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INTERDISCIPLINARY TEXTILE DESIGN RESEARCH FOR MATERIAL INNOVATION: SYNTHESISING DESIGN, SCIENCE AND INDUSTRY COLLABORATION

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Within the landscape of contemporary textile design research lies a rich site for collaboration, with the opportunity to draw on specialist knowledge across disciplines. This paper argues that Integrating textile design practice with specialist scientific and technical knowledge allows designers to engage fully with new processes, and develop new approaches to textile design to drive innovation in the field. The paper reflects on the interdisciplinary and collaborative elements of a research study examining laser technology for textile design. An interdisciplinary textile design research methodology is described, encompassing industrial and interdepartmental collaboration. Defining a specific strategy for the research was characterised by a fusion of science, design and craft practices. The interdisciplinary approach borrowed from action research principles, with design specific skills identified as key to advancing the study, together with the systematic rigor of controlled experimentation. Industrial input from the project's industry partners provided commercial validation leading to the development of four novel Laser Textile Design techniques for coloration and three-dimensional moulding of materials that offered environmental sustainability thorough resource efficiency and digital processing agility.

Keywords: Material Innovation; Collaboration; Textile Design Research; Digital Technology; Lasers

Introduction

This paper presents the author's reflections on the methodological approach used in an interdisciplinary collaborative research project. The author's role involved the research and development of novel design techniques using laser technology, referred to as *Laser Textile Design* (Morgan, 2016), considering improved environmental sustainability for textile design.

This paper highlights relevant approaches to practice-based and design-led interdisciplinary research problems. Providing examples from the Laser Textile Design study, it goes on to reflect upon the relationship between design and scientific methods in defining a specific methodology and highlights the key methods used for problem formulation, data collection, analysis, evaluation and dissemination of the research work. Conclusions propose the strategies used may offer a model for an interdisciplinary practice-based research methodology for future collaborative design science research.

Laser use in textile design has been addressed, predominantly from engineering perspectives (for example: Montazer et al, 2012). However, a growing number of design researchers are facing cross-disciplinary challenges and have commented on the significance of utilising a multidisciplinary approach in their research roles. Examples in the field of laser processing are described by Kane et al (2015). As the fields of responsive, smart, bio and digital textile research continues to expand, this paper is timely in suggesting an approach that considers interdisciplinarity and collaboration as key strategies for contemporary textile research.

The aim of the *Laser Textile Design* research was to develop new, sustainable, creative opportunities for textile design by investigating laser processing technology to achieve surface design and three-dimensional effects. As a practice based, multidisciplinary study situated in textile design, the research methodology employed drew on scientific knowledge frameworks used within optical engineering and dye chemistry, as well as design and craft based approaches. The project, involved collaboration between Loughborough University, De Montfort University and industry partners from distinct sectors of the textile industry: A contract interior manufacturer and a performance swimwear brand. Through this collaboration, it was expected that results could be utilised across multiple sectors of the textile industry, accessible to industry, education and independent practitioner alike. As the project developed, results were shared with the team ensuring that the research direction remained relevant from a commercial perspective. In order for the results to be appropriate, communicable and repeatable for textile design and textile production contexts, the work collected detailed technical data and scientific analysis alongside insights and creative opportunities for designers.

The role of textile designer and engineer rarely overlap within the textile industry. However, interdisciplinary collaboration between craft and science is increasingly being cited as a catalyst for innovation (e.g. Crafts Council & KPMG, 2016). Thus, textile designers working at the intersection between craft, design, technology and science are well placed to facilitate material innovation (Morgan, 2016b). In this research, textile practice was placed at the interstices between commercial design, engineering and craft as shown in figure 1.

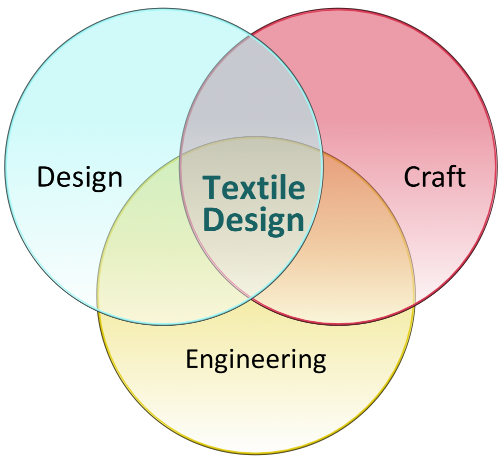

Figure 1. ***Laser Textile Design*** **at the intersection between design, craft and engineering**
Source: Morgan, 2016

Defining a specific strategy for this research was characterised by a fusion of scientific and design research methods as discussed in the following section. In addition, the work considered industrial input and collaboration from the project industry partners. This added further depth to the study in terms of commercial validation and relevance.

