



Isomorphic Textiles:

Designing through technology in the medium of WholeGarment® knitwear.

Alysha Gover 2010

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Attestation of Authorship

I hereby declare that this submission is my work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

Signed.....

Date.....

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I hereby declare that this submission is my work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

Signed.....

Date.....

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Over the last sixty years, knitting has evolved through new technology developments in the area of commercial knitwear. The birth of seamless knitwear in 1995 by Shima Seiki has become the pinnacle in cutting edge technology, with a women's pleated pull over with structure design recently being knitted in 23 minutes and 19 seconds, on the newest 'MACH2X15L' machine (Rodie, 2009). Accompanying this manufacturing capability, designers have been introduced to a range of digital tools and methods that have changed the way they approach the development of commercially knitted apparel products. However, while this technology is being taken up across the Fashion/Textile Industry, generally knitwear designers are still not confident in using this technology to produce creative, innovative designs through the virtual interface of CAD Design systems. A recent study based upon a comprehensive survey from the 2006 UKHEI (United Kingdom Higher Education Institution) recognised the conceptual shift required in integral knitting:

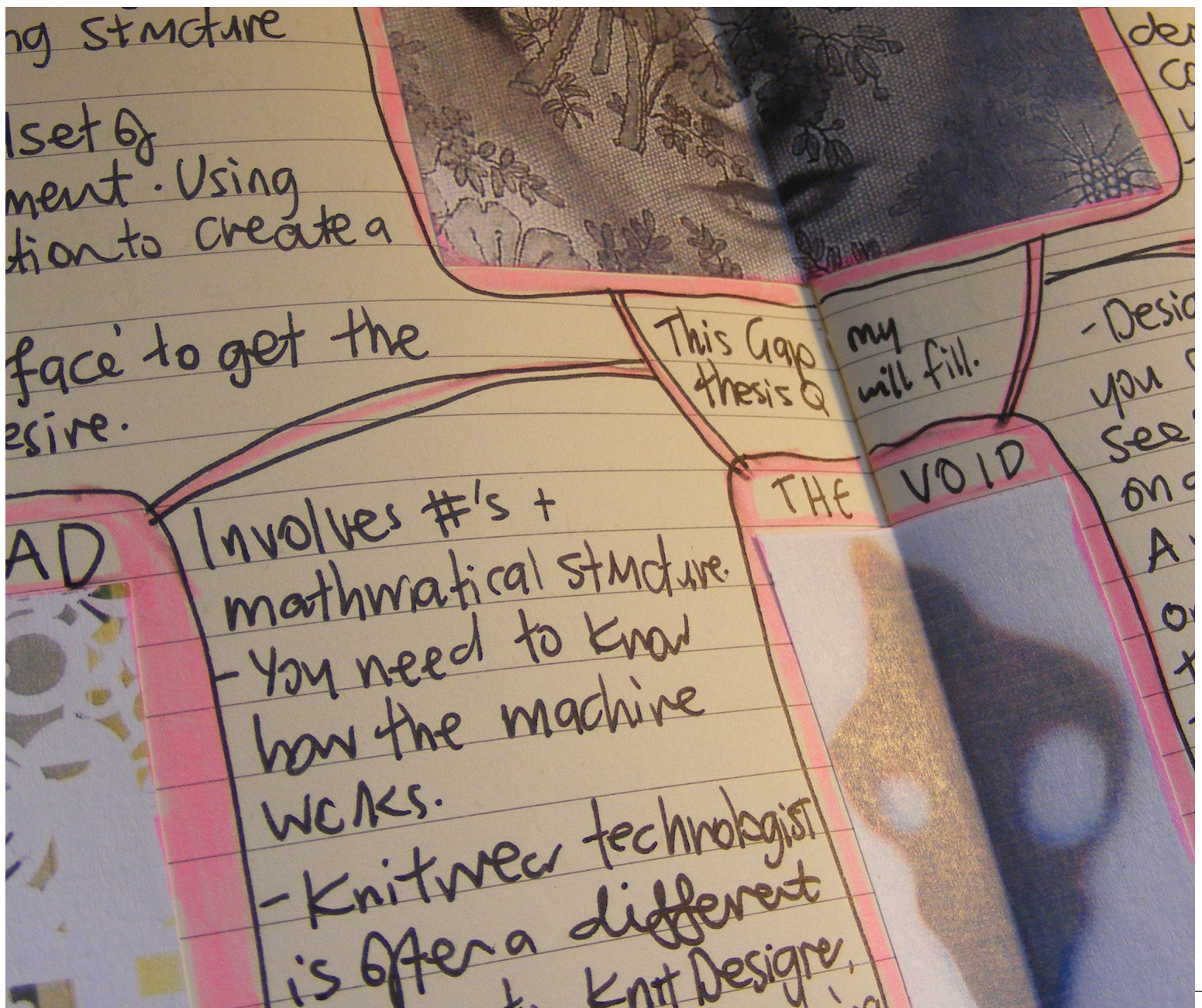
3D seamless machine knitting presents a new way of making clothing, forcing the designer to reassess ancient hand techniques.....the introduction of this complex technology forces a conceptual shift in the way knitted garments are designed and created (Sayer, Wilson & Challis, 2006, p.41).

This research aims to investigate technical and aesthetic directional choices made by the designer in WholeGarment® knitwear design. Hunter (2004) has recognised that that the automation of knitting software is a key element limiting flexible pattern creation in the revolution of integral garment technology. Though the technical machinery and programming has developed and become highly sophisticated this has tended to leave the designer bewildered as to where to begin with computer aided design in a virtual realm. As a researcher-practitioner in the field of knitwear design, I have

taken an exploratory approach conducting a series of informal experiments based on a series of design parameters through the production of sample swatches in different yarn types, various fabric construction techniques, digital textile printing and half scale knitted prototypes, which can be assessed for fit and garment construction. This practice-based, experimental research will assist in understanding and evaluating designing through technology, resulting in the completion of various knitted garments and a written exegesis.

The Appendix in this thesis is a report on a TEC (Tertiary Education Commission) funded summer studentship project, conducted at the Textile & Design Laboratory between December 2009 and March 2010. It is titled *Analysing the New Zealand Fashion Market: New Opportunities in Knitwear Design* (Gover, A. 2010). The project documented in the report has contributed immensely to the background research and understanding of the commercial application of machine WholeGarment® knitting. A capsule collection was developed as part of this project was used in industry to showcase some of the possibilities of WholeGarment® knitting and digital printing. The report demonstrates the value of applying educational research for practical industry application. Although the appendix is a separate body of work from the thesis, it is included as a foreground to this project. It provides information about the current New Zealand context and demonstrates insight into the background and rationale of this project in relation to the New Zealand knitwear market. In the report, the works of various designers and researchers working with these technologies have been documented to provide insight into a wider international context, alongside local applications.

Abstract



Introduction



Isomorphic Knitwear

The term 'isomorphic' is described in *Oxford Concise Dictionary* (1991) as: "something is different in ancestry but has the same form or appearance". In terms of this research, this process refers to the hand knitted garment in relation to a machine knitted WholeGarment®. This term recognises the different histories and processes that may inform the development of similar products.

If a hand knitted and WholeGarment® produced sweater were placed side by side, we would see that they both consist of sleeves, front and back, with ribbing around the cuffs, hem and neckline. They both have the same form and appearance, though they have been designed and produced in very different ways. The WholeGarment® sweater has no seams, an integral shoulder line and maximum comfort and durability as the structure is not weakened by seam intersections. This ancestry is technically astute and highly evolved, deriving from machinery engineering, rather than the historical hand crafted era. The hand knitted garment would consist of various panels of front, back and sleeves, all using a construction process to join the garment pieces together.

WholeGarment® knitting is essentially the ability to engineer a knitted garment through the use of technical software and machinery. The 'pattern databases' for creating whole garment have pre-programmed garment shapes which can be used with small changes to size and fabric structure. Due to the 'engineering' of the garments being a highly technical process, the limitations in terms of design innovation of WholeGarment® products requires a considerable amount of extra work. This process requires the building of the shape and 'packages' of the garment, which alternately requires a willing knitwear technologist who is also a pursuer of innovation. Often, this is an ideal concept, and realistically due to time constraints only minimal innovative changes are achieved.

This project explores the design process using WholeGarment® technology. This research will help articulate, explore and assess the use of design variables in the software and their application in garments. It is intended that this approach will help increase the potential and aesthetic value of such a technical product, whilst still enabling it to compete in the fashion market as a trend driven product of technical brilliance.

A paradigmatic shift in knitwear design and production

Historically, the technique of knitting has been associated with the domain of handcrafts. This rich historical affiliation, varying across many cultures and diverse social groups, has kept knitting evolving as an admired art and functional technique in the textile industry.

Although knitting was traditionally fashioned using needles held in either hand, the transformations and adaptations brought about the creation of the first knitting frame which introduced a series of technological changes to this process¹. This invigoration of turning craft into commercial machines increased productivity and saw the dawn of the industrial revolution which created the birth of modern knitting machines and the industrial production systems we know today.

