TOWARDS SUSTAINABLE DESIGN INNOVATION

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ABSTRACT

Academic research in textile design has traditionally been dominated by technical studies situated with science and engineering knowledge frameworks. Increasingly textile designers are undertaking research into technical areas with creative intentions and utilizing alternative modes of inquiry. Whilst both technical and creative studies contribute critically to the expanding field of textiles, we ask: "When working to apply newly established technical processes within an industrial context, does an interdisciplinary approach that embraces both scientific and artistic research support sustainable innovation?" The research discussed within this paper uses two current projects as case studies with which to review the opportunities and limitations of a research methodology that is essentially design-led but that embraces both scientific and artistic approaches to textiles research. Both studies focus on the development of laser techniques to create environmentally advantageous and commercially relevant surface patterning opportunities for textiles. The aim, therefore, of the research presented in this paper is to consider an interdisciplinary approach to textile design research and in doing so to reflect upon the relationship between the creative and engineering aspects of textile design, proposing a methodological approach for working with new textile processes towards sustainable innovation. In summary the research concludes that the relationship between the creativity and engineering for textiles innovation must be design-led via creative intention but underpinned with robust technical inquiry. As such, design can be seen to add value within sustainable innovation within textiles.

Keywords: Textile Design, Interdisciplinary Research, Sustainability

1 INTRODUCTION

Ecological, social, economic and cultural challenges and changes pertaining to sustainability- such as the excess use of chemicals and water production, over-reliance on a limited range of raw materials, alongside fierce demand for new goods and unsustainable use behaviours - have necessitated shifts in the way that we perceive the production and consumption of textiles. As our understanding of such problems develop, so too does our perception of the role and nature of textile design and research, and indeed Design more broadly. Design is considered by many as key to innovation (Micklethwaite and Chick 2012: 33), which is acknowledged as crucial for change (Design Council 2010: 09). Within this context, new paradigms of design continue to emerge (Madge 2009) as designers respond to the need to direct or 're-direct' (Fry 2009) their practice towards sustainable innovation.

Design strategies, including those employed in textiles, have moved from single issue approaches such as 'green design', to a focus on life-cycle thinking, consideration of corporate social responsibility towards approaches that perceive design as integral to sustainable life-styles and behaviours (Micklethwaite and Chick 2011). Whilst these strategies and approaches can be traced within current textile practices, design for sustainability within textiles can be perceived as being uniquely steered by the overt materiality of the discipline. As such, knowledge and understanding of materials and processes, both implicit and explicit, is pivotal in the way design practice and research is approached towards sustainable innovation in textiles.

This paper explores approaches to working with newly established textile processes, specifically laser processing, towards sustainable innovation. We ask: "When working to apply newly established technical processes within an industrial context, does an interdisciplinary approach that embraces both scientific and artistic research support sustainable innovation?" The discussion within this paper uses two current PhD projects as case studies with which to review the opportunities and limitations of this approach. Each of the projects focuses on the development of laser techniques to create sustainable yet commercially relevant surface patterning and manipulation opportunities for textiles. In terms of sustainability, the focus is on: the potential to reduce processing stages and locations in regard to coloration and surface design; reducing chemical (dye) use; energy reductions and the establishment of a process which can respond rapidly and specifically to changing commercial demands, thus potentially reducing waste stock.

Before discussing the projects, we provide some brief discussion around notions of innovation and interdisciplinarity within the context of sustainability.