Methods

The interdisciplinary textile design research approach is presented using examples from the *Laser Textile Design* research as a case study. The research was conducted using a mixed methods approach, integrating both qualitative and quantitative data to inform and analyse the research inquiry (Cresswell, 2014). The use of mixed methods complements the interdisciplinary approach discussed in the previous section, making use of methods that have roots in both design and scientific fields.

The methods used in this study were categorised into five stages of the research process as articulated by Niedderer (2009): Problem formulation, Methods of data collection, Methods of analysis, Evaluation and Dissemination and were used in the formation of an action plan for this research. Table 1 shows the role of methods used in this research adapted from Niedderer's 'Framework for analysing role of methods in research' (Niedderer, 2009:14).

Table 1. Role of Methods used in Laser Textile Design Research				
Stage	**Method**	**Purpose/Aim**	**Type**	**Additional**
Phase 1 Problem Formation *(Planning)*	Contextual Review	Review existing research in the field and Identify knowledge gaps	Mixed	Information from design and technical literature.
	Collaboration: Stakeholder discussion	Identification of industrial and commercial priorities	Mixed	Performance standards to be met. Desirable production and aesthetic abilities.
Phase 2 Data Collection *(Action)*	Creative Sampling	Identification of design opportunities	Qualitative	Observation on samples & exploratory design practice.
	Systematic Sampling	Identify effect of laser on textile substrates and optimise techniques	Mixed	Scientific experimentation, technical samples, numerical data & observation.
	Technical Testing	Test functionality of techniques	Quantitative	Numerical data from ISO/ established tests.
	Log book and technical file documentation	Record numerical parameters and design insights	Mixed	Written notes, numerical data, sketches, photographs.
	Collaboration: Formal Industry feedback using focus group methods	Collect insights, feedback and industry perspectives on the work	Qualitative	Data Collection exercises: group activities, ranking, written/ recorded discussion.
Phase 3 Analysis *(Observation)*	Reflective practice	Analyse processes & insights to inform further work	Qualitative	Insights leading to refined action.
	Analysis of testing results	Analyse success of material performance	Quantitative	Formulas, graphs and tables.
	Focused design practice: design development	Analyse design opportunities gained from laser techniques	Qualitative	Design Collection to answer industry brief.
	Industry feedback from focus group methods	Analyse success of design and commercial fit and industrial preferences/ priorities	Qualitative	Transcripts, brainstorming & ranked samples.
Phase 4 Evaluation *(Reflection)*	Analytical Framework	Ensures outcomes are measured against consistent criteria	Mixed	Measures success against design attributes, contextual viability & sustainability.
	Triangulation of technical and creative results	Evaluate success of techniques	Mixed	Comparison of design and scientific data. Advantages & Disadvantages.
Phase 5 Dissemination (Documentation)	Written documentation /external presentation	Communicate new knowledge	Mixed	
	Exhibition	Provide evidence and showcase samples	Qualitative	
	Project meetings and presentation	Provide progress updates to industrial partners.	Qualitative	Feedback informs direction of subsequent work

