INTERSECTIONS
A CONFERENCE EXPLORING COLLABORATION IN TEXTILE DESIGN RESEARCH
13 SEPT 2017
Loughborough University London

Evolutionary approach of a textile designer through cross-disciplinary research practice: A case study in the field of advanced methods for joining textiles

Helen Paine[1], Kate Goldsworthy[2] & Sharon Baurley[3]

1. University of Arts London; Norwich University of the Arts
2. University of Arts London
3. Zürich University of the Arts (ZHdK); Royal College of Art

TDRG124

Abstract: This paper will discuss the evolving methodological approach of Helen Paine who has a background in knitted textiles for fashion and completed her cross-disciplinary PhD at RCA in 2016. The PhD was sponsored by TWI: an engineering institution that specialise in materials joining and partnered with Speedo International to develop capability in the field of advanced methods for joining textiles. A multi-strategy framework that encompassed both craft-design and scientific methods was applied by the research to investigate new opportunities for ultrasonic and laser welding technologies. Specific insights relating to how and when either a craft-design or scientific approach was applied throughout the research trajectory will be discussed with the aim of contributing to an emerging methodology for textile-designers engaging in cross-disciplinary research practice.

Keywords: Cross-disciplinary practice; craft innovation; material futures; emerging technologies

Introduction

The conversation around the value of a craft approach in inventive contexts is gradually becoming more established. There are now a growing number of published case studies that discuss the value of the craft-person, and particularly a hands-on practical approach, in the development of new technologies and materials. A recent report jointly written by the Craft Council and KPMG described the 'spill over effect' craft is having in other fields when embedded within a cross-disciplinary framework (KPMG 2016). Accelerated opportunities in collaborative partnerships between different disciplines, including makers, have enabled the discovery of break through inventions. Rosy Greenless, executive director of The Craft Council, credits the role of the craft practitioner in the development of 3D printing, the application of prosthetics in surgery, and the design of wearable technologies set to revolutionise our clothing (Greenless 2016).

This paper will discuss the evolving methodological approach of Helen Paine who has a background in knitted textiles for fashion and completed her cross-disciplinary PhD at RCA in 2016 (Paine 2016). Paine graduated from her MA at RCA in 2011 and had an established hands-on practice-led craft approach to investigating technologies, specifically knit and print technologies for a fashion application. In search of widening opportunities for her work, Paine undertook a PhD in 2012 responding to an industry driven brief to investigate advanced methods for joining textiles that had been written by the project funders TWI. The main focus for the investigation was development of ultrasonic welding equipment and an emerging laser welding technology. A shift in established research methods as a craft-designer was required to meet the industry-driven expectations of the brief and an increasingly scientific approach was integrated to develop a method of locally modifying the elastic behaviour of stretchy fabrics using laser technology for a compressive effect on the body in elite swimwear applications. Through preliminary phases of the investigation industry case studies were sought in response to requirements of the brief and Speedo International became the main industrial partner. This paper will discuss how Paine's familiar methodological approach evolved with the aim of contributing towards an emerging methodology for textile and other craft-designers engaging in cross-disciplinary research practice.

Research background and context

Textiles joining at TWI

The brief for this PhD research project had been written by TWI (The Welding Institute). TWI is an R&D organisation that specialise in joining rigid materials, such as metals and plastics, for industrial applications. TWI has more recently acquired expertise in the field of joining textiles and hoped to extend knowledge in this area by commissioning this research project.

TWI's growing interest in textiles joining followed their contribution to the development of an emerging laser welding technology for textiles during the mid-1990s (Jones, Patil 2013). Transmission laser welding had prior to TWI's developments been restricted by its capability to only join dissimilar coloured plastics. This material limitation is due to the particular wavelength of the laser that is required to transmit through the surface substrate before being absorbed by the lower layer in the configuration (Jones, Patil 2013). TWI discovered that laser absorptive pigment usually contained within the bulk of the lower material layer could be applied at the interface of the joint in liquid form. The dye is green when applied to the fabric but becomes almost completely invisible once irradiated by the laser, thus eliminating the need for a dissimilar coloured adjoining partner. This revolutionary development allowed the joining of same coloured materials and opened up application opportunities within the textiles sector where product aesthetics are often a fundamental consideration. TWI have demonstrated feasibility across numerous product sectors including water proof clothing (Jones, Patil 2013), inflatable car airbags (Rooks 2004), polyester clothing (Hilton, Jones 2000) and home furnishings (Jones 2005).