2 SUSTAINABLE INNOVATION

Whilst there is no precise definition of 'sustainable innovation', reflecting the complexity sustainability concepts, Mark Charter and Tom Clarke (2007) suggests that it is a process whereby 'sustainability considerations (environmental, social and financial) are integrated into company systems of idea generation through to research and development and commercialization' and is applicable to 'products, services and technologies, as well as new business and organizational models' (Charter and Clarke 2007: 09). He refers to Stevels (1997) in outlining four levels of sustainable innovation: Level 1 is referred to as 'incremental' to describe small or progressive improvements in existing products; Level 2 as 're-design' or 'green-limits' in which existing products undergo major re-design but limited to what is technically feasible; Level 3 as ' functional' or product-alternatives' where new products or services concepts are developed to satisfy the same functional need as existing products but in a more sustainable manner; and Level 4 as 'systems' which considers design for a sustainable society (2007 : 10). Although a greater emphasis has been recently placed upon the social dynamic of design for sustainability, aiming towards Levels 3 and 4, Charter and Clark (2007:15) note that much sustainable innovation to date has been incremental focusing on environmental aspects, achieving innovation at the lower levels. At each level, perceived in relation to Borja de Mozota's 'Four Powers of Design' value model (2006: 45), design can be understood as a 'differentiator, interrogator, transformer and good business'; enabling industry to cope with the challenges and changes of sustainability.

Literature around sustainability research highlights the interconnectedness between natural and socio-economic systems (Schoolman et al 2011). As such, interdisciplinary approaches are necessary for developing research methodologies towards sustainable innovation.

3 INTERDISCIPLINARTITY AND TEXTILE DESIGN RESEARCH

Academic research in textile materials and processes has traditionally been dominated by technical studies situated with science and engineering knowledge frameworks. Increasingly, however, textile designers are undertaking research into technical areas with creative intentions, utilizing artistic modes of inquiry. In response to an increased confidence in both the embodied and articulated knowledge utilized and generated by textile practice (Igoe 2010, 2014 and Philpott 2012), textile design research methodology has evolved over recent years, moving towards research practices that are interdisciplinary and collaborative; constructing bridges between aesthetic and function (Philpott 2012).

In her discussion of the overlap between the artistic and scientific Rachel Philpott (2012) notes the tendency of the first wave of textile practitioners to undertake research into materials and processes, such as Frances Geesin (1995) and Sharon Baurley (1997) to emphasise the objective development of process and their scientific testing of material properties. In doing so, Philpott (2012) suggests that, perhaps due to the need to establish a relatively new research by practice model in a rigorous manner, they under emphasised their subjective position as designers and the aesthetic, cultural or emotional impact of their work. Since then, textile practitioners such as Zane Berzina (2005), Nithikul Nimkulrat (2009), Rachel Philpott (2011) and Kate Goldsworthy (2009), have established rigorous approaches that allow both the objective and subjective development of new processes and materials to contribute to and form the basis for new knowledge. Here we suggest the need to maintain and embrace a scientific element to design research in textiles towards sustainable innovation.

The bringing together of scientific and poetic approaches can 'illuminate different perspectives, allowing for investigation of the metaphysical, the emotional and the imaginative alongside the technical' (Philpott 2012). However, as Dorst (2006: 18) argues, 'It has become almost impossible for a single designer to possess all the necessary knowledge and skills to develop complicated design'. As described by Clarke (2011:7), it is 'multifaceted', bringing together historical references, technological innovations, production techniques and process. As a result, designers and design researchers rarely work alone but are required to work collaboratively across disciplines and to communicate with technologists and manufacturers. Working in this way enables new ideas to be tested towards implementation within the relevant context, facilitating innovation.

Design, is informed by a variety of intelligences including 'linguistic, logical/mathematical, spatial, musical, bodily/kinaesthetic and personal' (Dorst 2006:109). Each of which, can be scientifically and/or creatively understood as required by the problem in question. In regard to this, Nigel Cross (2001) examines the relationship between the two in his study, 'Designerly Ways of

Knowing: Design Discipline Versus Design Science'. He discusses the growth of scientific design process and design methods in the 1960's and identifies the reemergence of 'design-science' matters. He acknowledges a shift towards methodological approaches, publication themes and dialogue within this territory that encompasses both creative and scientific elements.

This way of working is, perhaps implicit in textile practice. As Textile designer, Anni Albers (1962: 2) commented, '…we find two distinct points of departure: the scientific and technological, and the artistic. Too often these approaches arrive at separate results instead of a single, all-inclusive form that embodies our needs: the need for the functioning of a thing *and* the need for appearance that responds to our sense of form'. Similarly, with sustainability in mind, Victor Papnek wrote that 'design must become an innovative, highly creative, cross-disciplinary tool responsive to the true needs of men' (1984 : x), supporting the need for an interdisciplinary approach to sustainable innovation.