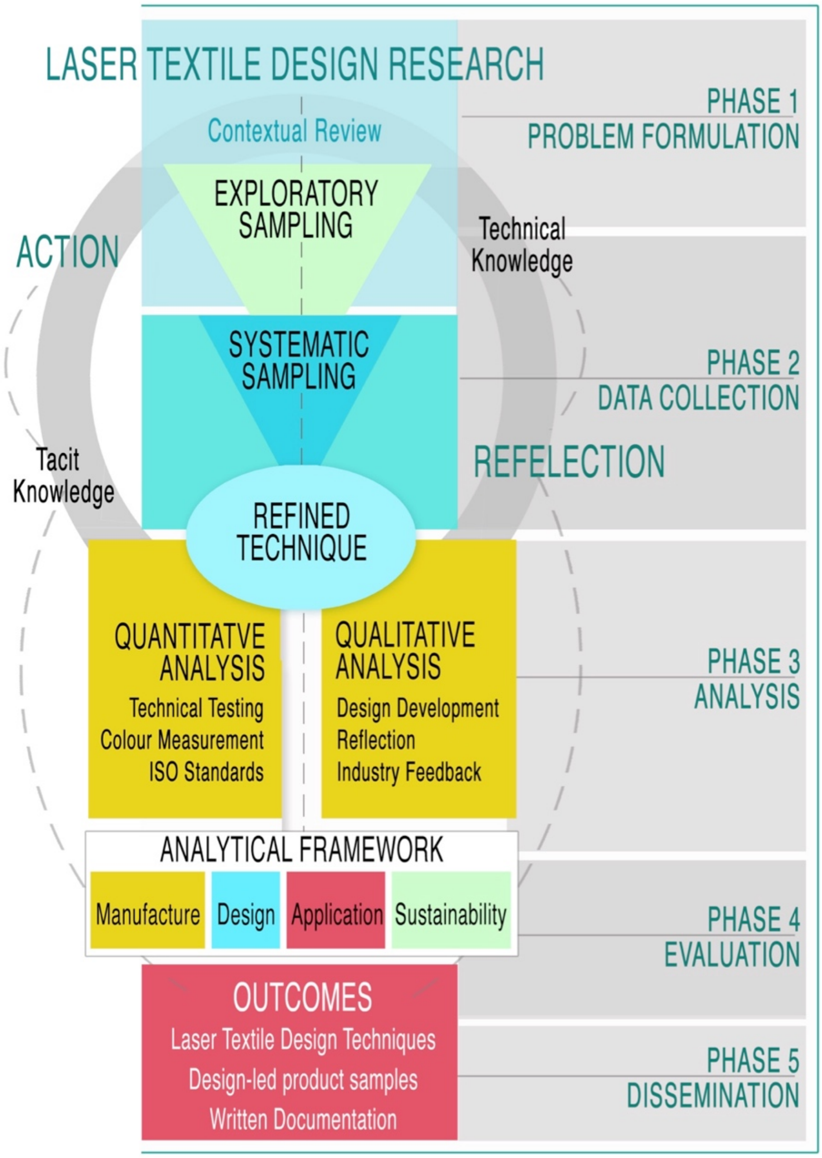

Figure 2. Action Plan for Laser Textile Design Research
Source: Morgan, 2016

The diagram in Figure 2 shows the action plan for the research, broken down into the five phases of work. It shows how the combination of textile design practice (in the form of creative sampling) and scientific experimentation (in the form of systematic sampling) were used as methods of data collection for research into materials and developing new processes for existing laser technologies. The diagram indicates how textile design practice was used to develop and to analyse data. Critical reflection on each phase informs practice whilst employing and building on tacit knowledge (Polyanyi, 1966) and technical understanding. Material samples and written documentation were generated throughout.

Work created as part of the practice then became the data for analysis and each set of action and reflection formed an iterative body of physical samples and a subject knowledge that could be explicitly documented in the form of samples and written results. The textile designs as data allowed qualitative analysis to reveal the suitability of the laser techniques for design opportunities, assessing aesthetic, tactile and emotional qualities through reflection and structured industry feedback; quantitative data was used to analyse parameter optimisation, functional and performance standards.

With reference to the Action Plan shown in Figure 2, the following section describes how methods were used in each phase of the research. Previous iterations of this Action Plan were articulated by the author during the earlier stages of the research (Morgan et al., 2014; Kane et al, 2015). The diagram has since been refined to represent the completed research process.

Problem formulation (*phase 1*)

Phase 1 began with a wide-ranging aim of achieving novel and sustainable surface design using of laser technology to modify textile substrates. The laser techniques were not predetermined, rather they emerged and were refined as the research and knowledge of materials and equipment progressed.

A literature and contextual review was conducted, including a review of academic and technical literature, design projects and innovations in the field of textiles for surface patterning, sustainability and laser processing. Visits to trade fairs, industry partner's companies, and conferences were also used to review industrial technology and commercial priorities, as well as current and predicted future trends for textile processing.

Data Collection (*phase 2*)

Establishing workshop conditions for this research involved an initial exploratory and somewhat 'playful' phase that allowed experimentation with a wide range of parameters and materials. Reflections from this early stage fed back into Phase 1, helping to inform the problem formulation. A technical understanding of the process and fabrics was also vital for this research. Thus, experimentation carried out took the form of systematic sampling, creative sampling and technical testing leading to a refined set of *Laser Textile Design* Techniques, described as follows.

Exploratory Creative Sampling

Used the designer's skills and experiential knowledge to explore design effects, aesthetic and tactile opportunities afforded by laser irradiation on textiles. It was through creative exploration in this research project that a familiarity between laser settings, graphic elements, material weight and composition was established. It was also through playful exploration that the affordances and constraints of this new medium could be learnt intuitively (McCullough, 1996), which built upon a cumulative tacit knowledge of material and medium properties.

