Colour Trans:form:ation

The application of Knit as Knowledge

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Abstract

It is widely acknowledged that textile processing is increasingly unsustainable, for example textile dyeing is experiencing a rising use of water, leading to a scarcity of freshwater globally (Easton, 2009, p145). It is imperative to investigate alternative strategies to colouration and whilst there is no single resolution to the problem, using design intelligence from diverse design specialisms, in this instance knitted fabric design, can offer a realistic framework within which to develop solutions.

Following established design methodologies, successful knit design requires knowledge of materials, process, technology and aesthetics which is utilised in unique combinations to create a specified product. Disrupting this approach to design through the application of innovative technologies or removing the concept of designing for a specified product, this unique body of knowledge can question wider societal problems, including textile coloration, and determine a range of solutions through knitted fabric design practice.

The paper will report on the development of sustainable textile coloration through innovative lighting technologies. New research explores the breadth of colour gamut achievable with a limited palette of yarn (so minimising dyeing) when recognised optical effects, for example optical mixing, are observed in different lighting conditions. The iterative design/research methodology used exploits the materiality and structural knowledge inherent in knitted fabrics and allows the creation of unique fabrics, which would be unachievable in any other medium, to test ideas abductively. A feature of this methodology is an acceptance of unexpected outcomes that challenge the concept of designing for a specified product. The fabrics produced are not in themselves functional, except as a communication tool for the knowledge revealed through the design research.

Key words

Sustainability

Knit

Colour

Perception

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Introduction

It is widely acknowledged that textile processing is increasingly unsustainable, for example textile dyeing is experiencing a rising use of water, leading to a scarcity of freshwater globally (Easton 2009, :145). Water is the medium in which dyes and dye auxiliaries are dissolved to enable their transfer to fabric. Not all of the dye chemicals are used in the dying process and textile wastewater is some of the most polluting textile waste (Angelis-Dimakis *et al* 2016:214). There is a focus on research into eco-efficiency strategies, which combine research into the economic and the environmental impact of dye processing to improve the efficiency of cleaning and re-using this water supply. This would reduce the need for extraction of freshwater (Ranganathan *et al* 2007:306-318). Whilst re-using wastewater is beneficial, it is imperative to investigate alternative strategies to colouration which will reduce water usage. Technical solutions such as the integration of colour directly into a polymer in synthetic fibre production will eliminate the need for any further wet-processing (Fig. 1) (MacRae 2010:384-399) however there is no single resolution to the problem. Using design intellect from diverse design specialisms, in this instance knitted fabric design, can offer a realistic framework within which to develop innovative solutions. To successfully use the knowledge embedded in a textile production process it is necessary to have a deep understanding of that process.

Figure 1 Dress produced from polymer coloured PLA.

Knit as a research tool

Successful knit design requires knowledge of materials, fabric structure, technology and aesthetics. In knitted fabric design unique combinations of this knowledge are literally built into the designed product and used to generate either two-dimensional or three-dimensional structures. This paper examines the potential to ask questions of this unique body of knowledge to answer wider societal problems and to determine a range of solutions through knitted fabric design practice, an area historically absent from academic study (Walker 2006 :190). It discusses knit as a research activity not a commercial practice and the originality of the research lies in the use of knit as a research tool.

Regardless of production technique (hand or machine), weft knitted fabric is constructed from inter-looped yarns produced sequentially in horizontal rows or courses (Fig. 2). The new stitch may be formed by pulling the new loop through the old stitch either from the technical back of the fabric to the technical front of the fabric or vice versa, producing vertical rows of knitted stitches (wales). In the production of a course of knitting, stiches can be by-passed (miss) or incorporated into the previous course (tuck) (Spencer 1983). These production choices can be combined and the relationship between the different types of stitch produced in a fabric will inform the properties of the resultant fabric allowing fabrics to be designed for specific functions and/or aesthetics.

Figure 2 The structure of Plain knitted fabric.

Knitted fabrics can start from a single loop and the final dimensions of the fabric are determined by increasing and decreasing the number of stitches in each course and the number of courses produced. Theoretically this may be infinite in terms of size and shape of fabric. Dependant on production methods fabrics can be produced in two dimensions or three dimensions, allowing product to be produced with zero material waste. In this research the ability to produce a shaped fabric without cutting was used to produce individual panels of fabric, knitted with a three-dimensional, integral tensioning system.