Textiles form a natural site for interdisciplinarity; encompassing aspects of art, design and engineering suggesting that textile practitioners, those who design and make textiles, possess a unique and multifaceted way of thinking (Igoe 2010:3), which is often articulated and communicated through materiality; stored in the hands of the practitioner and embodied in the resulting textile products. As such, the way in which textile practitioners approach their subject matter and articulate their practice, is often sympathetic with discourses around notions of craft. Theories of which, frequently identify the space between art, design and engineering as a rich site for creativity and productivity. The case studies described in the next part of the paper are used as a basis from which to reflect upon an approach to textile design research, which embraces this site as a platform from which to pursue sustainable innovation through interdisciplinary working.

4 CASE STUDIES

In 2010, as a result of on-going research into laser processing textiles, the ability to achieve differential dye uptake on textile materials using laser technology as a means of surface design was realised (Bartlett 2006, Matthews 2009, Addrison 2009). The potential of the process to facilitate a more ecological approach to textile surface design and coloration through reducing the amount of dye used alongside, savings in terms of energy and water in comparison to traditional techniques was suggested. Further research located existing technical research into the process (Shahidi et al 2013, Nourbakhsh and Ebrahimi 2012, Bahtiyari 2011, Yip et al. 2002 and Kan 2008) but identified that as a commercially viable design tool, the process had not been considered. A collaborative project was embarked upon between Design, Engineering and Chemistry, with the Society of Dyers of Colourists (SDC). The aim being, to develop the technique in a manner that would enable its potential implementation within industry. As such, it was hoped that through the research the work could move from creativity towards innovation. This project, which has recently been concluded, is referred to as Case Study 1 (CS1).

In parallel to the establishment of this project, in order to build upon the potential to use laser processing towards sustainable innovation, a project with De Montfort University, was established to further explore the opportunities for new surface design methods incorporating laser technology. A project that aimed to explore the opportunities of using laser technology to establish and enhance emerging textile biotechnologies as design tools, and conversely to explore the possibilities to extend the surface design opportunities of lasers through combining technologies was instigated. It is part of the Laser Enhanced Biotechnology for Textile Design (LEBIOTEX) project, which is supported by several major industrial partners (LEBIOTEX 2014). This project, which is currently running, is referred to as CS2.

This part of the paper provides an overview of each project focusing on the methodological approaches used in order to reflect upon,interdisciplinary research for textile materials and processes towards sustainable innovation.

CS1 Overview, Methods and Results

The project considered the aesthetic possibilities, production opportunities and ecological advantages of a digital laser-dye technique. The work was positioned in a practice-led, design research environment and approached from a textile design perspective. The study was approached in an interdisciplinary manner, using mixed methods, working between design, optical engineering and chemistry to facilitate both the technical and creative aspects of the project. Quantitative measurement and analysis of the textile outcomes alongside qualitative analysis that focused on creative exploration aided both a tacit understanding of, and ability to control, manipulate and transfer processing parameters. This enabled the design results to be reliably repeated and validated, establishing the potential to commercially apply the technique. Sportswear prototypes produced (Figure 2) in the study suggested a suitable market for processing polyester garments using the laser-dye technique.

Quantitative data was collected via structured laboratory experiments relating to the technical and mechanical aspects associated with laser-processing. Microscopic analysis of textile fibres, reflectance spectroscopy, colour measurement and analysis were undertaken. Experimental work included: laser parameter trialsconducted through the production of technical fabric samples as 'material' data; energy density vector grids, equations and calculations were established; 'grey' digital data was measured and applied numerically; tonal density graphs and calibrated colour charts were produced; microscopic fibre and yarn analysis was carried out; relevant ISO textile performance tests were conducted alongside ISO dyeing procedures and subsequent colour measurement and analysis. This aspect of the work was underpinned by the perspective of a textile designer and the procedures undertaken were essentially steered by both creativy and validity considerations of the laser-dye process.