Material led exploration in the early stages of the research identified four possible research directions as documented in Figure 3. This involved hands-on craft interventions such as hand mixing dyes, experimenting with materials and hand embroidery hoops.

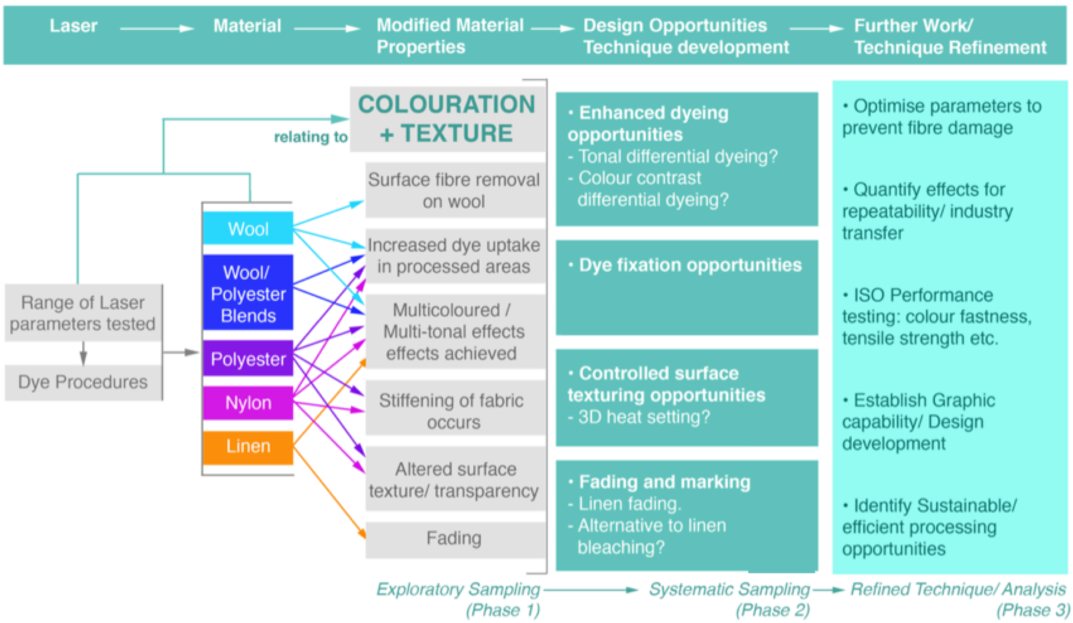

Figure 3. Initial Laser Textile Design Research Directions Identified from Material-led Exploration
Source: Morgan, 2016

Exploratory creative sampling resulted in technical and tacit knowledge of laser textile interaction. Laser modified material properties, as listed in Figure 3, became design opportunities to test and refine. Laser colouration and three-dimensional effects were identified as avenues for focused investigation.

Systematic Sampling

Systematic sampling involved the iterative, logical experiments carried out on textile substrates to prove or disprove the effect of laser interaction. Systematic sampling and technical testing worked towards optimising a set of *Laser Textile Design* Techniques. These experiments used a scientific approach, with set material and procedural boundaries to test a single variable. Systematic sampling was generative as each set of sampling informed progression of subsequent experiments.

Technical Testing

Tests adhering to ISO international standards were carried out to quantify the performance of laser treated textile samples, leading to a refined technique. In addition, specialist scientific equipment was used to observe and measure the dye performance, colour change and fibre modification caused by laser irradiation on textile substrates. Technical testing procedures included; microscopic and S.E.M. imaging; collecting colometric data; reflectance spectrophotometry, quantifying dye fixation, exhaustion; determining fastness to washing, rubbing; tensile and bursting strength (figure 4).

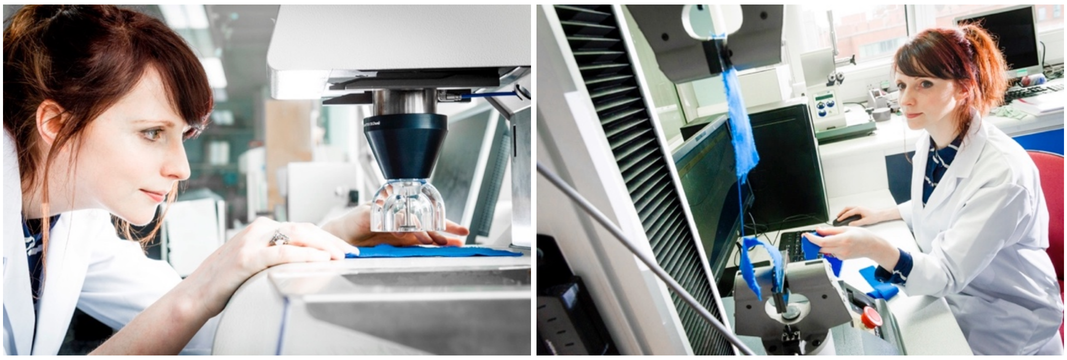

Figure 4. International Standard Textile Testing:
Conducting Burst and Tensile Strength Testing on Laser Treated Samples
Source: Morgan, 2016