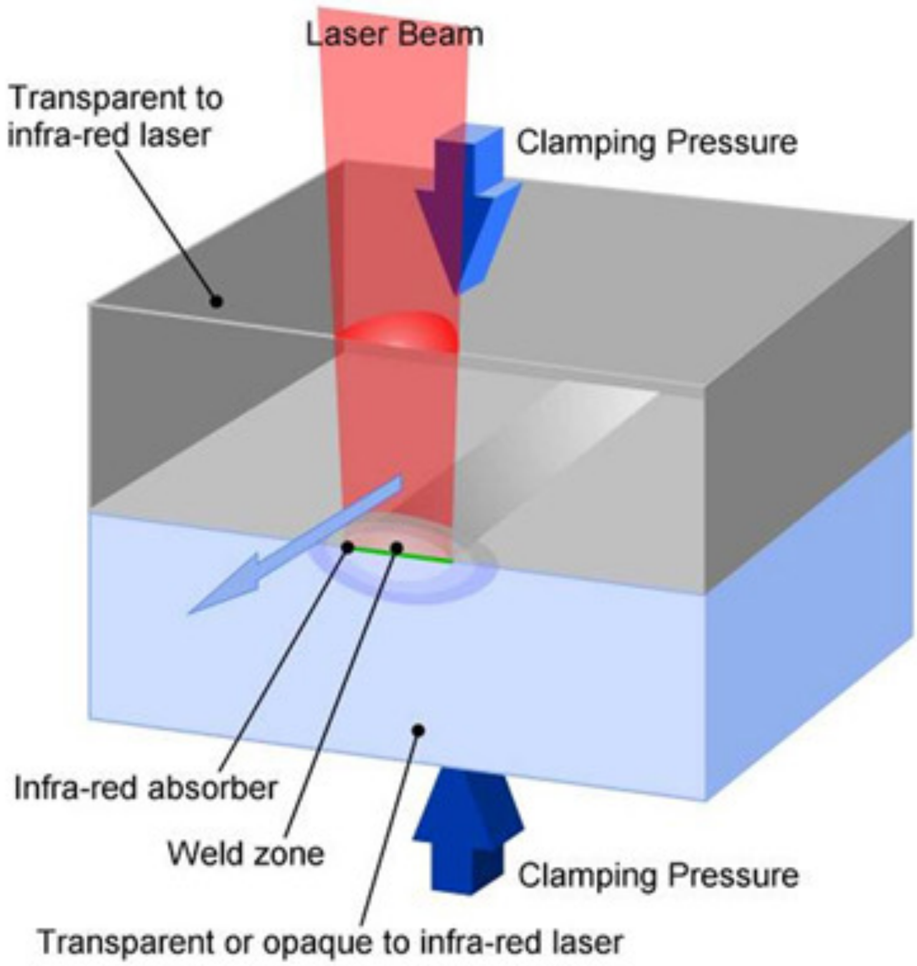

Figure 1. Material configuration for transmission laser welding of textiles
Image Courtesy of TWI

Coming from a background in textile design

Paine's background prior to undertaking this research project was in the field of knitted textile for fashion. During her MA at the Royal College of Art she had developed an interest in creating new material surfaces by combining knit and print processes. This interest grew from a live industry brief set by the trend forecasting agency WGSN. WGSN commissioned students at RCA to create inspirational material surfaces for their website in response to key seasonal trends. Paine was working under the theme of 'ceramic' and used polyfilla as a medium to coat knitted textile swatches. The samples were manipulated whilst wet and dried to create cracked surface finishes reminiscent of aged unglazed pottery. Paine developed these material samples for her final collection using commercially viable textile processes. A collection of experimental fashion garments was produced.

Figure 2. WGSN 'ceramic' knitted sample coated with polyfilla
Author's own 2010

Figure 3. Garment from final MA collection
Author's own 2011

It was during the MA investigation that Paine met with TWI. She was introduced to TWI via RCA to seek new joining processes for the textiles she had been creating, which were too stiff to be joined using standard knitwear techniques such as linking or overlocking. The funding for Paine's doctoral research was awarded on the basis of a proposal that had been written by TWI. Contributions were split between TWI's internal research fund and ESPRC. Paine was selected by TWI to carry out the research and worked from TWI's head offices just outside Cambridge for the first two years of the investigation.

The brief for the research was unlike any other that Paine had worked to previously coming from a background in textile design. There was a heavy engineering focus for the work that required quantitative testing methods to be used and an emphasis on repeatability for industrial applications. There was also a requirement for Paine to engage with industrial partners and seek a 'case study' for the research that would provide commercial validation for the development of techniques. Prior to this research, Paine had experience developing knitted textile collections, which were predominantly aesthetically driven in response to a particular theme. Material selections, colour palette, processes and textures were developed with reference to visual research. The PhD brief, in contrast, was technology driven, with a specific interest in the development of ultrasonic and transmission laser welding technologies (Paine 2016). Moving from the field of design into research and working to unfamiliar engineering requirements, it was necessary for Paine's established research approach developed throughout her education and early career to evolve and encompass new methods.

Methodology overview

The methodology for this research followed a 'multi-strategy' framework that encompassed both craft-design and scientific approaches. A 'craft-design' approach was coined by the thesis for the project. This approach bridges the disciplines of craft and design and was the familiar approach of the researcher coming from a background in textile design. 'Hands on methods of material investigation organised within a systematic reflective framework of inquiry that acknowledges the implicit knowledge of the researcher characterise this approach' (Paine 2016, p.33). Knowledge surrounding a craft or practice-led design approach is becoming more established with a growing number of published works in the academic design field (Kane 2007, Philpott 2011, Goldsworthy 2012). The approach follows a constructivist paradigm of inquiry that acknowledges existing knowledge of the inquirer (Gray, Malins 2004). Methods are typically qualitative in nature relying on the collection of non-numerical data.

A scientific approach, in contrast, adopts a positivist paradigm of inquiry that suspends the personal know-how of the investigator in the pursuit of absolute knowledge. Quantitative methods provide measurable evidence based results. A more contemporary interpretation of the scientific approach adopts a post-positivist paradigm that accepts complete suspension of personal insight is rarely achievable (Gray, Malins 2004).

Methods relating to either a craft-design or scientific approach were applied pragmatically as the research progressed in response to its current status or the problem faced. This approach can be aligned with Action Research, which places practice as the generator of new theory (Crouch, Pearce 2012) . Research progresses through reflective analysis on practice that inspires subsequent steps for investigation (McNiff, Whiteread 2005).

A map of research methods applied throughout the project trajectory has provided enhanced insight.