In the last century the development of hand operated machines was superseded by fully automated electronically controlled industrial machines, with the most recent development being knit technology to produce seam-free garments with no finishing construction required post-knitting.

As the developments in the knitting world continually progress, there are now six different machine manufacturers who are leading the development of seamless knitting technology. These companies specialise in the sectors of apparel, automotive furnishing, medical textiles and well-being wear (Belar-Rodie, 2009). Creating such a scientific and technological development has been the result of collaboration between mechanical engineers, knitwear technologists and computer programmers, who have been able to form an astute model of machinery to further advance knitting production. Through the amalgamation of technical, mechanical and scientific fields the foundation of modern knitwear is formed. The technological advancements of these machines are forming new production methods, where many processes can be completed by one machine. Integral

knitting machines- such as the WholeGarment®- are an example of this, as the product can be knitted to a completely finished standard, as when it comes off the machine only minimal securing of yarn ends need to be dealt with².

However, as this technology has informed a new method of creating knitwear, it has also preceded past methods which have been in place for many decades. Through the introduction of this technology a new understanding in designing knitwear is explored, and the application of grasping the limitations and possibilities of working in this technology driven medium are also challenged.

As knitwear design and production has become a digital medium, the designer has needed to reform the way they approach the design of knitted product. This anticipation was preconceived by George K Stylios in 2001, as he stated in the editorial of *The International Journal of Clothing Science and Technology* :

The seam free principle has demanded different treatments in the engineering of these machines, which has resulted in their electronic controls and the way they are instructed to perform knitting tasks to be different to conventional knitting. Consequently, to effectively learn how to operate the machines, the thinking should be different; it may even be a disadvantage now if someone knows traditional knitting. (p.85)

As knit technology has been developed and explored over the past 60 years, the concept of 'integral'³ knitting, which has been known since the 1950's (Sayer,2006), was recognised for its

potential to reduce the amount of waste created in cut and sew knitwear⁴.

This process of integral knitting allows a structural piece of knitwear to be formed into shape whilst on the machine. As a three dimensional product this knitting process has many benefits in relation to the former method of fully fashioned knitwear. The capabilities of WholeGarment® are unique in the fact that they differ from the traditional production and construction processes of other knit machines.

Project rationale and aims

The origin of this project stems from my engagement as a knitwear design student over the past six years, where I was introduced to a range of different knit processes, from hand operated domestic 'Brother KH-830' (Fig 1:1) machines to industrial 'Stoll' (Fig 1:2) and 'Dubied' hand knit machines, onto Shima SES 122-S 'Shimatronic' (Fig 1:3), producing fully fashioned knitwear, to most recently the SESWG (Fig 1:4), producing WholeGarment® knitwear. I became challenged by the shift from more manual processes where I could work as both designer and technician in a holistic manner, to using WholeGarment® processes where there was a divide between the design process and the production process, which required the services of a knit technologist. This formed an interesting chasm as WholeGarment® knitting took on an engineered form of a knitted product. In order for the designer to fully maximise the WholeGarment® technology, they must design through technology in response to the production process, which requires an understanding of the technicalities as to how the machine produces a WholeGarment® design. This posed a wealth of questions as a designer, due to the importance of design in such a highly technical process. Because of this development, design is threatened to become overlooked as so many technical processes take place in simply producing a garment. Sayer et al (2006) brought this issue to light in their study into technically made seamless knit products:

Do we really want our clothing to be designed by machine manufacturers? If so, then designing 3D seamless garments could become nothing more than a mix and match with predefined garment modules (type of neckline, sleeve shape, etc). Could this even be called design? (p.44).

By adopting a unique approach of design due to the need of technology, it has formed a new process for designing knitwear,

as the designer now also has to understand production, technical processes and programming elements which all impact and inform the design process from the very initial phases of idea generation right through to the finished product.

While recognising that some of these problems arise from the still recent introduction of these technologies and the limited availability of literature or experienced design teaching staff who are working with this technology, this seemed to be a fertile area for research, to help build up knowledge about how this technology can be understood and used to bridge, rather than reinforce, the divide between the scientific/technical aspect of WholeGarment® production and the creative/experimental side of design development. Richard Coyne and Adrian Snodgrass have described the division between techno/scientific approaches to design and artistic/generative approaches as "designs dual knowledge thesis" (1991). Historically, they suggest, the nature of the discipline of design was informed and formed by these two polarities. This project is informed by this recognition that design, in particular WholeGarment® knitwear design, needs to bridge this duality of approach.

Fig 1:1 Brother KH-830 Domestic hand flat knitting machine (top Left)

Fig 1:2 Stoll industrial hand operated machine (top right)

Fig 1:3 Shima Seiki SES 122-S Shimatronic computerised knitting machine (bottom left)

Fig 1:4 SESWG computerised knitting machine (bottom right)



Project Outcomes

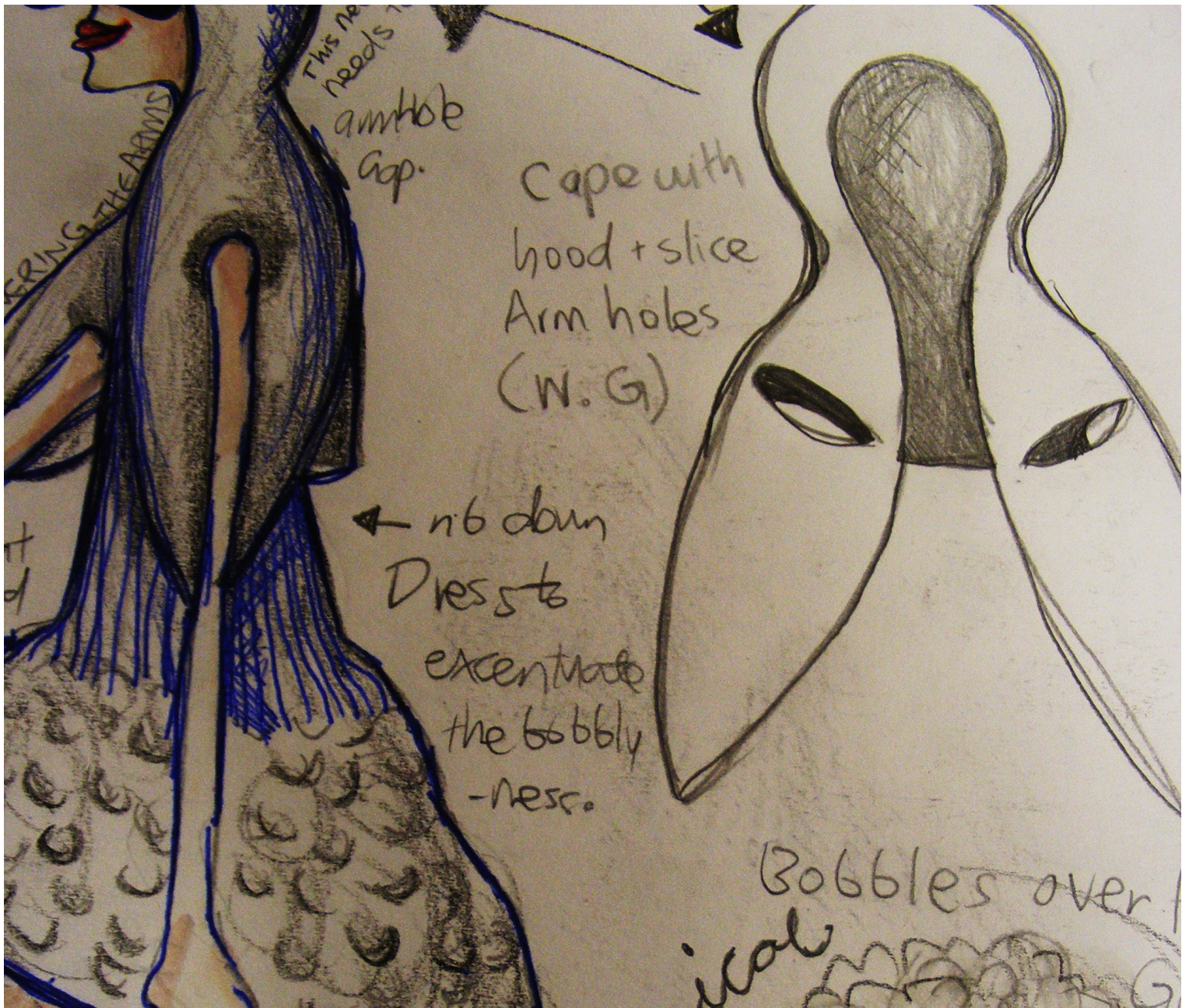
The project has involved a series of ‘quasi-experiments,’ which have informed the development of directional knitwear pieces for an exhibition setting⁵. The experiments required the identification of a number of design variables which are embedded in the design of the software. Different combinations and levels of these variables are explored as sets of design parameters informing the design and production of a series of knitted garments. The results of these different parametric combinations were analysed and used to inform the development of the final garments presented for examination. While the garments are a result and one outcome of this, the main outcome of this inquiry is the knowledge about WholeGarment® knit design that has been gained through this process and articulated in this thesis .