Observation and Reflection

In this research project, documentation in logbooks became important throughout, not only for recording technical data and parameter settings (figure 5), but also for recording design insights and intuitive interference with the laser machinery to try and capture the information gained through experiential knowledge. For example, knowing by sight when a material had received an optimal amount of laser irradiation and stopping the process. The laser parameters and the visual attributes could then be recorded by written and photographic accounts to allow replication of the results. Similarly, experiential knowledge of laser and material interaction helped to intuitively determine the range of parameters to work within for each new design, material weight or construction.

Figure 5. Documentation of Systematic Sampling: Observation and Written Reflection
Source: Morgan, 2016

Refined Techniques

Processing parameters and graphic capabilities were optimised and refined to develop four distinct *Laser Textile Design* techniques, as described in table 2. These included a laser enhanced dyeing technique for wool and wool blends, *peri-dyeing*: a laser dye fixation technique, a laser moulding technique and a laser fading linen technique (figures 6-9). Together these techniques offer tonal, multicolour, precise graphic processing and three-dimensional or relief surface design capabilities for wool, linen and synthetic substrates.

Table 2. *Laser Textile Design* Techniques

Technique	Description
Laser enhanced dyeing of wool and wool blend textiles (figure 6)	A novel laser technique developed from the research that uses the laser to modify the surface of woollen textiles, increasing dye affinity. The process removes microscopic scales from the wool fibre surface, resulting in an enhanced dye performance in the laser-treated areas. Targeted designs can be laser marked on the surface of the cloth making use of differential dye uptake to achieve multi-tonal surface design on wool and multicolour surface design on wool blends. It was demonstrated that the laser pre-treated wool can be dyed at a reduced temperature and time, saving water and energy as well as combining coloration and patterning in one process. During coloration, the potential for an estimated 54% reduction of energy was displayed. Textile performance tests show that high fastness to washing and rubbing was achieved to meet current industry and consumer standards. Laser engraving can also remove the felted or brushed surface fibres of milled wool, to reveal the underlying woven structure. This can provide three-dimensional relief surfaces in parallel with the multi-tonal design effects.
Peri-dyeing: Laser dye fixation for textile design (figure 7)	This laser based dyeing technique allows intricate targeted surface design of textile substrates. In this technique, the dye diffusion and reaction takes place at the point of interaction between the laser and textile material. Photographic quality graphics, and multicoloured surface design effects can be achieved on both natural and synthetic fabrics. The non-contact laser set up allows precision detail to be achieved on high-texture fabrics. Peri-dying enables digital design innovation, direct to garment processing and customisation in the manufacture of finished textile goods with sustainability benefits through reduced energy, water and chemical consumption.

Laser moulding for three-dimensional textile surface design (figure 8)	A technique using the photothermal properties of the CO2 laser has been developed, allowing three-dimensional moulding of synthetic textiles. This technique allows designs to be 'set' on synthetic fabrics using the laser, resulting in three-dimensional forms on the surface of the cloth. The moulding technique can be used to design accurate surface architectures providing potential for engineered functionality and three-dimensional design features for textile product applications. The laser does not require moulds or complicated loom set up to produce three-dimensional forms and offers ease of pattern change through digital generation of designs. Laser technology offers dry processing, without requirement for additional materials. The method allows decoration and functionality to emerge from the structure of the cloth without contaminating the mono-material fibres. The use of synthetic mono materials may provide additional sustainability benefits for ease of recycling at end of life.
Laser fading linen (figure 9)	A novel laser marking and fading technique uses laser precision to apply subtle designs on natural linen. As a completely dry process, this technique can be used as an alternative to printing methods for patterning linen without the need for water, printing pastes or chemicals.