Qualitative data collection occurred through experiential involvement. First-hand investigation of the laser-dye process enabled direct interaction with varied environments, disciplines, people, equipment, procedures, methods and techniques. Design practice included: pattern/surface design development by combining hand drawn material and CAD methods to formulate engineered structures towards final repeat designs; colour exploration exploiting the tonal capability of the laser-dye process through the development of specified patterns focused on achieving subtle, dramatic gradient shifts and a range of shade depths on the textile surface; and creating a textile collection in view of the potential commercial opportunities of the laser-dye process. A commercially applicable colour palette was integrated into the inquiry consisting of 10

Pantone® colours with six colour-ways. Pattern, dye/colour and shade depth combinations were finalised at this stage. An emphasis on 'subjectivity' attributed to qualitative methods complimented the researchers creative and interpretative background as a textile designer. Therefore, individual thought and expression was evidenced in the design and technically related aspects of the work through the design and development of fabric samples.

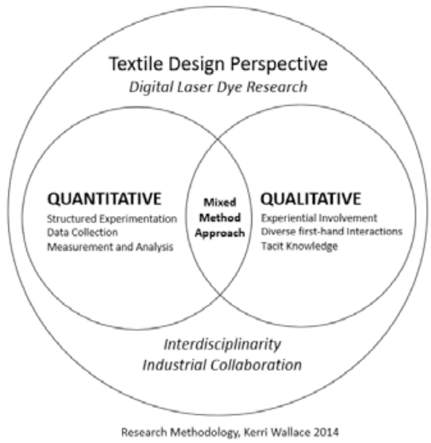
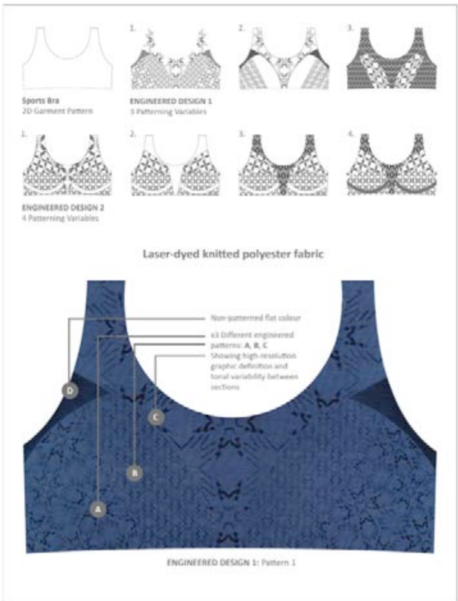


Figure 1 CS1 Research Methodology

Laser-dyed patterns were created with multiple dye tones generating a visible tonal spectrum as a central aspect of the resulting design aesthetic (Figure 2). A mechanical know-how of methods enabled even, level dye uptake making it possible to create a range of tones using a single dye colour in a way that could be repeated or altered by specification. An ability to know, understand and manipulate laser energy distribution when processing a piece of fabric in this way was a fundamental outcome of the project, establishing a model for implementing the process within industrial contexts. Experimentation presented opportunities for processing finished garments. The laser beam was able to scan across seams and stitching whilst retaining high-resolution graphic qualities and tonal definition. This is not achievable with conventional image-based coloration approaches on to finished garments (Figure 3)



Figures 2 and 3: CS1 Design outcomes

CS2 Overview, Methods and Results

The project discussed here is one part of the LEBIOTEX project, aiming to discover and develop novel textile design techniques using laser technology. Specifically concerned with affecting the surface quality of textile substrates using CO_2 laser processing, as a potentially more sustainable design method. The project involved industry partners from three distinct sectors of the textile industry. This included a designer and manufacturer of contract interiors; a leading performance swimwear brand; and a designer maker with a craft based practice. With input from three diverse partners, it was intended that any new techniques could be universally achieved and implemented across multiple sectors of the textile industry.