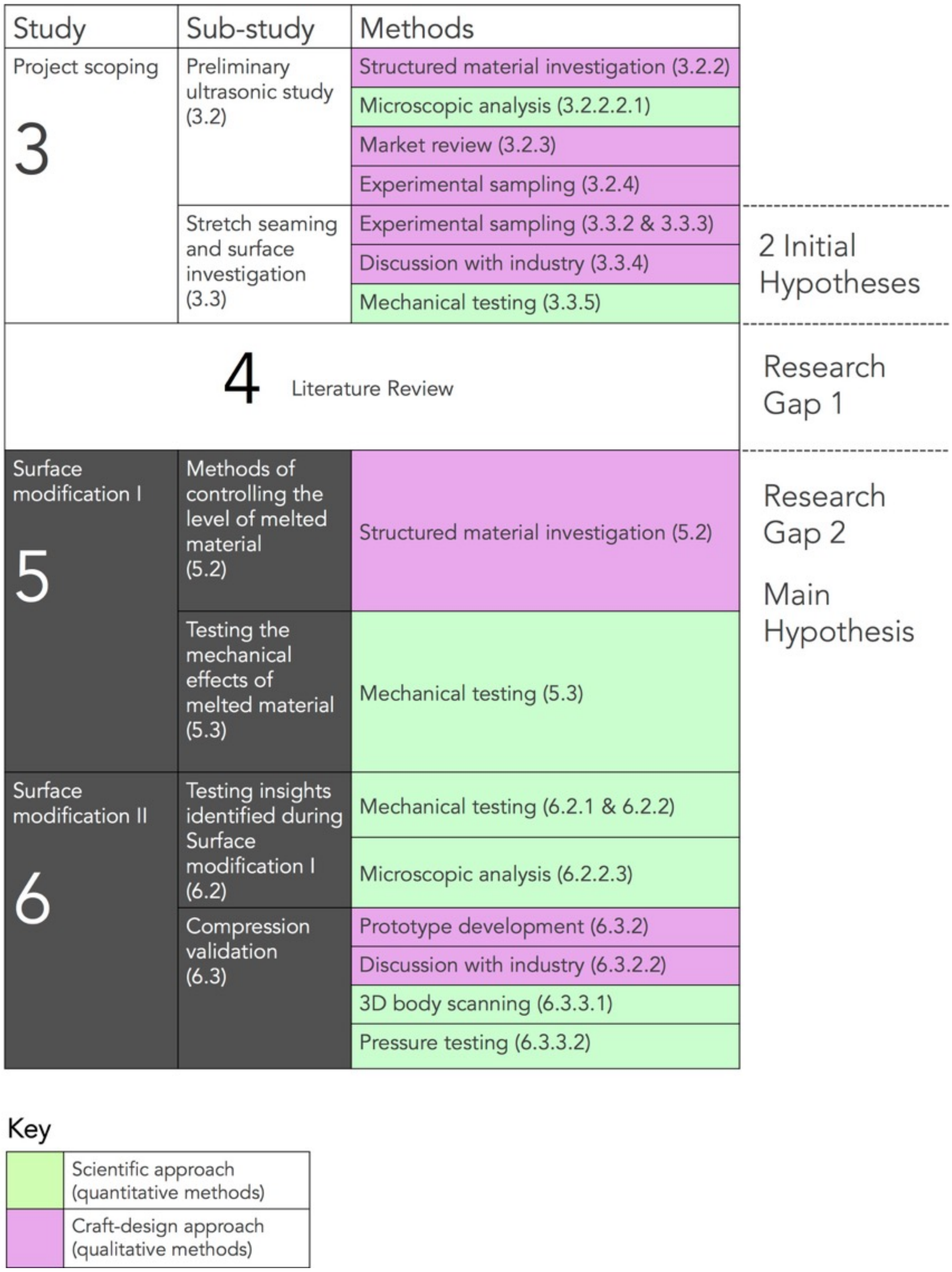

Figure 4. Map of showing research trajectory: studies, sub-studies and methods
Author's own 2015

On review of the project map it is possible to see how the research oscillated between a craft-design and scientific approach; indicated by alternating colours in the methods column. Purple is used to indicate the application of a craft-design approach and green indicates the application of a scientific approach.

A craft-design approach was applied predominantly at the beginning of the research whilst seeking hypotheses for further investigation during a period of research that has retrospectively been called 'project scoping' (Paine 2016). Material studies were undertaken and reflected upon to uncover new opportunities for further more structured investigation. During this period industry professionals at Speedo International were used as a sounding board for the commercial validity of techniques suggesting possible application opportunities and gaps for further investigation.

Research Gap 1 to use laser patterning as a method of controlling the elastic behaviour of stretchy fabrics for a compressive effect on the body was identified at the end of the project scoping phase as a result of cumulative insights. This formed the main hypothesis for the investigation.

A scientific approach was applied once hypotheses had been established to gain quantifiable evidence and was the predominant approach during studies surface modification I and II, which investigated methods of controlling the effect on the elastic behaviour of the fabric and measuring the compressive effect on the body.

This sequence of approaches, with a qualitative phase followed by a quantitative phase, has been characterised as a 'Sequential Exploratory Design' in the literature on multi-strategy approaches (Cresswell 2009). The quantitative phase of research builds on insights gained during the preliminary qualitative phase and tests developed hypotheses empirically.

Progression of methods in a cross-disciplinary research context

Selection of methods following either a craft-design or scientific approach was made on reflection of the research as it progressed. Most scientific methods were completely new to the researcher and had to be learnt from scratch. Working closely with experts at TWI and Speedo International it was possible to work alongside technical experts for the introduction of scientific methods and cumulative reflection with industry partners allowed new insights from the work to be drawn.

Methods whilst following a craft-design approach

Familiar craft-design methods were applied throughout the PhD, but there were changes in their application necessitated by the shift into academic research and responding to a brief that had been written by engineers with a technology-driven focus. This chapter section will compare experience using specific craft-design methods, defined by the PhD thesis, prior to and during the PhD to draw new insights.

Market review

Market reviews or 'comp-shops' as they are known in the clothing industry are carried out by textile designers to assess competitive products in the marketplace. This activity can be carried out online, but often involves visiting retail outlets for a closer inspection of products. Market reviews were used by the researcher prior to the PhD to gauge market trends and assist in building an overall mood or aesthetic for fabric collections. This method was also used to gain an understanding of silhouette, finishing and construction techniques for knitted garments, which cannot be accessed from images of garments online. It is not unusual for garments to be tried on to gain a more thorough understanding of fit and shape when worn. The physical handling of garments and close-up inspection enables enhanced product knowledge that can be applied to the development of practical studio work.