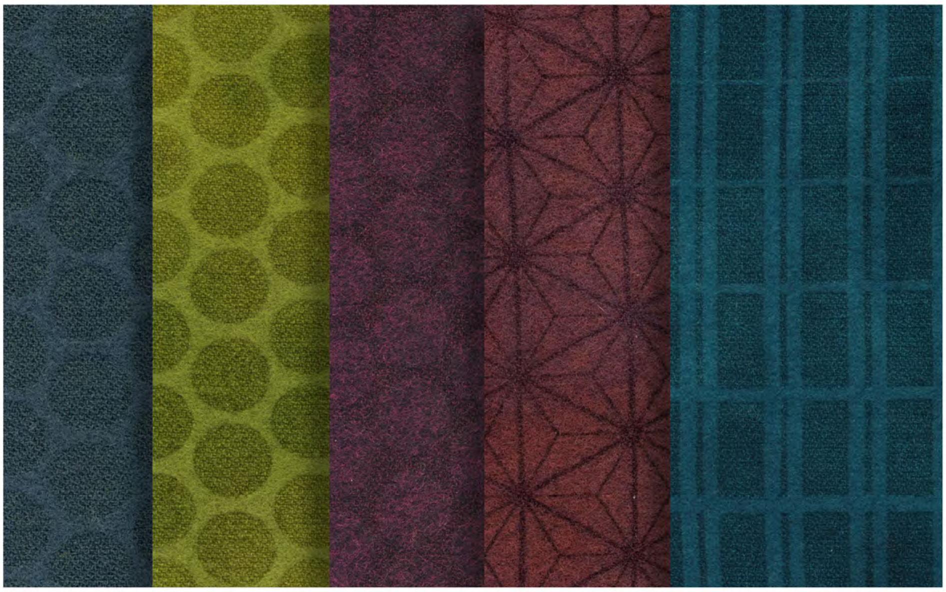

Figure 6. Samples created using the developed Laser Enhanced Dyeing for Wool Technique
Source: Morgan, 2016

Figure 7. Samples created using the developed Peri-Dyeing: Laser Dye Fixation Technique
Source: Morgan, 2016

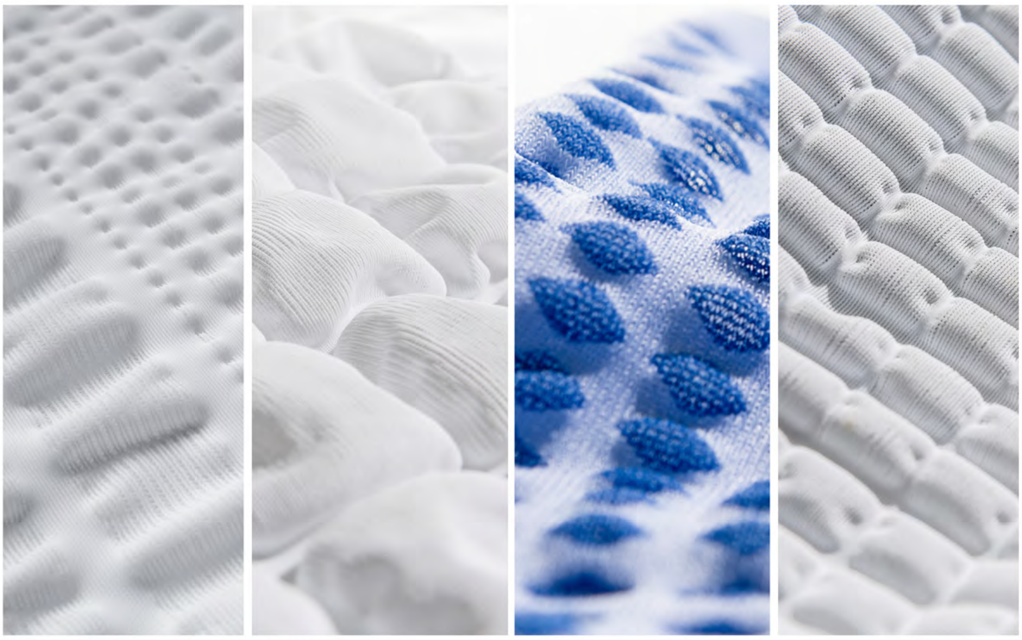

Figure 8. Samples created using the developed Laser Moulding Technique
Source: Morgan, 2016

Figure 9. Samples created using the developed Laser Fading Linen Technique
Source: Morgan, 2016

Analysis (*phase 3*)

As discussed previously, reflective practice was used as a form of analysis and applied throughout this research. This is shown in Figure 2 as circular, passing through and feeding into each phase. The reflective process was integral to decision making to provide direction and generate ideas during and after practical work also known as 'reflection in and on action' (Schon, 1983:97). In both instances, critical reflection informs the next actions to be taken. Questions arising from practice prompt further practical exploration, and the process repeats.