As alluded to in CS1, research in the area of laser processing for textile design straddles multiple fields of enquiry. As a multidisciplinary study, it was necessary to approach the research using multiple methods, allowing the outcomes to stand up with rigor on all straddled fields, which would traditionally fall under the separate categories of textile design, textile chemistry and textile engineering. Therefore, defining a specific methodology for this research was guided by both scientific and design methods. The diagram in Figure 3 attempts to show the synthesis of scientific and creative approaches to textile design research in this study, broken down into four phases of work. It shows the practice divided into two sections, *data collection* and *analysis*. The combination of design practice and systematic sampling was used as a method of data collection for material research and for developing new processes for existing laser technologies. The diagram indicates how practice was used to develop and to analyse data. Critical reflection on each phase informs practice whilst employing and building on tacit knowledge and technical understanding. Material samples and written documentation are generated throughout.

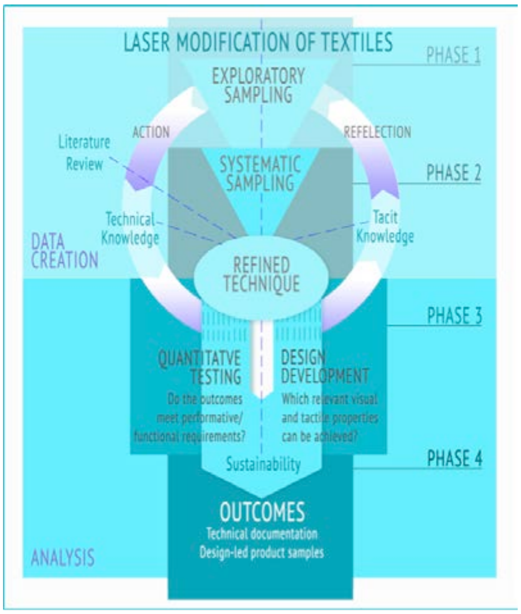


Figure 4: CS2 Research Methodology

The first Phase 1 begins with the broad aim of achieving novel and sustainable surface design by use of laser technology. While establishing workshop conditions for the research, an initial exploratory and 'playful' phase allowed experimentation with a wide range of parameters and materials. Although design research methods were suitable for textile sampling and developing techniques at studio scale, a technical understanding of the process and fabrics was also vital for the research. Thus, this practice also consisted of systematic scientific experimentation to establish quantifiable results using laser technology. Phase 2 provided proof of concepts as well as the ability to quantify, explain and refine the effects achieved on textile substrates, allowing techniques to be controlled and replicated. Both second and third phases of the research worked within the broad constraints and affordances established in the first creative phase. Phase 3 of the research, shown in Figure 1, indicates two strands of analysis examining the aesthetic and functional properties. This included testing the technique with quantifiable measurements reflecting the experimental conditions and technical language of engineering and industry testing standards. Finally the processes are tested for design potential using a mark making test sheet that has been derived from a more personal, creative design intention. The function of design in this instance is a form of analysis with an aim to establish how the practitioner's personal design language may be

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translated to fabric using the newly established technique. Again the synthesis of design and scientific approaches proved to be fundamental in identifying and demonstrating both the creative opportunities through visual means and the technical and performance properties through industry standard testing. Together revealing viability for their potential commercial context.

The outcomes of the research are noted in the diagram as phase 4. Using the developed process, physical designs were created and informed the discussion and documentation of potential advantages, impacts and viability. To date the project has achieved: a new surface design technique for woollen textiles using the laser as a pre-treatment to dyeing (Figure 5); a second enhanced laser dyeing technique, that has achieved multicoloured surface design effects with no thermal damage on polyester, wool and nylon substrates; a method using the photothermal properties of the CO_2 laser that allows three-dimensional moulding of knitted synthetic fabrics without the use of pattern moulds (Figure 6); and a new decorative surface design technique for the patterning of linen textiles.