Market reviews were used in a similar way during the PhD: to assess existing products in the marketplace constructed using advanced joining methods and to identify gaps for further investigation. An investigation of methods for joining stretchy sportswear garments followed the insight that stretchy fabrics become rigid once welded. This review sought to identify and understand commercial processes used to join stretchy fabrics without impeding the intrinsic stretch characteristic of the fabric. Insights assisted in further practical developments working with stretchy fabrics. Specifically, it was understood that overlocking and flat locking stitch types used to join stretchy fabrics have long looped thread configurations that enable the seam to stretch with the fabric. This informed the development of a series of patterned welded seam designs that retain stretchy portions of fabric along the seam length and prevent seam lockout.

Figure 5. Review of garment silhouettes for final major MA project
Author's own 2010

Figure 6. Stretch seam investigation for PhD
Author's own 2012

Experimental sampling

Experimental sampling is a method used by knitted textile designers to develop initial material ideas in response to a body of primary and secondary research and was frequently used by Paine prior to undertaking the PhD. It is a preliminary 'playful' method of material investigation carried out once yarns and knitting machinery have been selected. Visual cues from the research relating to colour and texture inform the preliminary experimental material sampling of the knitted textile designer. Material samples from these initial trials are reflected upon, edited and refined during subsequent phases of design development.

Visual cues for material development relating to colour and texture were absent from the technology-driven initiatives of the PhD investigation. Experimental sampling was carried out to seek new opportunities for the technologies and relied on the tacit knowledge of the researcher coming from a background in textile design to identify novel and interesting leads for investigation. Material studies were influenced by the literature on textiles joining and an increasingly technical approach was taken compared with experimental sampling carried out whilst working as a knitted textile designer prior to the PhD. It was necessary to keep all material samples and record processing conditions so that experiment reports could be written in a clear and concise way that would be comprehensive to the cross-disciplinary partners involved in the PhD. Through diligent recording of process parameters, it was possible to identify patterns in material behaviour that would not have been otherwise possible. At first, this controlled way of working was difficult to adjust to for the researcher who sensed a loss of 'creative flow' in the work and impact on the novelty of material outcomes. Periods of freer material investigation were programmed at occasional intervals throughout the research trajectory to allow for more fluid development of design ideas.

Experimental sampling was used during the project scoping phase of the PhD investigation whilst seeking hypotheses for further development. A preliminary study using ultrasonic welding equipment tested the effect of the technology when applied to a selection of textile base fabrics. A variety of knitted, woven, synthetic and mixed fibre fabrics were investigated. The mechanical and aesthetic effect of various differently patterned anvil wheels on the surface of the fabric was assessed by hand and eye. The anvil is a rotary wheel that applies pressure to the fabric and pulls it forwards through the machine from the front to the back; imparting an embossed pattern onto the surface of the fabric as it moves. A novel wavy three-dimensional effect on the surface of stretchy fabrics was identified and developed through freer material investigation to create all over surface effects with an appearance akin to seer-sucker. It was on the basis of a review of these initial experimental samples that Speedo International became a partner for the research.

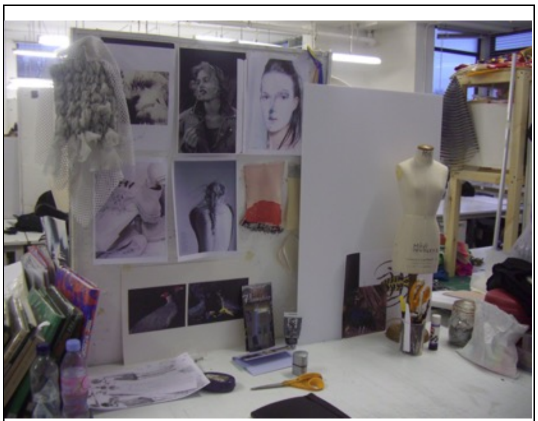

Figure 7. Experimental samples and visual research from Paine's final major MA project
Author's own 2010

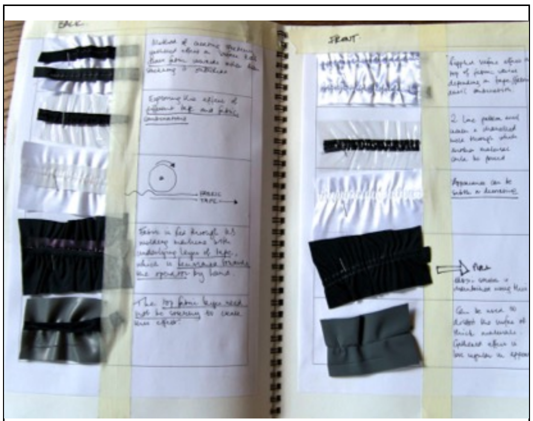

Figure 8. PhD sketchbook of experimental samples created using ultrasonic welding equipment
Author's own 2010

Structured material investigation

Structured material investigation typically follows a period of experimental sampling and a lead for further investigation has been developed. Materials are tested at precise incremental settings to gain a detailed understanding of the effects of different process parameters. Prior to undertaking the PhD structured material investigation was used to develop textile processes. For instance, knitting tensions with specific stitch structures and yarn combinations were trialled at incremental settings and examined by hand and eye in order to establish optimum handle and appearance. Similarly, heat press settings for coating of knitted samples were tested incrementally using a process of trial and error until the desired handle and aesthetic effect was achieved. Working as a knitted textile designer only parameter settings for successful samples were recorded. For the engineering style reports that were expected by the PhD brief it was necessary to record parameter settings for all material samples. Although this habit was difficult to adjust to at first, sample specification sheets became a method of documenting practice and provided physical records to reflect upon for development of the investigation. Following an insight that stretchy fabrics take on a three-dimensional wavy seam aesthetic after welding, a structured investigation using state of the art ultrasonic welding equipment with digitally programmable machine settings was carried out. This enabled process parameters to be recorded with enhanced accuracy.