Quantitative Analysis

Analysing the quantifiable measurements from Phase 2 reflected the technical language of engineering and industry testing standards. Again, this circular process fed back into further action allowing technical refinement of the effects, providing proof of concepts as well as the ability to quantify and explain the effects achieved on textile substrates, allowing techniques to be controlled and replicated.

For example: the ability to specify and repeat results was gained from quantifying colour at varied laser parameters; analysis of technical test results allowed appropriate parameters to be chosen to ensure performance properties were of a commercial standard; and comparing the process to standard dyeing procedures enabled the quantification of energy savings.

Qualitative Analysis

Design Development

The processes were also tested for their design potential through focused design practice. A design brief, provided by the industry partners, resulted in a focused design collection in answer to the brief. The function of design in this instance was used to analyse how an aesthetic design language may be translated to fabric using the newly established techniques. Sketchbooks, mood boards, photographs and CADs documented the design development process for the creation and choice of graphics for laser processing (figure 10).

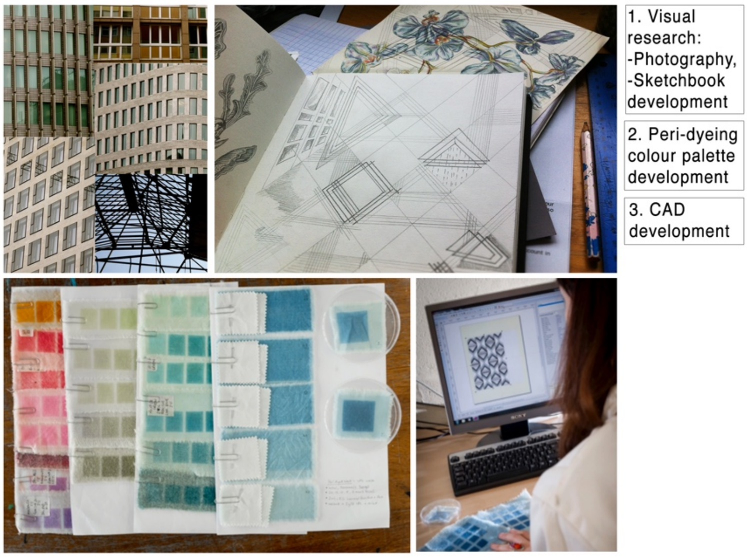

Figure 10. Design Development: Utilising *Laser Textile Design* Techniques in Response to Industry Design Brief
Source: Morgan, 2016

Industry Feedback

The collaborative relationship with the project's Industry partners was used to collect data during regular project meetings throughout the duration of the research. A more formal approach in the latter stages of the research was used to collect feedback using focus group methods including group discussions, written, brainstorming and ranking activities (figure 11). Groups consisting of members from across design, product development and material innovation teams of the two industry partner companies were used to conduct the sessions. Focus group data was collated and transcripts were coded to analyse the success of design, function and commercial fit of the Laser Textile Design techniques and sample collection, and to establish areas of commercial interest. Focus groups, meeting feedback and personal logbooks provided an ethnographic approach and allowed the research to move forward, not only on successful technical and aesthetic results, but also on feedback relative to those with vested commercial interest.

Figure 11. Participants Examine *Laser Textile Design* Collection
Source: Morgan, 2016

Evaluation: Analytical Framework (phase 4)

To ensure consistent evaluation of the research outcomes, an analytical framework was used (Grey & Malins, 2004). Figure 12 shows the analytical framework compiled for this research. The framework was compiled after discussions with the industry partners, reflecting the established priorities and necessary considerations of a new textile process or material design collection.