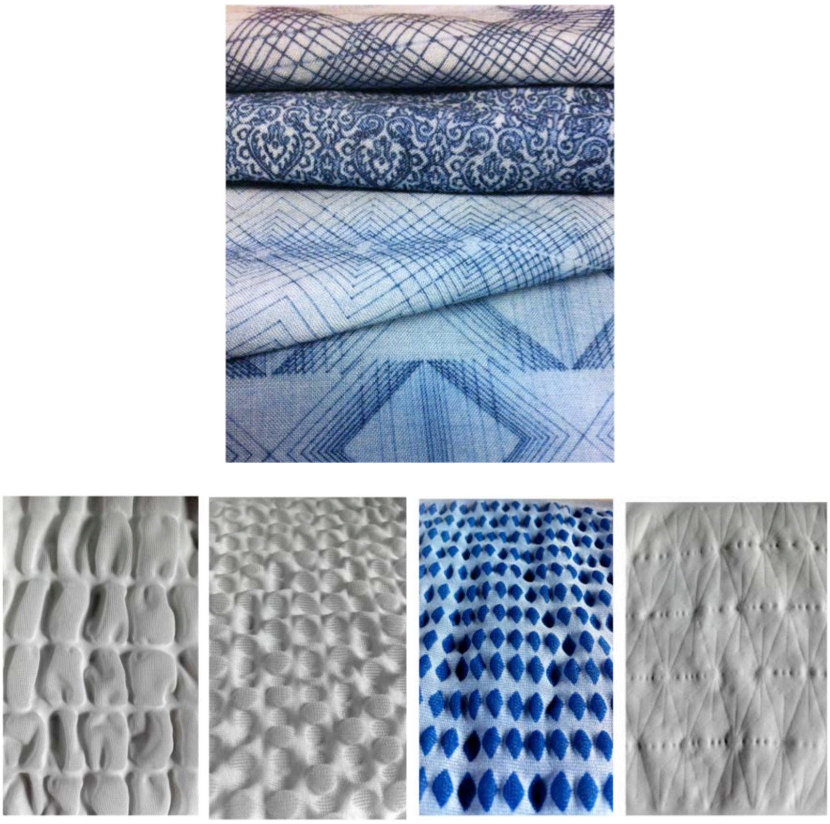

Figure 5 and 6: CS2 Deign outcomes

5 DISCUSSION

In both case studies a practice-based approach to textile design research in which knowledge was generated as the design practice progressed was evident. In this sense, the work can be described as *Research through design* (Frayling, 1993) where design practice is used as an essential part of the research both in conducting investigation and as a means of expressing

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the results. Central to this was the acknowledgement, use and development of tacit knowledge in terms of both the aesthetic and technical progress made within the research. Whilst this tacit or 'craft' knowledge was central in both projects, it is important to note that at points within the work what would be perceived as familiar textile design practice embraced more traditional notions of scientific experimentation. We reflect on how the two relate, the drivers and the effect on the results and their potential impact in terms of sustainable innovation.

Exploration and experimentation

This design practice led both projects in that the intentions of the work were to explore processes and materials in such a way to as achieve new, viable textile designs. Essential to both projects was a period of initial exploration through which a tacit and fluid working knowledge of the materials and processes in hand could be established in order to support creative exploration and development. Philpott (2007:2) discusses exploratory play as "a process of knowledge generation... which allows practice-led research to flourish and advance beyond that which could be achieved by scientific research methods used in isolation,". Supporting Philpott's comment, identified in CS2 but true of both studies, through this 'playful' phase in the research, a familiarity between laser settings, graphic elements, material weight and composition was established. McCullough (1996) describes this exploration as learning the affordances and constraints (p. 248) of a new medium. This learning built a cumulative 'tacit' knowledge of material and medium properties. This is reflected in the qualitative sphere of the methodology modeled in CS1 (Figure 1) and in 'Phase 1' in that modeled in CS2 (Figure 2). In each 'model', tacit knowledge, crosses over into quantitative and/or more 'systematic' periods of work. This echoes scientist Michael Polyanyi's (1966) suggestion, in reference to the subject of research discovery and writing, that tacit knowledge involves the foresight to anticipate a solution to an undetermined or *hidden* problem. As Barrett and Bolt (2007) suggest, in creative arts practice, strategies are not predetermined, but emerge from action over time.