The knitted loop can be deformed under tension and knitted fabrics have inherent stretch and recovery properties which can be manipulated both by fabric structure and size of the knitted loop in relation to the yarn used. In terms of fabric structure, a fabric formed from wales of face stitches and wales of reverse stitches (rib) will have more stretch and recovery than a fabric produced solely from face stitches (plain knit) and as a balanced fabric eliminates the inherent fabric curl observed in plain knit. A small knitted loop will produce a more rigid fabric with less stretch and a larger loop will produce a flexible fabric with drape. The physical structure of the knitted fabric can be further manipulated through consideration of the material choices made during production. Additionally, Hand or CNC production allows individual stitch selection, enabling structural and/or colour changes throughout the fabric. In this research the knitted panels were produced in a rib jacquard structure using CNC production. This allowed individual needle selection to produce complex patterning on a flat, smooth surface. The final pieces were tensioned using an endo skeletal framework.

Current knit design research exploits the complex relationship between fabric structure and materials to produce innovative conceptual approaches within design. Jenny Sabin, used knit knowledge in the production of Lumen (2017) an architectural scale installation at MOMA, New York. The digitally knitted structure was responsive to the environment and viewer proximity through material use, and the structure used the ability to produce three-dimensional form and externally tensioned stretch in the generation of roof canopies. In Inflection (2016), Scott and Gaston investigated knitted material systems informed by investigation of traditional material use in the Oriental Collection at The Royal Armouries, Leeds. Analysis of lamella armour, which utilises the interaction of two textile substrates to produce a formable, three-dimensional textile and re-curved bows, which utilise tensioned composite materials to produce force through form, directed the design of an architectural scale installation. Using the inherent stretch and three-dimensional shaping capabilities of knit, the final form of Inflection was dictated by internal tensioning structures to produce a fabric with both rigid and flexible characteristics. Applying knit material, structural and technical knowledge to a set of questions posed by historic artefacts produced a new body of knowledge in material systems in both research outcomes. Trans:form:ation extends this research field utilising the same exploratory methodologies as Lumen and Inflection in the combination of knowledge of materials, fabric structure, technology and aesthetics.

Sustainable design

It is widely acknowledged that more sustainable design and production processes are necessary in the fashion industry, and the scale of the problem is too large for a single solution (Goldsworthy 2017, Fletcher 2012, Seigle 2011). Montagna and Carvalho (2018) divide problems of sustainability in the textiles industry into three stages, production (for example, fibre, yarn, fabric and garment), pre-consumer (for example, packaging and transport) and post-consumer (for example, laundry and disposal). Within textile production there has been focus on material use and colouration. Whilst colour is paramount in consumer purchasing choices (Bray, 2009, p1) dyeing processes have increasing negative environmental impact leading to a scarcity of freshwater (Ranganathan *et al* 2007:306-318, Easton, 2009: 145, Angelis-Dimakis *et al* 2016:214). Depending on substrate and dyestuff choices, up to 60 litres of water are used to dye 1kg of yarn. Additionally, up to 20% of the dye and additives are released in the dye effluent (Kant, 2012: 22-23). A major problem for the textile industry is reducing the harmful effects of dyeing whilst maintaining consumer choice. Creatively applying, knit knowledge to this perennial problem, using design methodologies, offers an innovative approach to reducing the negative environmental impact of textile dyeing.

Approaches to improving the negative environmental effect of textile dyeing utilising reduction of chemical waste within the dying process (Blackburn 2009, Aoudj *et al* 2010, Bhuiyan *et al* 2016) propose a partial solution but still require large quantities of water during the dying process. This research aims to reduce the necessity to dye fibres or yarn whist maintaining design appeal to offer a real-world solution to this perennial problem. Reduction of resource use is at the top of the waste hierarchy (DEFRA 2011) and as such it offers a more sustainable solution than increasing the efficiency of wastewater recycling. In knit design, design choices in coloration can be made at multiple stages in the design process which offer a range of opportunities to effect change towards more sustainable design practice. The later in the production process the coloration takes place, the more flexible the design options are. As colour choices in this work occur during the knitting stage, colour flexibility occurs at the end of the production process.