The project outcome is largely centred on the design implications of using WholeGarment® technology. Through each experiment the isolation of the design variables allows a focused space for product and design development concerning the aesthetic nature of the knit prototypes. This area is left open to analyse each set of quasi experiments and draw further research and conclusions from using these knit parameters in singular measures, and in combination with each other. Knitwear design already has underlying mathematical and scientific principles due to machinery and yarn compositions; so it was fitting to approach this project in the form of quasi experiments based on genetic-like algorithms. The over arching structure of quasi experiments to frame this design work bought a systematic way to track the progress of these tests.

Chapter One: Contextual Research

This chapter presents and discusses some critical and contextual issues that underpin this research. There is an emphasis on the relationship between technology and the design process, with different sections focussing on: CAD systems, fashion designers

whose approach is influenced by technological developments, mathematicisation in knitwear design, the designer/technologist interaction and the common ground between knitwear and architectural design.



Technology to inform the design process

The practice of designing knitwear has shifted into a digitised and virtual process to align with the technological developments of the fully automated knitting machines. Through a computer aided design (CAD) system knitwear can now be conceptualised and designed in a virtual realm. Shima Seiki's Design CAD SDS-ONE® system simulates knitted fabric to show the designer a computer generated conceptual model of the proposed design, with the latest Apex® CAD model showing three dimensional rotations of garments and drape on a virtual mannequin. This CAD method of designing differs from the traditional method of knitwear design on paper through sketching and collating flat, two dimensional images. Digital technology becomes a tool in the knitwear designer's process to ensure an accurate and realistic representation of the proposed design. This minimises mistakes, cuts down on the amount of yarn needed for toiling, and fast tracks the designer to a closer version of the initial intended design, as the designer has more control over the making process through programme compatibility.

The use of designing through software on CAD programmes does have some limitations, due to the parameters set by the technology. This can be a loss for the designer, and is always initially felt when transferring inherent design skills to a digital design application. Though this can be a shortcoming of designing through technology and can be somewhat creatively stifling, there are often alternate ways to work around this issue.

Through using technology such as that available on the Shima SDS-ONE® design system, the knitwear designer can also create a greater level of communication through information shared with the technologist, as both design CAD and technical CAD use compatible features. This is useful in the conceptual stage

of designing when technical information is needed to assess preliminary knitting characteristics, such as stitch combinations, hem choices and garment construction. Not only do software programmes for designing give a heightened awareness of the digital realm and a fuller bodied experience of the designs, they also allow a diverse to approach knitwear from a different perspective. This is due to the new possibilities created by cutting edge software on the market at present.

Another example in the use of technology within the design process can be seen in the software programme developed to imitate a designer's process of idea generation. This was shown in Johnson, Petre and Sharp's article *Complexity through combination: An account of knitwear design* (2006).

Through observing the role of the knitwear designer a software programme was developed based on the steps designers take in creating a pattern. Using a defined set of parameters to generate random pattern choices, motifs or borders for garments, the software generated possible outcomes for the design. This project did not have an automated evaluation system built into it, but rather, the results were evaluated and judged by the eye and experience of the designer in terms of what was regarded as a 'good' design.

The set of parameters given by the programme included:

- The number of objects;

- The specific objects and their placements;

- A specific combination of object-placement pairs, (e.g., combining one object in a border with another in a central motif); and the colours to be used.

(Johnson, Petre & Sharp, p.212, 2006).

Through the use of the computer being employed as a design tool, the following feedback was given:

On the order of 20% of the automatically-generated designs were deemed acceptably pleasing by human judges. There were evident comparisons to be drawn between automatically-generated acceptable designs and human-generated designs. None of the automatically generated designs reached the design quality of the best human-generated designs, but our aim was to test the viability of the model, not to show that it could produce designer-quality designs (Johnson, Et al, p.212, 2006).

Evaluation could be programmed into the machine, using human judgement such as symmetry, regularity/randomness, shape repetition, colour combinations/contrasts. This was looked at further in the conclusion of the paper, if future development was to be done on this software.

This example can be related to the historical project of the 'Design Methods Movement' and the ongoing efforts of the 'Artificial Intelligence in Design' group who sought to develop computerised approaches to designing. The failure of the Design Methods Movement and the limited success of the Artificial Intelligence in Design group indicate that technology alone cannot be used to achieve a good design. The position taken in this thesis is that a well designed garment requires an understanding of the potential of the technology as a tool in combination with a designer's thinking and experience to develop a successful method of designing knitwear using complex digitised knit production systems.

2D & 3D CAD Design

The Shima Seiki Apex® CAD design system released earlier this year already has three dimensional garment design capabilities. This cutting edge technology is still very new and a lot of CAD systems are still manifest as a two dimensional design medium. Hardaker and Fozzard (1998) in their article *'Towards the virtual garment: 3D computer environments for garment design'* discuss the concept of garment creation philosophy when designing virtually. Whilst using a CAD system to design a garment, Hardaker and Fozzard have identified that one of either four approaches is taken:

1. A "first principles" approach, whereby the design is originated on screen.
2. Adaptation of a 3D garment block (the work of Matsuura has been developed into a commercial system, the Asahi 3D).
3. Visualisation and development of conventionally designed 2D patterns in a 3D environment.
4. The use of an expert system⁶ to interpret the fashion sketch to produce a 3D visualisation.

(Hardaker & Fozzard, 1998, p.5).

In this research I have employed the "first principle" approach when designing WholeGarment® creations. This is implemented when I first initially start designing it is straight onto the screen, rather than onto paper. Through using a CAD based design approach I can refer to past styles I have created on the Shima system to cross reference my designing phase. Using this method generates ideas quickly and efficiently by using a mesh mapping and template mapping technique on the Shima SDS-ONE® system. This allows the designer to change the silhouette and shape of the garment virtually on a mannequin to support

initial idea generation or ideation. This has the potential to take a design concept straight to the process of a virtual prototype, in contrast to traditionally having to achieve a sketch before this stage (Hardaker & Fozzard, 1998).

Fashion Designers who use Technology in Design Practices

Whilst the creation of fashion has traditionally been an intimate hand tailored skill; from pattern drafting through to garment construction, recent developments in technology, engineering and textile design has brought about a new approach to how fashion designers construct and produce garments.

Issey Miyake:

Japanese fashion designer, Issey Miyake, is most widely known for his modern interpretation of making and designing clothes via technology. His process challenges and redefines the traditional production process by intercepting it through technology. Miyake has shifted the concept of fashion design towards the realm of garment engineering, which allows new and innovative processes to take place. In the book *APOC: ISSEY MIYAKE & DAI FUJIWARA* (Virta design Museum) Miyake states:

I have endeavoured to experiment to make fundamental changes to the system of making clothes. Think: a thread goes into a machine that in turn, generates complete clothing using the latest computer technology and eliminates the usual needs for cutting and sewing the fabric

(2001, p.5).

This approach to production will not entirely replace methods of traditional garment assembly and production; rather it contributes to fresh ideas in an exciting field of fashion and technology interaction.

As my project is centred around technology innovations in the fashion industry, Miyake's work such as his 1999 'A POC'

(Acronym for: A Piece Of Cloth) collection is supporting evidence

in the shift being experienced as fashion changes from a framework birthed from the industrial revolution, to a technical field of creativity led by the innovation of machine possibilities.

Miyake has not only adopted technology to inform his design process, he has restructured the entire process of making garments; from innovative fibre experimentation to production methods, to the end wearer's intimate involvement with the creation of the garments. Miyake acknowledges the timely shift in how fashions were historically and currently produced, and questions if fashion will be able to keep up the 'same old methodology' as it has done in the past (Virta Museum, 2001).

The cutting edge APOC collection is not only a feat in technology, rather it would not have progressed without the minds of innovative designers such as Miyake and protégé Dai Fujiwara. Miyake states: "I believe that technology can function only as long as we have the ability to imagine a sense of curiosity and a love for our fellow men (2001, Virta Museum, p. 69).

Seen in Fig 1:6 APOC has a warp knitted construction, created on Miyake's APOM (A Piece Of Machinery) through visual representations similar to checker boards which the computer reads and knits or weaves accordingly. The white squares indicate 'sink' and black indicates 'surface', with these instructions being interchangeable depending on the look wanting to be achieved (shown in Fig 1:7). This tubular fabric construction is created so that the wearer can cut the structure to form different garment combinations without the fabric unravelling- as a traditional knitted structure would.

As his APOC collection is described by Chandlers, Miers and Sato as "A state of clothing that reflects its time and lifestyle" (p. 68), this approach is also shown in his technologically renowned collection 'Pleats Please' of 1991 (see Fig 1:8 & 1:9).