This reciprocal relationship between exploration and experimentation has been foundational to the momentum and 'success' of both CS1 and CS2. At times the experimentation seems to have dominated the work, perhaps in part due to the learning curve undertaken by designers to work in this manner. The depth of knowledge and technical fluency gained has provided the confidence to push the design potential of the process and to fully understand and communicate it's opportunities and limitations in relation various materials and product contexts.

Results and communication

Both projects were collaborative involving industry partners and stake-holders external to academia. As such there were multiple demands in terms of the nature of the data sought through the work. Although both projects were design led in terms of their overarching approach and intention, there was a requirement for data beyond the design results themselves. As outlined and seen in Figures 1 and 2, both projects produced quantitative date resulting from various process experiments and testing, alongside the physical samples and reflections resulting from the design process, which can be perceived as qualitative.

The physical textile samples, as data, led collaborative discussion through the demonstration of design concepts and provided a starting point for exploration of future possibilities. They also, however, provided a trigger for deeper probing in terms of technical queries, production possibilities and specification opportunities. As such the quantitative sphere in CS1, which included optimisation of the digital laser-dye process, and Phases 2, 3 and 4 in CS2 proved, essential in maintaining and progressing dialogue with various stakeholders and for keeping the opportunities for innovation open. It was important in both projects, however, to pull the work back into the exploration phase to maintain the design direction of the work and to enable the new knowledge gained to retain relevance and balance in terms of both the creative and engineering aspects of textile design.

6 CONCLUSIONS AND FURTHER WORK

The approach used, has yielded both design outcomes and technical models for new processing opportunities in textiles in relation to specific commercial contexts, thus creating a strong platform for innovation. The research results of the case studies used suggest the potential to make changes to the way in which textiles are colored and patterned by providing alternative technological techniques, which are ecologically advantageous. The work could be perceived to focus on the lower levels of sustainable innovation described by Charter and Clarke (2007). Level 1 innovation can be identified within the results of the projects used as case studies, in the sense that incremental ecological improvements in the textile coloration process have been made possible via the techniques established. The provision of these techniques, which simultaneously dye and pattern textiles in a new way could also be seen as a major ‘re-design’ of existing or traditional methods, thus achieving Level 2 innovation. Considered Borja de Mozota’s value model (2006), the techniques - facilitated by design - have the potential to: ‘differentiate’ textile products creating a competitive advantage in terms of sustainability credentials; ‘integrate’ via the improvement of existing processes and products; and ‘transform’ by enabling companies to address several challenges posed by the need to move towards sustainability thus supporting ‘good business’.

Further work presents the opportunity to focus the methodological approach discussed towards Charter and Clarke’s (2007) higher levels of innovation, perhaps by exploring the possibility of integrating the techniques within evolving systems of re-use and closed loop systems for textiles, and possibly to support systems of local production. In relation to Borja De Mozota’s value model (2006), the techniques potential to further support ‘ good business’ in relation to return on investment (ROI) for example, need to be considered. Further effort to provide quantitative data regarding the ecological benefits of the techniques in relation to specific commercial contexts is needed to fully make the case for innovation. A start on this has been made through the use of Life Cycle Analysis within the framework of the LEBIOTEX project.

In regard to the broader implications of the research, it would be of interest to consider the relevance of this approach to sub-disciplines of design other than textiles. The approach taken may prove sympathetic to areas in which materials and processes are engaged with in a 'hands-on' manner and form a central element of inquiry. Both creative and technical methods have been crucial in achieving the research outcomes in regard to the case studies discussed, and have resulted in a solid platform for further collaboration and implementation with the project partners and potentially industry more broadly. As discussed in relation to the two case studies, an acknowledgment and active engagement with 'craft' knowledge in both the creative and technical aspects of design research underpins the approach put forward for sustainable innovation in textiles.

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