Figure 9. Development of coated knitted samples for final major MA project
Author's own 2010

Figure 10. Digital display of recordable parameters on PFAFF ultrasonic welding equipment
Author's own 2013

Figure 11. PFAFF ultrasonic welding equipment
Author's own 2013

Discussion with industry

Knitted textile designers work in response to a design brief. Commissioning partners use the format of the brief to stipulate the theme of the work and outline deliverables. Contact with the industry partner is made at the beginning of a project when the brief is introduced and at the end of the project when the work is presented. Contact can also be made at interim meetings to help steer design development and review progression. These meetings are typically proposed by the industry partner. Paine had experience working in this way for numerous fashion companies prior to undertaking the PhD.

Discussion with industry in the context of the PhD work relates specifically to Speedo International. Unlike previous interactions with industry prior to the PhD, Speedo International had not written a brief for the work. Interactions were initiated by the researcher and used to critically reflect on material samples produced to identify possible application opportunities, thus ensuring commercial validity.

A discussion with Speedo International during the project scoping phase of the work can be used to illustrate how the research was influenced by industry. Practical research had been carried out in response to two initial hypotheses and presented to Speedo International. During collective critical assessment of the samples an opportunity to use the laser technology to control the elastic behaviour of stretch fabrics to have a compressive effect on the body was identified. This functional opportunity for all-over surface effects influenced the next phases for the research that investigated methods of controlling extensibility of the fabric.

Figure 12. Critical reflection on material samples with innovation staff at Speedo International
Author's own 2014

Prototype development
Prototype development is used by knitted textile designers to demonstrate material samples as concepts for full-scale garments. Some briefs require a collection of samples and visualisations demonstrating garment ideas, whereas others require full-scale mock-up of garments.

Shaping of fully-fashioned knitted garments is integral to the knitting process, thus knitting of fabric and product often go hand in hand. Stitches are transferred either inwards or outwards from the cast on section along the length of the fabric to build up a shape that follows a flat pattern design. Flat pattern designs are created from a toile. A toile is a term used in the clothing industry to describe the preliminary mock-up of a garment in an inexpensive substitute fabric such as calico. Jersey is often used for knitwear toiles as it has required stretch characteristics to mimic the final fabric of the knitted garment.

Figure 13. Toile from MA final major project
Author's own 2011

Figure 14. Full scale garment prototype from MA final major project
Author's own 2011

Whilst studying for the PhD expertise of technical staff at Speedo International was called upon to assist with the development of prototypes. The aim of prototype development was to test the compressive effect of laser patterning on the body. Two suits were produced: one with the laser patterning and one without.

An existing Speedo full body suit was selected through consultation with Speedo, which would provide maximum coverage of the body to test the compressive effect of laser patterning across multiple areas of the body. Areas of the body to target for an optimised streamlined silhouette were selected through review of Speedo's past racing suit designs. Suit panels were cut and constructed by technical staff at Speedo International. Laser patterning was applied to flat panels by Paine at TWI.

Both suits were tested across 5 key areas of the body using a pressure measurement system and 3D body scanning technology. Access to testing facilities was provided by Speedo International. Through this collaborative investigation, it was possible to compare the results between the laser patterned and plain swimsuit and prove the compressive effect of the fabric on the body.

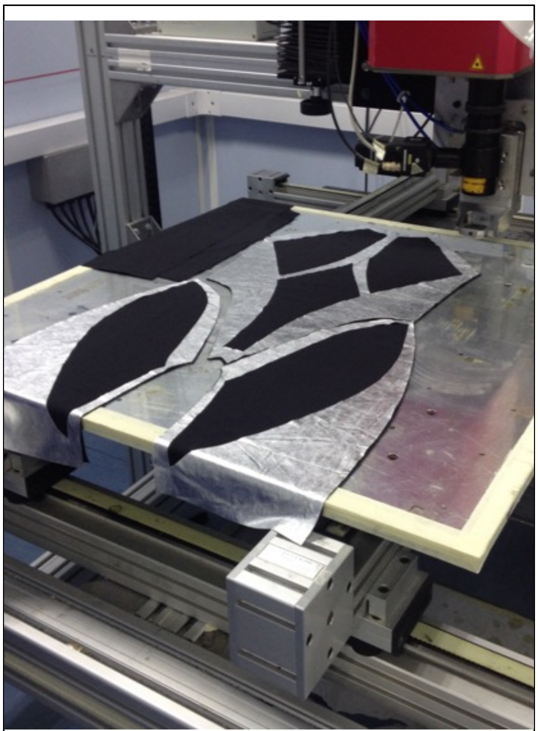

Figure 15. Preparation of flat panels for laser treatment at TWI
Author's own 2015

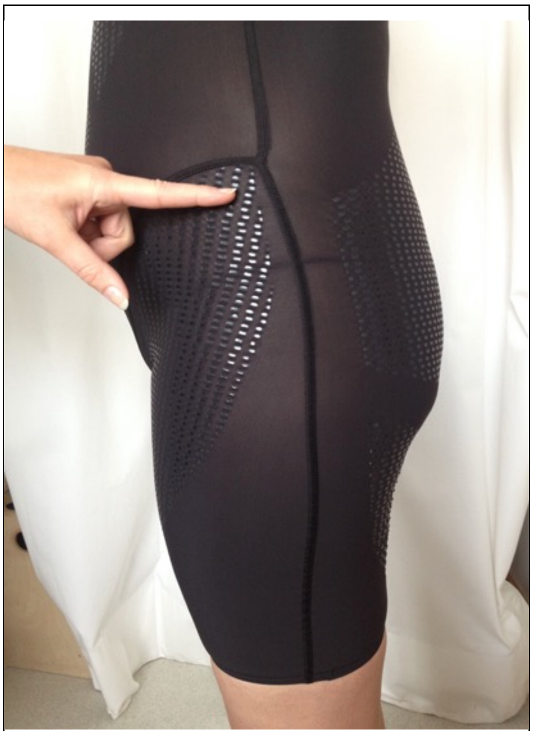

Figure 16. Development of laser treated prototype swimsuit at Speedo International
Author's own 2015

Methods whilst following a scientific approach

Scientific methods were primarily used by the PhD to fulfil the technology-driven requirements of the brief. It was only through persistent exploration of scientific methods at the beginning of the PhD that an understanding of the ability to prove changing material behaviours empirically was understood. Specifically, a change to the mechanical behaviour of stretchy fabrics was felt by the hand once welded: it was only through quantitative testing that a controlled effect on extensibility could be objectively proven. This chapter section will reflect on experience working with specific scientific methods through the PhD to highlight learning and insights gained.