Although Miyake is renowned for his affiliation with technology, the creative director of Miyake studios, Dai Fujiwara also acknowledges the historical context of where the evolution of garments through technology has originated:

"The process of making things advances, but never severs its ties with the knowledge of the age that preceded it" (Chandlers, et al, 2001, p.70). In Miyake's case, it was the traditional simplicity of the Japanese philosophy of garment design seen in the



Fig 1:5

Issey Miyake, 1993.

Fig 1:6

depicts the 'codes' fed into the APOM .





Fig 1:7

Garments from Miyake's 'One piece' S/S 2001 collection . These knits are reminiscent of whimsical forest animals.



Fig 1:8
shows the pleats innovation in his 'Rhythm Pleats' S/S
collection of 1990.



Fig 1:9

shows the pleating process translated into lively sculptural ballet costumes. Miyake worked with Choreographer William Forsythe of the Frankfurt ballet company (1991).

kimono which originally inspired APOC.

A historical affiliation also arises for seamless knitwear, though highly technical, it still acknowledges the historical context it has evolved from due to its isomorphic nature of having similar characteristics to traditionally constructed knitwear.

Through Miyake and Fujiwara's technologically informed garment design process it has aided me in applying a similar approach to how my design process is influenced by technology. In this way, technology can be used as a tool to create innovative patterns and designs for knitwear on Shima Seiki machines. In this context it has helped me to assess the balance between technology and the influence it has on the design process.

From an Australasian perspective the use of technology in designerly processes has had a heightened profile due to the '*Endless garment: The New Craft of Machine Knitting*' exhibition held in Melbourne at the RMIT (Royal Melbourne Institute of

Technology) Gallery in early February this year. The exhibition brought together twelve international and Australian high profile designers who are all using varied forms of technology in the application of knitting or textile printing. This awareness of technological processes in the southern hemisphere shows the capabilities of these prevailing technologies, which are being applied through industry production and experimental measures at university institutions throughout Australasia⁷.

The potential use of technology specifically related to my work in the field of integral knitting in combination with digital printing is already undertaking commercial application in the New Zealand fashion market. In an industry survey undertaken in May 2010 as part of an educational report also shows the encouraging response of designers willing to use this technology to creatively extend their fashion ranges. Although the response was positive, companies who declined the involvement in this technology was due to limited knowledge in this area, and the heightened cost of the product⁸.

Hussein Chalayan

Turkish born designer Hussein Chalayan focuses on using a variety of untraditional materials interwoven with technological devices to create fashion pieces which aren't only relevant to a fashion context, but display innovation from a variety of fields. ("Hussein Chalayan," 2006).

Known for using aeroplane wing remote control technology (Fig 1:11), unusual material fabrications, (Fig 1:12) electrical wiring (Fig 1:13), LED lighting features (Fig 1:14) in his fashion collections, his concepts commonly derive from a visual narrative told through his garments. Focusing on the aspect of clothing the body, Chalayan creates not only runway shows, but also performances, as his clothing takes on multiple functions. This is seen in his Autumn/Winter 2001 collection *Afterwords* (Fig 1:15) which is based on the anthropological nomadic life style of only taking the 'clothes on your back'. The models proceed to unbutton fabrics from pieces of furniture which are then attached to the body in the form of clothes. Chalayan's form of conceptual fashion heightens the viewer's awareness of the frequent relationship technology has in the incorporation of fashion, and the fluidity of Chalayan's clothing not fitting into one category or product description .

Chalayan's approach to fashion influences my work in the field of new technologies. As a forerunner in this area Chalayan is approaching technology from a fashion perspective, which clearly shows in the aesthetic direction of his work. In this way he always produces technologically advanced garments with beautifully crisp designerly elements.



Fig 1:10 Hussein Chalayan.

Fig 1:11 Hussein Chalayan, *One hundred and eleven*. S/S 2007.



Fig 1:12 Hussein Chalayan, *Air Bourne*, A/W 2009.



Fig 1:13 Hussein Chalayan, *Air Bourne*, A/W 2009.

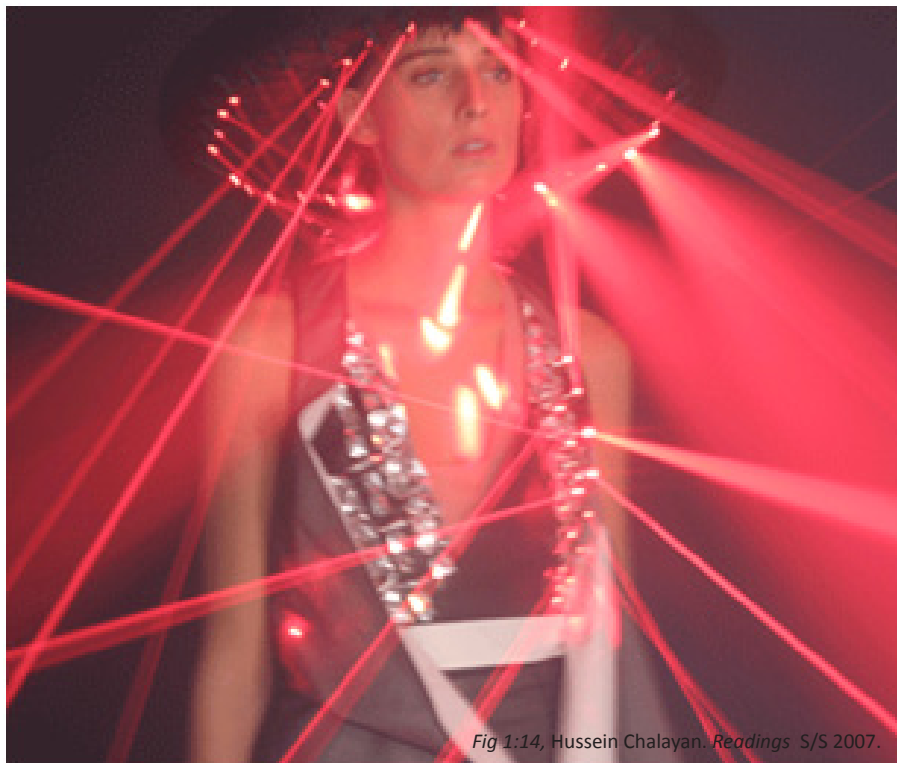


Fig 1:14, Hussein Chalayan. *Readings* S/S 2007.

Also known as 'smart' fashion, the practical inclusion of information transmitting devices in clothing is increasing due to new developments in the production of smaller, more flexible electronic components. This was reviewed by Patrick Tucker in the article '*Smart fashion: the digitally enhanced wardrobe arrives*' (2007) when he attended the Smart fabrics Trade show held in Washington DC. In the field of Smart Fibres and Intelligent Textiles (SFIT) many well known companies such as Nike and Rosner (Tucker, 2007) are looking into the research and development areas of SFIT to evolve their clothing into a fusion of body coverings and electronic devices. Products such as GPS, heart monitoring systems, and fibre optic technologies are being seen in the commercial application of fashion apparel. Electro conductive yarns blended with Lycra, created by Textronics (Tucker, 2007) have already been patented as a fibre with conductive properties to create warming and cooling systems subtly built into garments through yarn integration (seen in Fig 1:16 and 1:17).

Through the application of smart textiles Hussein Chalayan is a leading example of the physical incorporation of technology into high-fashion garments in the design process. This relates to my area of research through WholeGarment® technology and the future applications this could have in SFIT technology.

Fig 1:15 Hussein Chalayan. *Afterwords A/W 2001.*



Fig 1:16

The patented Lycra/conductive yarn blend by Textronics Company.



Fig 1:17

Showing the practical application of this conductive fibre in a sports bra.



Interaction Designer Grace Kim incorporates LED lights into her hand felted textiles which release small pulsing white lights transmitted at random intervals. This inclusion of smart technology in an urban fashion context allows fashion to be useful yet adventurous through the inclusion of technology.

Fig 1:18 Hand felted LED bag by interaction designer Grace Kim.



Fashion/Textile designers using mathematical processes for design

Knitwear design is based on a highly mathematical amalgamation of processes. However this mathematical aspect of knit design is generally masked by the CAD interface, and not used by knitwear designers, but rather by technologists who use programming skills. Thus while it would seem natural to also incorporate mathematical structures whilst designing, there are not many examples of designers taking this approach themselves. English knitwear designer Freddie Robins has consciously employed mathematical sequences into her design process to generate innovative ideas. She is interested in striving for perfection in mass produced garments using WholeGarment® technology to create multiples of her work for an art exhibition context (Robins, 2010).

One of her methods is knitting using a mathematical aleatoricism. This theory is based upon the generation of exploiting 'randomness' in design. Her series *'How to make a piece of work when you're too tired to make decisions'* (2004) was created by throwing three dice. Each die represented decisions that were to be made about yarn colour, rows of stitches, and knitting actions (www.freddiebobins.com). By generating this method of 'randomness' her knitting took on unique shapes and structures, and these methods or instructions could be altered at anytime, or when necessary. Seen in Fig 1:19 the pieces of knitting are forms of innovative shapes, which could be reflected into garment shape development if the process was to be developed.