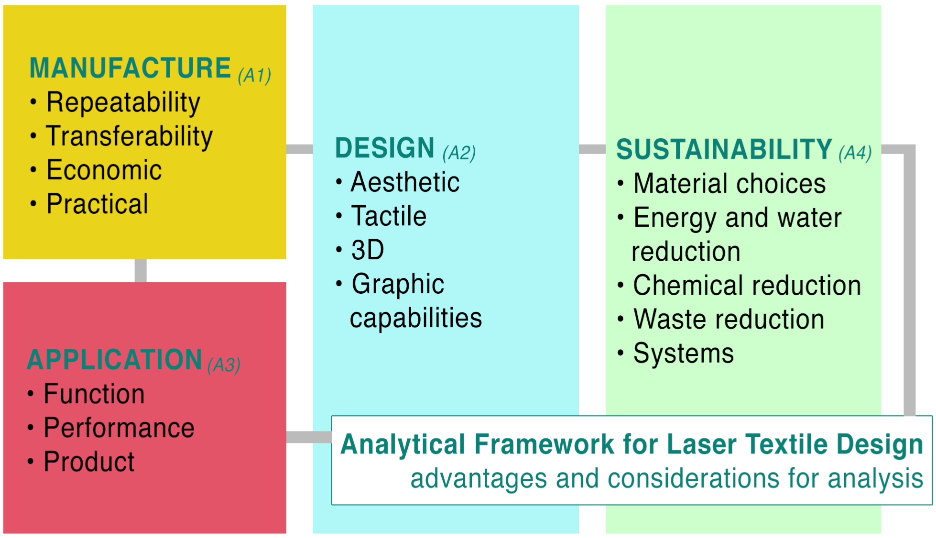

Figure 12. Analytical Framework Summary for Laser Textile Design
Source: Morgan, 2016

Four strands of analysis were used to evaluate the perceived value of the research to the textile industry; considerations and advantages for manufacture, design, application and sustainability. Technical testing and systematic sampling results were used to evaluate the repeatability, consistency and transferability of the techniques from a manufacturing perspective (*A1*). A design collection and experimental samples were used to evaluate the design opportunities (*A2*) through visual and tactile means. Industry standard testing results and industry feedback informed evaluation of the techniques in relation to their application opportunities (*A3*), with aesthetic and functional properties together revealing viability for their potential commercial context. The measures of success of sustainability (*A4*) refer to a list of considerations for reduced environmental impact compared to equivalent textile processing techniques.

Evaluating the *Laser Textile Design* research against the framework ensured that sustainability, commercial fit, aesthetic and technical performance standards were addressed, appropriate to the project's industry stakeholders.

This revealed the digital *Laser Textile Design* techniques offered new, unique creative opportunities for textile design, colouration and three-dimensional effects. They allowed patterning of fabrics in ways that had not before been possible. Enhanced colouration techniques provided a documented 54% reduction in energy, with further reductions suggested by the elimination of immersion dyeing through the *peri-dyeing* process, while the linen and laser moulding techniques provided complete elimination of wet processing for surface design. In addition to supporting cleaner and more efficient textile processing, digital *Laser Textile Design* showed the potential to contribute towards a sustainable tool for production and supply across sectors. With potential to add to the market offering of digital on-demand, rapid prototyping, and customisation services evidenced by direct-to garment sampling. Therefore, contributing to a move towards a more sustainable, agile textile design industry.

Dissemination (phase 5)

Using the developed process, physical designs were created and informed the discussion and documentation of potential advantages, impacts and viability. This took the form of conference papers, reports, presentations and exhibition of the work. Project meetings, regular presentation and discussion with industry professionals, as well as attending conferences also provided feedback that informed subsequent direction of the work. The project has led to further funding from the Arts and Humanities Research Council (AHRC), The technology Strategy Board (TSB) and commercial clients to further examine different aspects of the commercial, technical and sustainability aspects of the work.

Conclusion

This paper has described the methodology used to develop four *Laser Textile Design* techniques. It has been discussed that industrial collaboration and an interdisciplinary approach allowed the work to be examined more broadly as a tool for textile design and manufacture, advancing agile digital systems with eco-efficiency benefits.

While design-led, the interdisciplinary textile design research methodology synthesised a combination of design and scientific approaches to research, with commercial validation through collaboration with industrial partners. The combination of hand and digital textile design practice, quantitative scientific experimentation, international standard textile testing and qualitative industry feedback facilitated material and process innovation for textile design with documented design, sustainability, manufacturing and application benefits.

The methodology provided a defined framework, methods and action plan that can be adapted to accommodate project-specific requirements. Therefore, it has relevance for future design researchers, offering a clear approach to negotiate cross-disciplinary fields and collaborative stakeholder engagement, with an aim to foster responsible design-led material innovation.

This work shows that integrating textile design practice with specialist scientific and technical knowledge allows designers to engage fully with new processes, and develop new approaches to textile design to drive innovation in the field. This crossing of boundaries combined with collaborative industrial input can provide thorough investigation of subjects, maintaining rigor across all straddled fields and leading to material and process innovation beyond creative output.

To date this body of work has led to further funding for research into: industrial exploitation of the developed laser techniques; research into improved optics for laser processing textiles; and material characterisation of laser texture modification of textiles for sportswear. In addition, using the action plans and frameworks laid out in this paper, the author hopes to develop the methodological approach into set of guidelines for future researchers and welcomes collaboration in doing so, from fellow researchers working at the intersection of design, science, engineering, industry and academia.

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