Microscopic analysis

Coming from a background in knitted textile design Paine had no prior experience using microscopes to analyse fabric samples. Understanding of material behaviour for knitted textile designers is acquired through the process of making and experience of handling different fabric types. Technical blocks of learning covering hand, domestic and industrial knitting machinery techniques were included during Paine's BA and MA education. Knowledge relating to the varying handle and visual qualities of fabrics produced using different stitch, yarn, and machinery types had evolved through experience. This tacit knowledge held by the textile designer is applied to create fabrics in response to a design theme or trend. Visual analysis of fabrics had only been explored on a macro scale prior to undertaking the PhD.

Microscopic analysis is an established method used by engineers and scientists to investigate materials at a micro level. As part of the TWI brief it was expected that traditional scientific methods such as microscopic analysis would be used within the scope of the PhD. Working at TWI for the first two years of the investigation there was open access to the optical lab with a large range of microscopes that could be used with technical assistance.

Paine worked with a technical assistant using scanning microscopy equipment and a stereograph to explore her welded textile samples throughout the PhD trajectory. Through this microscopic analysis of fabric samples Paine was able to assess qualities felt by the hand at a fibre level and prove hypotheses empirically. Specifically, Paine was able to prove that mechanical locking of stretch fabrics after welding was due to melting of thermoplastic fibres that destroyed the knitted fabric structure in the weld region.

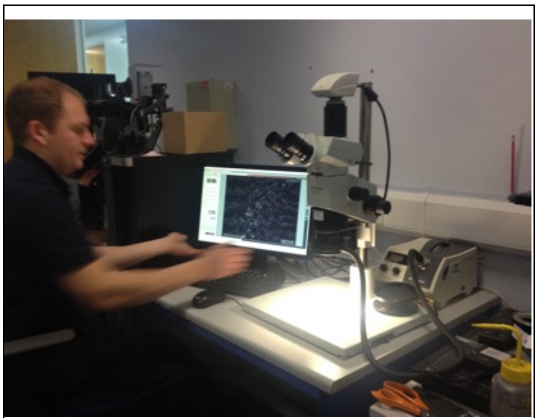

Figure 17. Working with stereograph microscope and technical assistant at TWI
Author's own 2014

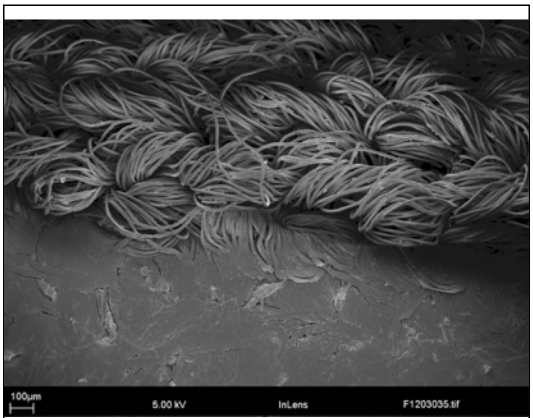

Figure 18. SEM image of ultrasonic welded knitted textile sample
Author's own 2012

Mechanical testing
Mechanical testing is a method used by engineers to test the properties of materials in response to controlled force. Paine had no experience of mechanical testing prior to undertaking the PhD project. Technical testing of textile materials is not a typical requirement for textile designers. The technical standardisation and testing of fabrics occurs during the latter stages of textile development towards product launch.

Responding to a brief that had been written by engineers there was an expectation that mechanical testing of fabrics would be used to quantify the strength of welded textile joints. An understanding of this process was gained through reading technical literature on textiles joining and observing engineers at TWI. Specialist equipment used for testing fabrics was made available to the researcher by Speedo International. A technical assistant provided an introduction to the equipment and assisted with preliminary material tests.

There was some reluctance from the researcher at first to deviate from familiar craft-design methods. However, by applying this unknown method she was able to prove scientifically the main hypothesis that laser melting could be used to control precisely the elastic behaviour of stretch materials. Fabric samples were treated with the laser at incremental speed and power settings that influenced the amount of melting through the depth of the material. This was evident from the change in intensity of the laser marked line on the surface of the fabric. The effect of melt pattern density on the surface of the fabric was also investigated at incremental levels. A simple stripe design was used with varying distance in between melt lines. The fabric became increasingly stiff to handle as material melting increased. Mechanical testing provided empirical evidence in support of this effect and demonstrated that the extensibility of the fabric could be controlled precisely using pre-programmed parameter settings.