This body of work by Robins is similar to my research through the function of adopting a mathematical approach to designing. This further shows that by using a mathematical method of designing you can still create innovative shapes for application in garment silhouettes. These aleatoricisms could easily be applied to integral knitting using an automatic software programme. The computer will be able to 'read' these shapes in terms of 'wales and courses' and knitting rows, which comprise a knitted garment.

Fig 1:19

'How to make a piece of work when you're too tired to make decisions' (2004)

Machine knitted wool, dress pins.

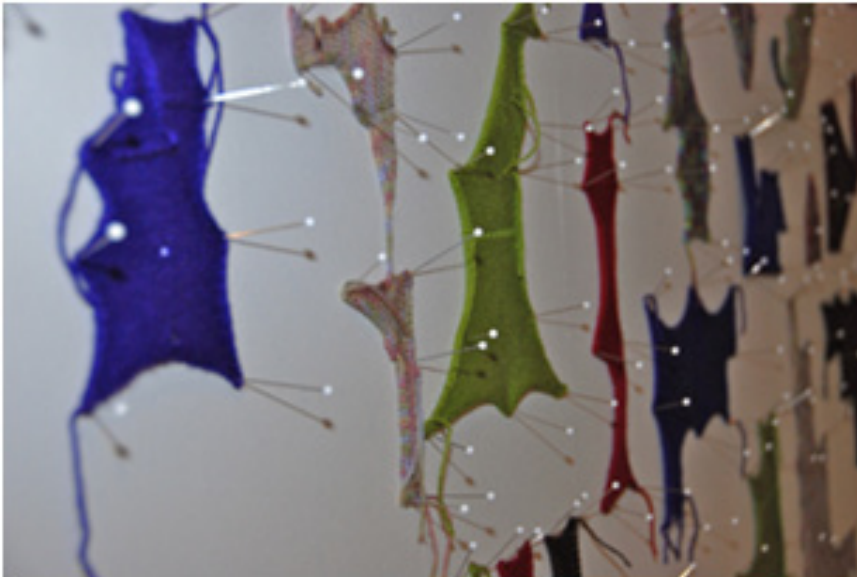


Fig 1:20 Detail.

'How to make a piece of work when you're too tired to make decisions' (2004)

Machine knitted wool, dress pins.



Oregamic Pattern cutting

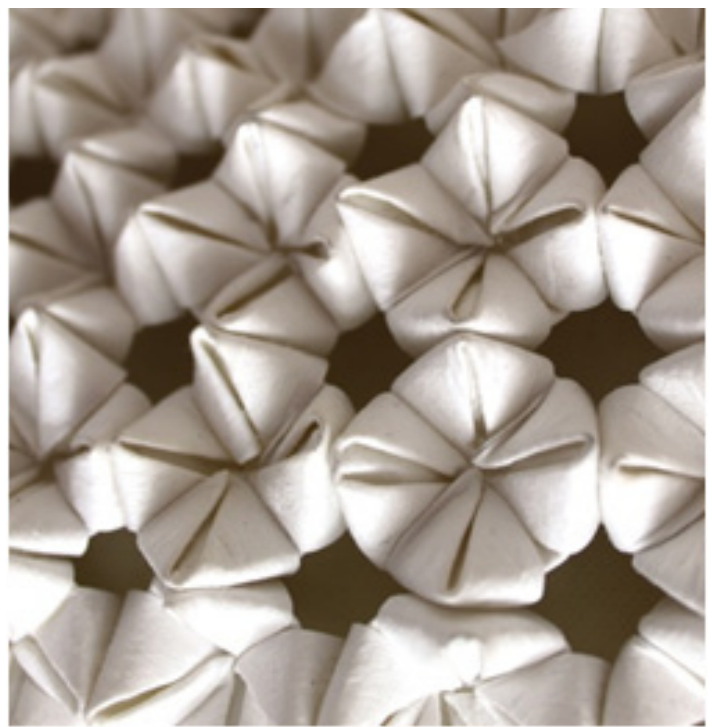
Elena Salmistraro creates textiles through the intricate repeats of elementary folds to create a three dimensional surface structure in her accessories collection *Prickly Blooms* (2010).

Using a water resistant paper-like fabric called 'tyvek' she creates small duplicating shapes which form a textile covering for the body. The techniques seen in Fig 1:21 and 1:22 display a mathematical approach to creating a textile and garment simultaneously. Due to the mathematical nature of this project these shapes can be scaled larger or smaller through the use of an equation or algorithm.

Fig 1:21 Salmistraro's textured bodice.



Fig 1:22 Textured bodice, Detail.



Tessellated Textiles

This undulating textile rug is made from a flexible wood by German textile designer Elisa Strozyk (2009).

Based on the manipulation of tessellating patterns the wood is divided into small segmented star-like shapes. These shapes form 'hinges' so when joined they create movement in the textile structure. Reminiscent of amphibian skin, this textural wood fabrication displays a creative yet controlled form of designing through the process of mathematical repetition.

Fig 1:23 Strozyk's fabric- like rugs are using solid materials which are cut cut in such a way to act as a textile fibre would.



Fig 1:24 Strozyk's wodden textiles employing a mathematical structure.



Designer and Technologist

Before the evolution of WholeGarment® technology, there were three main roles for people who aided the creation of knitwear. The knit designer, the shape designer, and the knit technologist (Etkert, 1997). Through the developments of the seamless technology, those roles have been folded into two main constituents, the knit designer, and the knit technologist. This is largely because the shaping of the garment is built in through computer programming.

Due to these roles condensing to form two separate jobs- that of the designer and that of the technologist, there is need for strong communication from both parties in order to achieve the desired result. This communication lapse is largely due to the only accurate representation of knitwear, is that of it:

The only accurate model of a knitted structure is a knitted structure. Knitwear information is intrinsically difficult to communicate. The existing symbolic descriptions are either incomplete or very complicated to use. Verbal descriptions are patchy and prone to different interpretations. Knitwear is difficult to sketch. (Eckert, 1997, p. 65)

This quotation from Eckert's Phd on knitwear design clearly displays the lapse in communication between the designer and knitwear technologist. Calling it the 'information bottleneck' Eckert (1997) gives a good account on the basis that much information is lost or miss directed through this passing on of information. With her research conducted over a decade ago, this major issue in knitwear design has been halved due to the incorporation of compatible software programmes for intelligent knitwear design.

The relationship of the designer/technologist is highly important in creating a knitted product, yet also very commonly taken

for granted that the information communicated to each other is understood on the same level. Etkert (1997) revealed that the thought processes, visualisation tools, aesthetics, and vocabulary differ immensely between the field of designing, and the field of knit programming. Etkert (1997) even goes as far as to state that they are largely two disassociated groups of people, in terms of age, gender, job satisfaction and employment at the company. This can cause further misunderstandings whilst working together. This working relationship is one of the main areas where ideas are miss-communicated, and therefore, a dissimilar outcome is achieved, much to the disappointment of the designer.

This situation is relevant to me as a knitwear designer who aims to produce innovative textile products through the use of technology. This is only possible via a knitwear technologist who can confidently programme the knitting software. The area concerning communication is incredibly important in my research, and to assure ideas are passed on effectively I often use tools such as sketches, past knitted swatches, or computer generated images to clearly stress the aesthetic and feel of the design I wish to achieve.

Though Etkert has placed the designer and technologist in the realms of 'chalk and cheese', a more recent study undertaken by the University of Ljubljana, Department of Textiles, Slovenia, and the University of Zagreb, Department of Textiles, Croatia, has appraised knitwear designers and knit technologists via a questionnaire, and has concluded they have more in common than evidently shown (Cuden, 2009).

Designers and technologists both agree that the technological possibilities of the knitting machine can give the designers new ideas, and also agree that having knowledge in production technology is also an important part of designing (Cuden, 2009).

This cross pollination of knowledge to both knit designers and knit technologists allows a common area of innovation to be fostered, which in turn will allow new possibilities in garment design to be achieved. It is helpful in my project to work with a knit technologist who also wants to research the creative possibilities and innovations of the Shima Seiki technology. With this commonality it is clearer to articulate the design creation process as there is a reciprocated willingness to try new ideas in experimental areas of design.

This concurrence of ideas if not clearly explained, or the similarity of thought not shared, can often cause dual frustration on both parts as the communication is eroded by common misconceptions in the understanding of jargon, technical terminology, and abstract ideas, which only leaves imagination to decide on the visual aesthetics of the garment.

This research specifically investigates the area of quandaries between designer and technologist from a knit designer's perspective of grasping this new approach to the design process when using this technology. This is opposed to designing knitwear on domestic or hand operated industrial machines. The handover of control in the making process is often difficult for the designer to first experience, as traditionally knitwear designer's are using hand operated machines which offer complete control from design, to fabric creation, which is different when designing through technology on the Shima Seiki systems. These design parameters of working within pre-constructed programmes, and also through a technologist needs to be understood in order for these limitations to be overcome. As digitised knitwear requires specialised skills, it makes sense to employ the knowledge of a technologist to enhance technical design elements of knitted products. Sayer et. al (2006) also acknowledges this in the following comment:

Alongside this technology shift, the role of the designer must also change; an ability to understand 3D design concepts and the machine parameters is required to compliment traditional skills. Moreover, an ability to communicate effectively with technical colleagues is essential (p.43).