Previous research

The research further develops previous work which investigated the use of optical effects and coloured light to manipulate colour and therefore pattern perception in Fair Isle knitted fabrics to extend product longevity through variation in design (Gaston 2016). In this earlier work, the tacit knowledge of a knitwear designer that changing one colour within a knitted Fair Isle pattern can dramatically change the visual perception of the whole pattern was initially investigated within a positivist framework, which is not conventionally appropriate within concept driven design practice. The effect of changing the yarn colour within specific areas of a design on pattern perception was tested systematically and empirically in knitted fabric. The individual stitch selection capabilities available in knit production ensured a versatility in the colour and pattern arrangements within each fabric produced during the research. Pattern perception relies on border recognition between contiguous areas of the design. This can be influenced by gradient of hue and value of colour and by line quality (Kanizsa 1979: 138). In a knitted fabric, the border between one colour area and its neighbour is influenced by the irregular profile of the knitted stitch and by the hairiness of the yarn offering a unique perspective on the use of colour theory in fabric design (Gaston 2016). Observation of serendipitous and unexpected outcomes which occurred during recording and reporting this research were used to influence the design direction of the project and led to the innovative use of lighting to influence the perception of colour and therefore pattern. A further finding from the original research that related directly to the use of knitted fabric was that the irregularity of the profile of the knitted stitch and the hairiness of the yarn used reduced the gradient between contiguous colour areas and this encouraged optical mixing of small areas of colour when viewed from a distance. It was this secondary finding that was explored during the current research project.

Optical colour mixing is a visual perception illusion where small discrete units of evenly distributed colour give the effect of a tint (Day 1933:265). This additive colour mixing produces more vibrant colour than physically mixing subtractive colour pigments (Itten 1961:110) and is illusory as the optically mixed tint, for example pink, can not be seen at the same time as the constituent colours, in this case red and white (Hilbert 1987:35-36).

Colour is a perceptual effect of the relative excitation by reflected light of visual receptors in the eye (Purves and Lotto 2011:56, Kuehni and Schwarz 2008). The quality of reflected light is a result of the spectral properties of the incident light and the reflectance properties of the surface viewed (Westland 2002:141). Changing the incident light will affect the perceptual colour viewed (Fig. 3)

The hypothesis investigated in this work was that the need for dying a wide gamut of colour can be reduced by introducing optical mixing at a fabric structural level and by altering the perception of colour through viewing in different lighting conditions.

Figure 3 Test samples of optically mixed colour in different lighting conditions.

Locating the research

The impetus for further research came from the opportunity to exhibit current knit design research projects at the Pannett Art Gallery in the coastal town of Whitby, UK. The Pannett Art Gallery houses a collection of the Weatherill family marine paintings from the nineteenth century and a collection by the Staithes Group of artists. Its temporary exhibition programme includes both traditional painting and conceptual contemporary art. Pre-twentieth century the Whitby coastline was the main supplier of alum, used as a mordant in textile dyeing. The cliffs along this coastline are scarred by the mining activity undertaken to extract it. Alum belongs to the potash family of minerals, all of which contain potassium. In a controversial move, Sirius Minerals was granted permission to extract potash in the form of poly-halite, used as a fertiliser, and are currently building mines which will re-scar what has hitherto been an environmentally protected area. The exhibition offers the opportunity to highlight the negative environmental impact of industry through exhibition of potentially beneficial design solutions to current textile processing problems, in a geographically and historically relevant location. The work also intended to reference work in the permanent collection of the gallery, in particularly the Weatherill Collection.