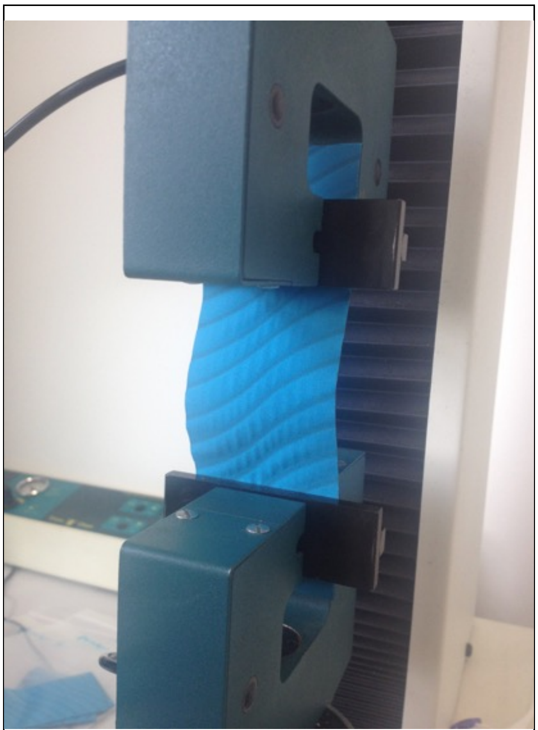

Figure 19. Mechanical testing of laser treated fabric sample: sample relaxed without tension
Author's own 2014

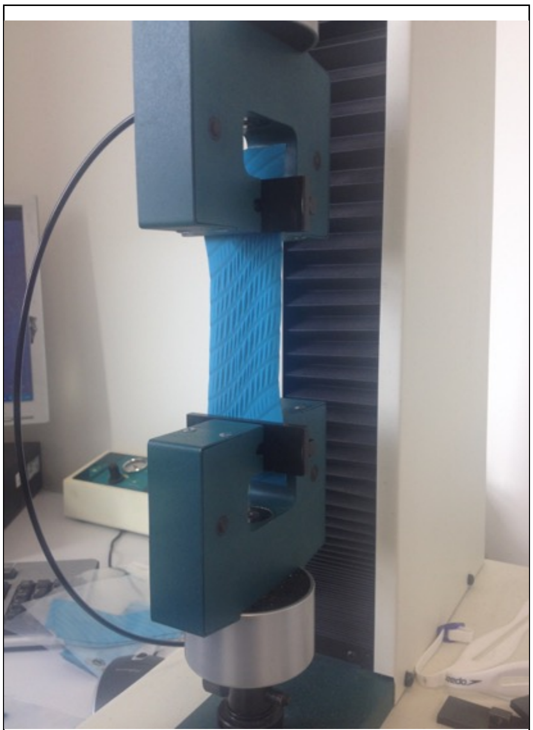

Figure 20. Mechanical testing of laser treated fabric sample: sample under tension
Author's own 2014

3D body scanning

3D body scanning was a method used towards the end of the PhD research to test the compressive effect of laser treated fabrics on the body. A laser-treated prototype suit was worn inside a 3D body scanner and measurements were taken across 5 key areas of the body. These results were compared with the same person wearing a swimsuit without laser patterning. Any reduction in body measurements could be attributed solely to the laser surface treatment of the fabric. Speedo International made the body scanner available to the research.

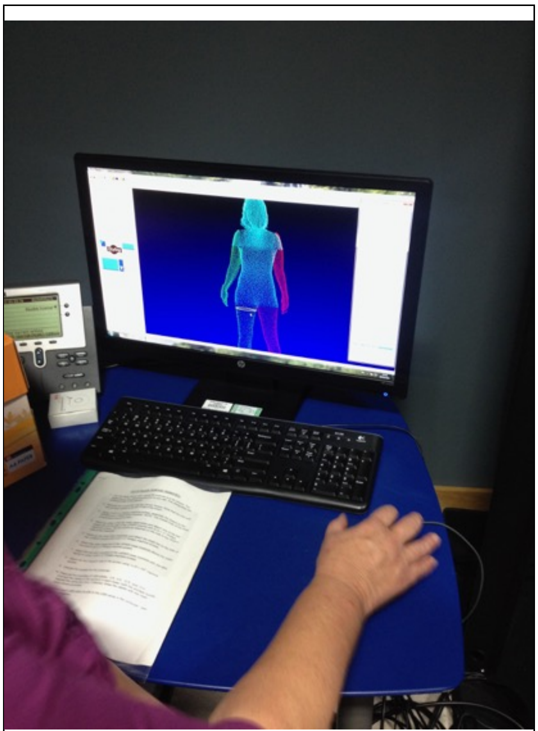

Figure 21. On-screen image created using 3D body scanning equipment at Speedo International
Author's own 2015

Figure 22. Paine inside 3D body scanning booth at Speedo International
Author's own 2015

Pressure testing
Pressure testing was an alternative method used to test the compressive effect of laser treated fabrics on the body. Pressure measurements were taken between the fabric and skin using a hand-held device. Results were compared between a patterned and non-patterned swimsuit across 5 different areas of the body. The equipment for this test was made available by Speedo International.

Conclusions/Insights

This paper has discussed the evolution of methods adopted by Helen Paine during her PhD research project moving from a background in knitted textile design for fashion into an environment of cross-disciplinary academic research working with scientists, engineers and industry towards the development of emerging textile joining technologies. Craft-design methods that were already familiar to the researcher have evolved in respect of the technological requirements of the brief and new scientific methods have been introduced. Through a comparative analysis of methods before and during the trajectory of the PhD it has been possible to identify the following key insights:

- The craft- designer needs to be flexible in adjusting established approaches to bridge gaps and build trust across disciplines: Paine found by adopting a scientific approach she was able to communicate her ideas at TWI in an engineering environment.

- A pragmatic approach that uses both scientific and craft-design methods is needed so that investigation responds to research findings as they progress: Paine applied either a craft-design or scientific approach on reflection of the research findings progressively throughout the investigation.

- The serendipity of a hands-on craft-design approach lends itself to the beginning of an investigation when hypotheses are being sought: Paine adopted this approach at the beginning of her PhD working with ultrasonic welding equipment to uncover new opportunities for the technology.

- A scientific approach can be used to test hypotheses developed through experimental sampling and provide quantitative evidence for effects first felt by the hand: Understanding of changes to the mechanical behaviour of materials was gained first by the hand and then tested empirically using mechanical testing equipment.

- A diligent approach to recording reflections and experimental settings is required whilst applying a craft-design approach so that insights can be progressed through subsequent structured investigation: Pre-prepared spec sheets allowed Paine to record reflections 'in action' and provided physical records of practice to reflect on retrospectively.