A knitwear designer's role of designing can be abstract and unclear until a final product is produced. Etkert (1997) brings to point that the only thing to represent a knitted structure, is a knitted structure. Black (2010) also comments on the technical

representation of knitwear, as it is simultaneously a two dimensional fabric, a three dimensional form, all whilst being knitted into a shaped textile panel.

At the embryonic stages of design, often 'moods' are communicated, a form of intangible information, which cannot be technically communicated to the knit technologist. As a further example of 'moods' in knitwear, Black (2010) describes the different 'feel' knitwear conjures up in the following statement:

"knitting is many things to many people: it can be cosy, sexy, decorative, classic, oversized, micro, clinging, enveloping, chunky, see-through, sophisticated or theatrical"(p. 124).

As another way of communicating to technologists, often past-referencing will take place where similar styles from previous seasons will be used as examples of a 'base' garment, then changes will be made from there. As some knit designs are initially difficult to visualise, building up a visual picture using another previously knitted garment makes it a lot clearer. In a study conducted in the field of helicopter design, (discussed by Etkert & Stacey,2000) it has shown that the process of explaining a proposed design also uses past designs as a reference. This was because so many of their designs were highly customised, it was difficult to try and imagine the complexity without a visual or mental aided description. These two fields of knit and helicopter design are linked by having the same visiospatial qualities through the complexity of the designed product. Many elements need to be communicated simultaneously in order to create a whole picture, and this is the troubling quandary knit designers and helicopter designer's alike find themselves in.

Within the context of this research project it is proposed that communication difficulties between designer and technologist can be improved by designers being able to access information and develop greater understanding of the limitations and potential of WholeGarment® knit technology. This research explores the medium of WholeGarment® knitwear to help understand and articulate design possibilities. It is hoped that this approach will add to the body of knowledge about WholeGarment® knit design processes and thereby assist communication between designer and technologist.

Common Ground: Knitwear designers and Architectural practices

Another key context for this project is architectural approaches to structure. My own approach and philosophy is based on the concept of knitwear as an engineered, architectural structure. This is defining commercial knitting as an automated form which is produced from a CAD programme, similar to the way modern architecture is created and designed. The language, ideas and inspirations can flow freely between these two areas of knitwear design and architecture. This cross-disciplinary use of language was shared in the book *'Skin & Bones: Parallel practices in Fashion and Architecture'* (Hodge, 2007). The discipline of fashion has adopted words commonly used in architecture such as 'architectonic', 'constructed' and 'sculptural'. Similarly words now appearing in architecture have been used from fabricating fashion techniques. These include 'draping', 'wrapping', 'weaving' and 'folding' (Hodge, 2007).

Though the scale of creating clothes for the body and creating buildings for humans to dwell in differs substantially, they hold similar fundamental objectives such as shelter, identity, and expression which create a fusion in the two fields of design. Another reason for the two fields moving closer together is the result of new industrial technologies and manufacturing processes (as discussed by Hodge, 2007). The use of CAD systems to create design simulations can be interchangeable within the two disciplines, as seen in the cross pollination of trained architect and engineer Elena Manferdini, who has recently applied her specialised skills to the field of fashion design. The parallels in software systems have allowed her to design couture pieces which have been laser cut with hand finishing techniques applied to create 'one of a kind' designs (seen in Fig 1:25).

This example of software being used by visionary architects such as Manferdini who are frequently designing in a digital medium creates exciting applications to fashion, which can be further explored as the two disciplines merge closer together. Hodges (2007) further goes on to comment on the work of Fashion Designer Rei Kawakubo's work which can similarly be better described using architectural terminology, as opposed to fashion jargon⁹. This frequent blurring of boundaries will only become stronger as the use of technology increases and product versatility is produced to allow a free exchange of surface treatment applications.

This area of research between the spatial relationship of building engineering and knitted garment production gives me a strong and diverse field of references in terms of design aesthetics and knitted structure development, as I too see myself adding to the blurring of the lines in between these disciplines.

Similarities across these two disciplines stem from the conceptual stages of designing in both fields being computer oriented through specific CAD programmes. Technology has informed both fields in recent years as the mode of designing has progressed from hand rendered to computational modelling. By designing WholeGarment® knitwear (as opposed to the former: piece knitwear) you are effectively engineering a structure to be inhabited by a living being. This process has parallels to designing the structure of a house. Seam intersections, structures and finishing can be related to architectural notions of joints, framing and surfaces. Above all, the spatial focus of these processes and their relationship to the human body are critical. In addition the shift from virtual ideation and design representation into tangible products is also common to both processes.

The way architects and knitwear designers form their design process uses similar methodological approaches of reflective practice and 'doing and making' developments. This is seen in



Fig 1:25. Manferdini's work was featured on www.span.vox.com, a website concerned with the implications of 'architecture, technology and the digital realm'. This image shows Manferdini's laser cut garment which envelops the fields of fashion, architecture and industrial design. Using gaming and architectural software such as Maya which has three dimensional rendering capabilities she is able to create hybrid form of wearable architecture which can adorn the body.

the making of scaled housing models in architecture, and knitted prototypes in knitwear .

Knitwear can also be described as 'architectonic'. This word is derived from the root word 'tectonic', with the Greek word of 'tekton', meaning carpenter or builder (Liu & Lim, 2006). This word later evolved to incorporate the meaning 'process of creation', referring to the artistic works. According to Liu and Lim (2006) this included the aspects of skill, method material and concept. In the article '*New tectonics: a preliminary framework involving classic and digital thinking*' (2006) Yu-Tung Liu and Chor-Kheng Lim discuss the changing form of architecture to a digital realm.

The tectonics of architecture involved two main elements, the inner shell corresponding to the outer shell. The tectonics of the building was the form of how materials are connected together, via beams, metal work or wooden framework. Through the digital design progression of architecture, Liu and Lim (2006) argue that there is no longer 'tectonics', but rather 'anti-tectonics'. This is due to the focus being applied to the materials of the buildings themselves, rather than adding further materials to form the structure. This is a similar approach to WholeGarment® knitting, as there is no longer seam construction, the attention is going into the engineering of the pattern and the flexibility of the yarn.

Chapter Two: Methodology



Introduction

In this chapter the project methodology is discussed initially in relation to broader epistemological frameworks that have underpinned this project and then in terms of more specific methodological and methodic approaches. The first section draws from Coyne and Snodgrass's writings about design's 'dual knowledge thesis' (1991) which recognises the long standing dualistic positioning of techno-scientific approaches in relation to creative-tacit approaches in design and its research. It is suggested that this positioning can also be recognised in the separation of roles and activities between the highly technical domain of wholegarment knit programming/production and the creative and intuitive approaches of the knitwear designer. Coyne and Snodgrass are highly critical of design's dualistic knowledge thesis and its effect on design knowledge. They propose a hermeneutical or interpretive approach as a way of challenging such division. This research project has used an interpretive approach, utilising both the structured and parameterised organisation of the knit design software and my own experience and 'tacit' understanding of the knit design process through a series of "quasi-experiments". (This specific term is used to define the set of experiments undertaken in this thesis. Quasi implies an 'almost' experiment- not like a traditional scientific experiment with a strict control and test conditions, but rather the experiment compares different test parameters against or combined together with each other, often picked intuitively by the researcher to increase the unexpected and 'experimental' aspect of the test. The experiment is then measured against a list of features, referred to in this thesis as a 'fitness test', which gauges the effectiveness of the design produced as a garment. This is then evaluated and the success of the quasi experiment and the outcome is reflected and analysed for the summary of this thesis.) This enables the potential of combining and recombining different parameters to push the boundaries of WholeGarment® knitwear design approaches

are explored so as to achieve more innovative outcomes and to better understand and articulate the potential and limitations of wholegarment knitwear design .

The second part of this chapter addresses approaches to parametric identification and combinatorics based on an approach inspired by theories of evolutionary selection processes and their use in genetic algorithms. This section discusses the modularisation implicit in this approach (and in the knit design software) and the development of 'fitness' criteria as a critical framework for evaluating knitwear design outcomes. It should be emphasised that this approach is used metaphorically as a principal rather than as a formal, logic based, algorithmic approach. Finally the practice-led approach to design research, which is central to this project, is discussed in terms of an action research frameworks and Donald Schön's theory of reflective practice.

A Hermeneutical Approach to Design and its Research

Coyne and Snodgrass (1991) outline and challenge design's dual knowledge thesis in relation to two historically distinct and competing approaches to design. The notion of the dual knowledge thesis expresses these fields of thinking and their associated practices as either scientific and logical or intuitive and romantic with both approaches related to different disciplinary approaches to design. The 'mysteriousness' behind the notion of designing alludes to the designer not being able to articulate their process, or give reasoning for it.