Methodology

Walker suggests that design needs to challenge orthodox thinking, initially with ideas that are not conventionally commercial, but re-situate design solutions within new conceptual paradigms (Walker 2006: 7). In this research the designed artefact is the expression of the concept not a resolved commercial solution continuing the knit design research methodology used by Scott and Gaston (2016), Sabin (2017), and Popescu (2018). The research was conducted using a critical design methodology which questions a problem concurrently to providing a solution (Mäkelä and Routarinne 2006: 118). It is speculative and challenges preconceptions and assumptions of conventional understanding (Dunne and Raby 2007), in this case that coloration of textiles depends on the use of externally applied dyes. The overarching aim was to further develop the understanding of the effect of optical mixing on pattern perception in different lighting conditions whilst investigating the potential of the concept to challenge existing coloration technologies in textile production. The core principles of the research are located in established colour, pattern and visual psychology theory, developed through positive enquiry, however this research employed generative practice which was speculative and contrary to positivist research expectations. The research rejected analysis of specific wavelength of colour observable in different incident lighting conditions as a methodology suitable for this stage of design research. Whilst a theoretical approach can predict colour, this requires the understanding of a specific language of colour not widely available in the design community. Also, the perception of colour, particularly in combination is purely visual. The research could have been done theoretically but this is not a design approach that is useful to designers.

Design decisions and outcomes

Using tacit and explicit, expert knit knowledge (materials, structure, technology and aesthetics) a collection of five fabrics were produced. The use of materials, fabric structure and knit production technology was informed by explicit research-for-design. This form of knowledge generation is deep, specific and informed by the needs of the project (Dorst 2003, Walker 2006, Mancini 2008, Cross 2011). The aesthetics were developed using iterative practice, dependant on intuition and tacit knowledge, combining colour, form and pattern. Tacit knowledge is gained experientially during the process of designing (Kershaw and Nicholson 2011:119) and is revealed during reflection on the design process (Kolb and Fry 1979: 79-92). Based on the work of Polanyi (1966), Friedman (2007) notes that this personally situated design knowledge is predominantly useful to those who design. Using the framework of knit knowledge, the following design decisions were revealed.

Materials

Material driven design starts with an understanding of the materials used and how they react to processing (Cox 2017: 179). The research collection was knitted in Z Hinchcliffe 100% lambswool (2/17Nm). This yarn is commercially available in a wide gamut of colour. Lambswool is a woollen spun yarn which is scoured (wet-finishing or washing) after knitting to remove spinning oils and raise the individual fibres in the yarn to produce a soft hairy finish. The hairiness of the yarn reduced the visual gradient between two contiguous colours in the fabrics which encouraged increased optical mixing.

Structure

Doğan (2017) argues that sustainable design should re-contextualise existing products and processes (Doğan, p322). No new fabric structures were developed for this research, but outcomes were produced in a conventional four-colour, birds-eye back, jacquard structure. Knitted jacquard structures allow different areas of fabric to be knitted in independent colours through selective yarn use. Four-colour refers to the number of colours in each course (row) and not the number of overall colours used. Birds-eye back means that when a yarn is not knitting on the technical face of a fabric it knits on every other needle on the technical back of the fabric. Short floats between the technical back stitches are trapped within the fabric and are not visible. The double-faced fabric and the quantity of yarn used in each course produces a firm fabric with good structural integrity, suitable for hanging with minimal support.

Technology

The fabrics were knitted on a Shima Seiki SES 122 5 gauge knitting machine. This double-bed, CNC machine allows face and back stitches to be produced simultaneously and individual needle selection both of beds of needles, which are required in birds-eye back jacquard fabrics. The machine has stitch transfer capabilities allowing the production of shaped fabrics and three-dimensional forms. A deep knowledge of knitted fabrics and machine programming is required to operate the machine successfully.

Aesthetics

Aesthetics were informed by the needs of the research, the location of the work and the preferences of the designer, facilitated through knit knowledge.

Initial colour choice was intuitive but based on the knowledge of which colours demonstrate the greatest shift in perceived colour when viewed under different lighting conditions. The three colour conditions considered were cyan, magenta and halogen (yellow) light, replicating secondary additive colour. The practice-led research approach was necessary in the development of appropriate colour palettes as viewing the work in three colour conditions required the ability to work with three colour arrangements simultaneously. Changing a colour in one lighting condition results in a change in all lighting conditions which can dramatically alter pattern perception.

The form of fabrics created was designed to suggest the sail shapes observed in the Weatherill Collection held by the Pannett Art Gallery. The main image referenced was Brig George of Whitby by Richard Weatherill (1844-1923). The fabrics were knitted to shape with integrally knitted wall fixings resulting in zero waste manufacturing.