- Working with cross-disciplinary partners can enable access to testing facilities and insights that will expand the reach of the work beyond the craft-design field: Paine was able to access industry- specific insights and testing methods working with Speedo International and TWI that allowed her to validate functional opportunities first gauged through experimental material investigation.

- Hypotheses that are built from cross-disciplinary cumulative insights assist in engaging all parties in a collaboration: Paine spent the early stages of her PhD scoping opportunities for investigation; testing ideas through material sampling and gaining insights from industry.

- Physical representations of ideas developed through material sampling and prototyping activities can be an attraction for industry partners seeking new product opportunities: preliminary material samples developed using ultrasonic welding equipment were shown to Speedo at an initial meeting with TWI.

Since completing her PhD Paine has worked for Speedo International as an Innovation Design Consultant. Collaborating with technical experts at Speedo's in house R&D facility she has continued to apply cross-disciplinary research methods using both scientific and craft-design approaches to develop innovative material solutions.

Acknowledgements

The authors would like to extend thanks to Speedo International and TWI for their generous support of the work.

This research has been funded by TWI.

References

BIGGS, M. and BUCHLER, D., 2007. Rigor and practice-based research. Design Issues, 23(3), pp. 62-69.

CRESSWELL, J.W., 2009. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. 3 edn. California: Sage Publications.

CROUCH, C. and PEARCE, J., 2012. Doing Research in Design. London: Berg.

DORST, K., 2010. The nature of design thinking. Presented at: Interpreting Design Thinking: Design Thinking Research Symposium 2010.

GOLDSWORTHY, K., 2012. Laser-finishing: a new process for designing recyclability in synthetic textiles, Thesis (PhD), University of the Arts London.

GRAY, C. and MALINS, J., 2004. Visualizing Research: A Guide to the Research Process in Art and Design. Aldershot: Ashgate Publishing Ltd.

GREENLESS, R., 2016. The UK craft sector isn't a 'hipster' economy. It's sparking innovation. The Guardian.

HILTON, P.A. and JONES, I., 2000. Laser welding of fabrics using infrared absorbing dyes. Presented at: Joining of Advanced and Speciality Materials III, 9-12 October 2000, Missouri, USA.

JONES, I., 2005. Laser joining fabrics improves productivity. Industrial Laser Solutions [online], available from: http://www.industrial-lasers.com/articles/2005/01/laser-joining-fabrics-improves-productivity.html [Accessed 24 May, 2012].

JONES, I. and PATIL, A., 2013. Laser seaming of fabrics. In: I. JONES and G.K. STYLIOS, eds, Joining Textiles: Principles and Applications. Cambridge: Woodhead Publishing, pp. 398-434.

KANE, F., 2007. Designing nonwovens: craft and industrial perspectives, Thesis (PhD), Loughborough University.

KPMG, 2016. Innovation through craft: opportunities for growth

MCNIFF, J. and WHITEREAD, J., 2005. All You Need To Know About Action Research. London: Sage.

PAINE,. H., 2016. Laser Shaping: A method for controlling the elastic behaviour of stretch fabrics for a targeted and graduated compressive effect on the body, Royal College of Art.

PHILPOTT, R., 2011. Structural textiles: adaptable form and surface in three dimensions, Thesis (PhD), Royal College of Art.

PHILPOTT, R., 2013. Engineering opportunities for originality and invention: the importance of playful making as developmental method in practice-led design research. Studies in Materials Thinking [online], 9(1), available from: https://www.materialthinking.org/papers/127 [Accessed 28 February 2015]

POLANYI, M., 1966. The Tacit Dimension. Chicago: The University of Chicago Press.

PRESS, M., 2007. The emerging role of craft knowledge in our digital culture. In: S. ALFODY, ed, Neocraft: Modernity and the Crafts. Halifax: The Press of the Nova Scotia College of Art and Design, pp. 249-266.

ROBSON, C., 2011. Real World Research. 3 edn. West Sussex: John Wiley & Sons Ltd.

ROOKS, B., 2004. Laser processing of plastics. The Industrial Robot, 31(4), pp. 338-342.

RUST, C., 2004. Design enquiry: tacit knowledge and invention in science. Design Issues, 20(4), pp. 76-85.

SCHON, D.A., 1983. The Reflective Practitioner: How Professionals Think in Action. London: Maurice Temple Smith.

SCRIVENER, S., 2002. The art object does not embody a form of knowledge [online], available from: https://www.herts.ac.uk/__data/assets/pdf_file/0008/12311/WPIAAD_vol2_scrivener.pdf [Accessed 21 March, 2014].

TASHAKKORI, A. and TEDDLIE, C., eds, 2003. Handbook of Mixed Methods in Social and Behavioural Research. California: Sage Publications.

Dr Helen Paine
Dr Helen Paine is a Research Assistant at the Centre for Circular Design University of the Arts London and Senior Lecturer at Norwich University of Arts across MA courses. She has experience working as an

innovation design consultant with sportswear and automotive partners. Her research interests lie in craft innovation and multidisciplinary collaborative practice.
h.paine@chelsea.arts.ac.uk

Dr Kate Goldsworthy
Dr Kate Goldsworthy is Co-Director of the Centre for Circular Design at University of the Arts London. She is a designer and academic working to bridge science, industry and design through multidisciplinary & practice-led research towards a circular economy. She is a member of the EPSRC Forum in Manufacturing Research, and is Theme Leader in the Mistra Future Fashion Programme.
k.goldsworthy@chelsea.arts.ac.uk

Pr Sharon Baurley
Professor Sharon Baurley is Head of Industrial Design at Zürcher Hochschule der Künste / Zürich University of the Arts (ZHdK). She is also visiting Research Professor on Design Products programme at RCA and is a fellow of the Higher Education Academy.
Sharon.baurley@rca.ac.uk