Coyne and Snodgrass (1991) refer to a third way, a hermeneutical approach to designing as a 'both and' approach, which invalidates the idea of the 'dual knowledge' thesis in which research can only be thought of in two differing areas of thought, not both simultaneously. They write:

"The hermeneutical nature of understanding is shared by both the 'divergent' activity of designing and the 'convergent' activity of solving a mathematical problem." (Coyne & Snodgrass, 1991,p.126).

As a research practitioner in the field of knitwear design it is necessary for me to simultaneously engage both technical/scientific and aesthetic/creative fields in order for my research to become successful. My research methodology is framed through a hermeneutical approach, as I seek to work interpretively and incorporate both the scientific and intuitive fields into my enquiry about design methodology in the knitwear discipline (this can be seen in the diagram Fig 2:2).

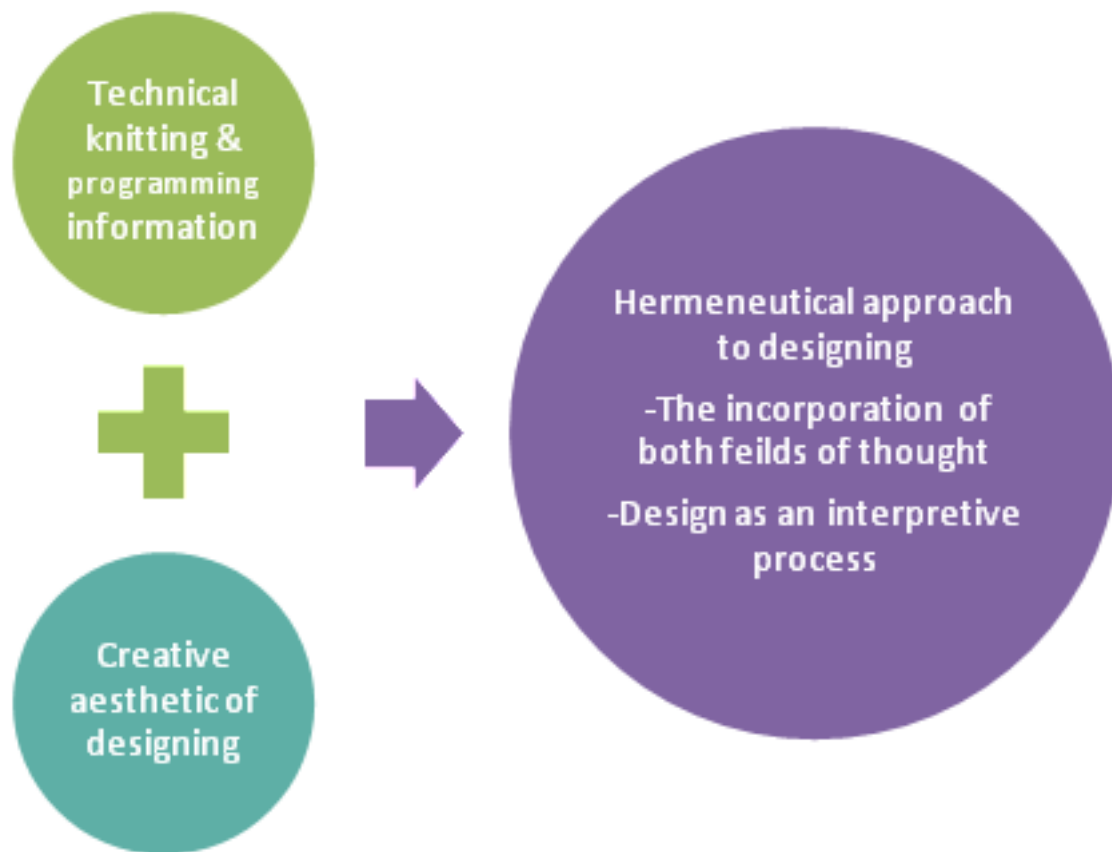


Fig 2:1 Both creative and scientific approach working together in a hermeneutical framework

The cloud of mystery which shrouded design as romantic, spontaneous and illogical act that could not be articulated through words is addressed through a hermeneutical understanding where design is framed through the interpretation of processes in working with objects and contexts to discover new meanings. As Coyne and Snodgrass (1991) have noted:

“Hermeneutical philosophy represents a paring away of esoteric and abstract theories and models used to explain everyday phenomena, such as language and thought.” (p. 125).

This research into the knit design process has required that I effectively communicate my design experiments, developments and new understandings - not only through sketches, images and products, but also through writing and speech. This is important in the context of this thesis project, which requires evidence, information and insight to contribute to the discourse about this still largely unarticulated area of research within a fashion knitwear context.

Framing the information I discover throughout my thesis project, whether it is written, photographed or sketched, these new understandings will contribute towards addressing the lack of information widely available in terms of WholeGarment® and design processes. With this project I endeavour my work to help aid the progression of further innovative designing in the field of WholeGarment® design.

This articulation is an important part of the development of knowledge about WholeGarment® knitwear design methodology and its disciplinary identity and validity as a field of research, as it can be effectively communicated through words and theories,

not just through the production of designed artefacts. It is hoped that this approach will allow knitwear design processes to be more objectively examined and become more rigorous. Designing, according to Coyne & Snodgrass can be described as a dialogue between the designer and the design situation (1991, p.125).

There is much in designing that is private and personal to the designer. That which cannot be explained is attributed to the subjective nature of the design process. Design therefore inherits a style of rhetoric whose origins lie deep within the Romantic Movement in art. Claims to mystery and subjectivity are acceptable in accounting for design thinking, whereas there is general discomfort when similar claims are made of the way science operates, legal judgements are made or medical diagnoses are derived. (p.125)

This dialogue can be understood interpretively, that is hermeneutically. The notion of applying a ‘metaphorical’ algorithm to objectively analyse the design process using WholeGarment® technology allows the designer to focus on the potential and limitations faced when designing products in this medium. The next section of this chapter will investigate the implications of mathematical approaches to designing and how they are relevant to the field of knitwear design.

Modular Design through Genetic algorithms

Johnson, Et al, (2006) discuss four different design methods they have seen used by knitwear designers. These are described as: Simulated annealing, Neural networks, Hill climbing and gradient decent, and Genetic algorithms. As the latter two are applicable to this research project they are discussed more in depth below.

Hill Climbing and Gradient Decent:

In terms of designers selecting the best designs, Johnson, et al (2006) proposed the idea of 'Hill Climbing and Gradient Decent', where the 'best' designs are selected while the other designs are discarded, allowing a flow of continual better and better designs, climbing further up the hill, until a concluding design is chosen. The downfall with this method is that a designer can become stuck in a position of keeping to a strict use of motifs and themes, hence the 'gradient decent', as designs become unable to be judged separate from themselves, as they are all so similar in visual aesthetics, not one stands out from the others.

Genetic Algorithms:

This basis of designing is formed upon a set of what would be termed 'good' designs, being 'bred' to generate a new set of superior designs. Johnson, et al (2006) describe these in terms of ABCDEF, (each letter signifying a determinate specification of the design: shape, colour, pattern etc) bred with VWXYZ, and equally pleasing set of designs. They could produce elite 'design offspring' consisting of ABXZW and VWCDE. This cross pollination of ideas brings about 'new innovations' through combining new ideas.

back upon, these designs would be looked at through a 'fitness test'. This is used in mathematical algorithms as a form of measurement to evaluate the validity and appeal of the designs. The fitness test parameters for the experiments conducted through knitwear design can be seen in Fig 2:4.