Previous research (Gaston, 2016) had demonstrated that pattern comprised of geometric shape transformed dramatically when viewed in different lighting conditions. Key shapes were identified and embedded within the sail-shaped fabric. In keeping with the size of the gallery wall, the scale of the individual elements of pattern were enlarged to enhance the impact of the exhibit and were produced as three-coloured jacquards (Fig. 4).

Figure 4 The pilot fabrics produced with enlarged, geometric pattern.

Whilst the fabrics produced demonstrated perceptual pattern change, the overall aesthetic of the fabric was not successful in terms of the designer's preference. Returning to the original image sources a more complex pattern was produced overlaying a range of sail shapes (Fig. 5). This was knitted as a four-colour jacquard.

Figure 5 Design ideas based on overlapping sail shapes.

Optical mixing is enhanced through the interaction of small discrete units of colour (Day 1933: 265). This has previously been explored experimentally through blending in yarn (Chevruel 1839) and in woven fabric (Warburton and Lund 1956). The uniqueness of this research is it's use of knit as an exploratory research tool to investigate colour theory and visual perception. In a knitted fabric the smallest unit of colour possible is one stitch. Therefore, a birds-eye pattern was used on the face of the fabric as well as the back of the fabric. Each area of pattern was defined by a two-colour birds-eye mix. This allowed four solid colour yarns to be used as six blended colours.

Colour A + Colour B

Colour A + Colour C

Colour A + Colour D

Colour B + Colour C

Colour B + Colour D

Colour C + Colour D

Colour position was determined empirically. To maintain the integrity of the pattern the same colour pair was not used in contiguous sections. To encourage a dramatic change in perceptual pattern adjacent areas were knitted in colours that appeared to constellate in one lighting condition and contrast in another lighting condition. As three lighting conditions were used, the fabrics were designed in three colourways simultaneously. This is a complex design challenge as changing the position of a colour to enhance the design when viewed in one lighting condition can be detrimental to the effect when viewed in another lighting condition. The iterative design was undertaken using tacit and explicit knit knowledge (materials, structure, technology and aesthetics). Reflection on the process and outcomes extended the understanding of colour and visual perception theory.

Five fabrics were produced using a combination of three designs and three colourways. In this research the colour gamut available to the designer was extended from four solid colours to six blended colours. It would also be possible to use the solid colour in the same designs as the blended colour extending the gamut of colour available to 10 colours. There is potential to change the proportion of the two-colour blends from the 1:1 blend used in this research to 1:2 or 1:3. This could be used to create a more subtle range of colours however it would produce larger areas of individual colour units which may reduce the optical mixing effect. Similarly, the effect of three or four colour blends could be explored. Success of the use of colour change generated by viewing condition was measured by the extent of change in the visual perception of a pattern when viewed in different lighting conditions. For example, in fabric A (Fig. 6) the dominant form when viewed in the cyan light was a darker, vertical area, but when viewed in magenta light the dominant form was a lighter, diagonal area.

Figure 6 Fabric A viewed in three lighting conditions.

The work was hung under a continuous sequence of changing coloured light which altered the perceptual pattern observed by the audience (Fig.7).

Figure 7 Knit as knowledge used to explore colour and visual perception theory.

Conclusion

The work was successful in terms of extending the gamut of colour available to a designer without increasing the environmental impact of dying through optical mixing and changing the viewing conditions in which the fabrics were viewed. It extends the knowledge of colour generated through optical mixing and viewing condition within the context of knit as knowledge. The research offered a re-framing of a problem and the physical outcomes of the work are a visual representation of the new knowledge produced, in a form useful to its audience.

Of equal importance was positioning knit as a research tool as opposed to a commercial production process. Knit as knowledge was applied to established cyclic design research methodologies (Fig. 8) and the complex interaction of the different fields of knowledge required for successful knit design produced results that could not have been achieved in any other medium.

Figure 8 A cyclic design research process with aims of each area (red text) and outputs (blue text).

The methodology of utilising knit as knowledge can be applied to a range of problems, equally the methodology can be extended to different design disciplines, where each discipline can offer a unique body of knowledge as a solution tool kit.

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Figures

Figure 1 Dress produced from polymer coloured PLA.

Figure 2 The structure of Plain knitted fabric.

Figure 3 Test samples of optically mixed colour in different lighting conditions.

Figure 4 The pilot fabrics produced with enlarged, geometric pattern.

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