This principal of genetic algorithms adapted for knitwear design can be seen in diagram Fig 2:3. Once reflected and looked

Fig 2:2 Dual Knowledge approach to research:

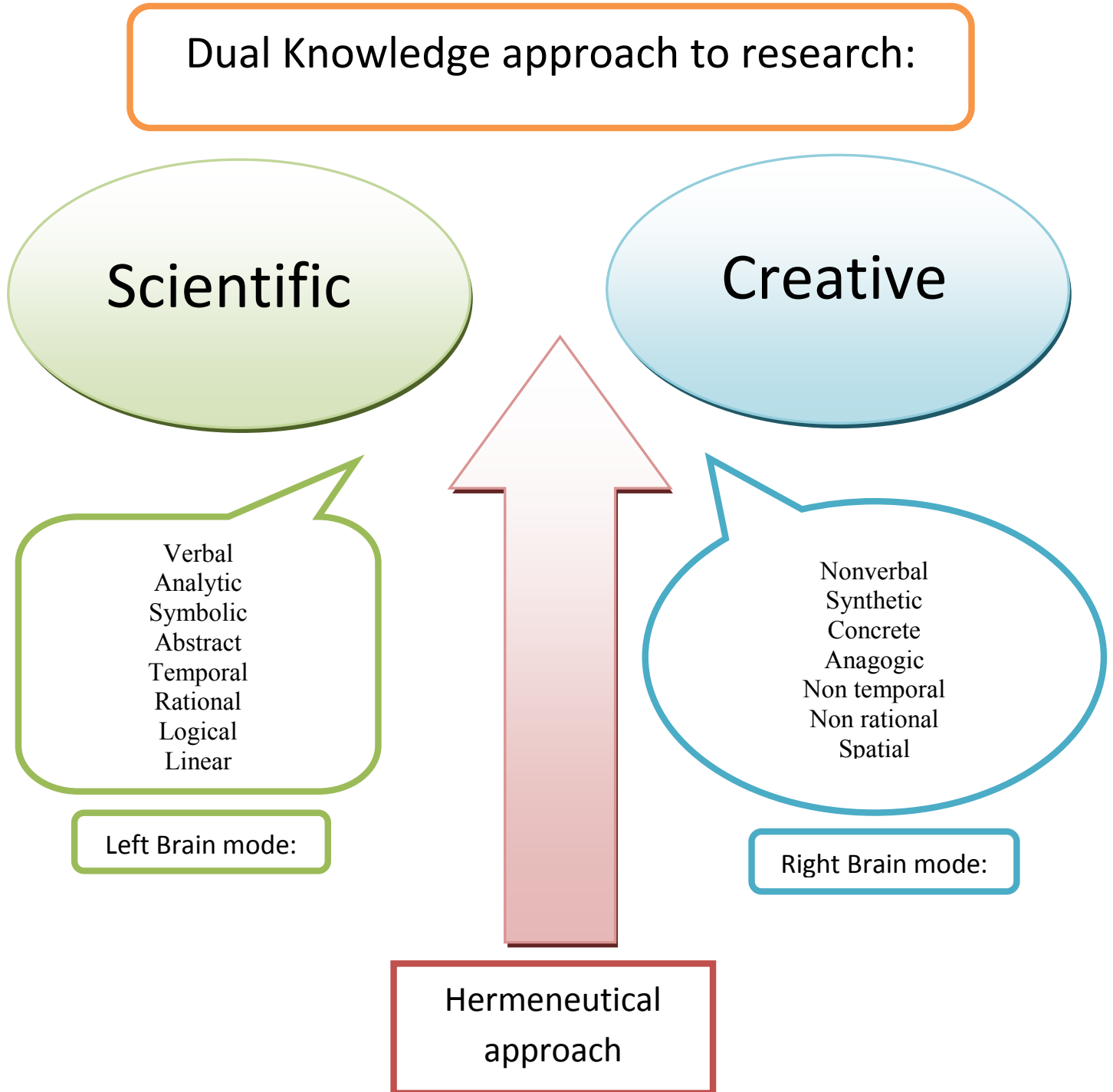
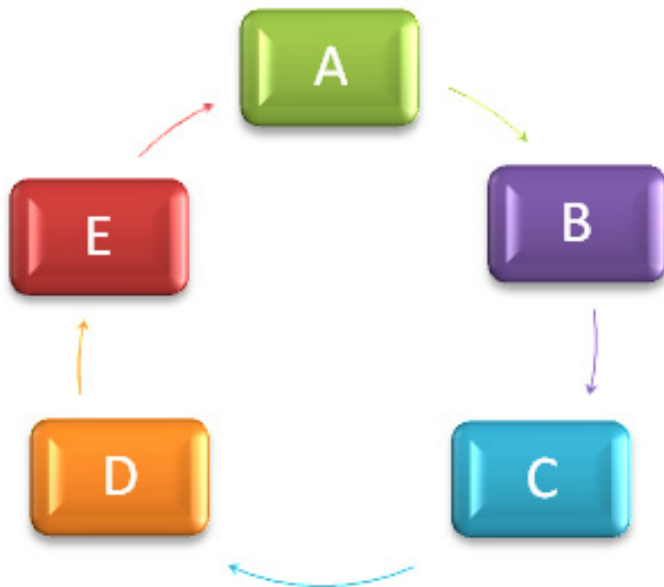


Fig 2:3 Using Genetic algorithms In designing knitwear:



- A: Shape Development
- B: Garment Characteristics
- C: Structure Design
- D: Colour Integration
- E: Textile Print Application

This structure allows the development of a series of genetic like combinations to inform the design process. The generation of designs leads to the selection and combination of successful outcomes to generate design choices

- ABD
 - Shape dev
 - Garment character
 - Colour/jacquard
- ABED
 - Shape dev
 - Garment character
 - Textile print
 - Colour/jacquard
- ABC
 - Shape dev
 - Garment character
 - Structure
- ABCD
 - Shape dev
 - Garment character
 - Structure
 - Colour/jacquard
- AB
 - Shape dev
 - Garment character
- ABE
 - Shape dev
 - Garment character
 - Textile print
- A
 - Shape dev
- ABCDE
 - All of the above.

Fig 2:4: Fitness Test for Knitted textiles.



This algorithmic approach to designing for WholeGarment® knitwear helps the designer identify a clear system for approaching what is already a highly technical and complex process. While the machine is capable of knitting a seamless garment, the inclusion of numerous design features or changes can often create a headache for the technologist, due to the technical parameters restricting choice and possibilities for the designer. This cause of frustration is due to the designer wanting to incorporate many design features in one garment, but, due to lack of technical understanding, not realising the complications in knitting such a technical garment. Taking a genetically inspired approach allows the design researcher to identify what is possible, so that the technician is not overwhelmed by the inclusion of too many different elements at once. This process of designing and letting the garment evolve and progress in stages also allows the designer/researcher to have a deeper understanding of each process. This knowledge will be useful when undertaking similar designs in future, empowering the designer with more knowledge about technical processes.

Categorising the different technical and aesthetic choices a designer has to make creates a set order of choices to logically

think in depth about these options. It also lays out clear parameters for the knitwear technologist to work within. This specific approach to design generates room for movement and change, as one decision can impact a past or future decision in the design process. This is included as part of my designing mode of 'doing and making' in the design development stages, which refers to a continuous cyclic process which engages different design components that are being incorporated as the garment progresses. By employing this technique in my design process, I can be specific about the outcome for the desired garment, meaning there is no need to include all design components simultaneously. In one design, a certain component such as stitch structure may be the sole focus, therefore digital printing would not be used as it would over power the former.

The identification of the techniques which can be used to construct a knitted garment allows the knitwear designer to focus on specific technical issues which might arise due to the inclusion of other design attributes. As a piece of engineered clothing which is being systematically generated, this presents the issue of whether any other innovative measures can be added to the garment to be fashion forward and trend driven.

Practice Led Approaches

Coyne & Snodgrass (1997) also discuss Schön and design as reflection-in-action as 'reflective conversation' with the situation (Coyne & Snodgrass, 1997). They see this process of dialogue as a hermeneutical circle:

The designer proceeds by way of a continuing inter-referencing of a projected whole and the particulars that make up a design situation... In the design process we project meaning on the whole and work our implications of this projection by referring back to its parts. There is a prescient anticipation of the whole, which is then explicated in the individual parts. The design is continually re-determined by an anticipatory movement of pre-understanding. The designer has an anticipation of the whole which guides his or her understanding of the particularities. Understanding arises by a process of constant revisions.

(Coyne & Snodgrass, 1997, p.22).

Schön's Reflexive Practice

As my design and research processes undertakes a cyclic and reflective approach, Schön's theory of reflective practice (1987) is important to the critical development and evaluation of my work. Through each modular stage of the design process I am able to reflect on the previous stage, which informs the current process. Schön calls this 'reflexive practice'. This allows the designer to not just think in hindsight, but to think and act on the research whilst working on it.

Schon' describes this as a ladder of reflection:

We can introduce another dimension of analysis [for the chain of reciprocal actions and reflections that make up the dialogue of student and coach].

We can begin with a straightforward map of interventions and responses, a vertical dimension according to which higher levels of activity are "meta" to those below. To move "up", in this sense, is to move from an activity to reflection on that activity; to move "down" is to move from reflection to an action that enacts reflection. The levels of action and reflection on action can be seen as the rungs of a ladder. Climbing up the ladder, one makes what has happened at the rung below an object of reflection (Schon, 1987,p.114) in (Hazzan, 2001, p.165).

Coyne and Snodgrass recognise Schöns approach as hermeneutical. This reflection is used in my work to evaluate each technical and aesthetic aspect of my designing process (see diagram in fig 2:6 for more detail). As this reflective stage is an upward moving cycle, it also informs the 'evolutionary' approach my garments maintain. This is applied as I sequentially

move through the design process, often building and adding to existing design elements, hence – 'evolutionary'. An example of this is evident in the adaptation of hem lengths, sleeve lengths or neckline finishes, seen in Fig 2:5.

These three sequential images show the changing hem lengths as the design was reflected upon whilst designing. This was by 'moving up the ladder' the design researcher was able to make informed decisions about the garment design whilst making it.

You can see the hem lengths vary, until in the third image, when the idea evolved to the 'top of the ladder' a conclusion was reached.

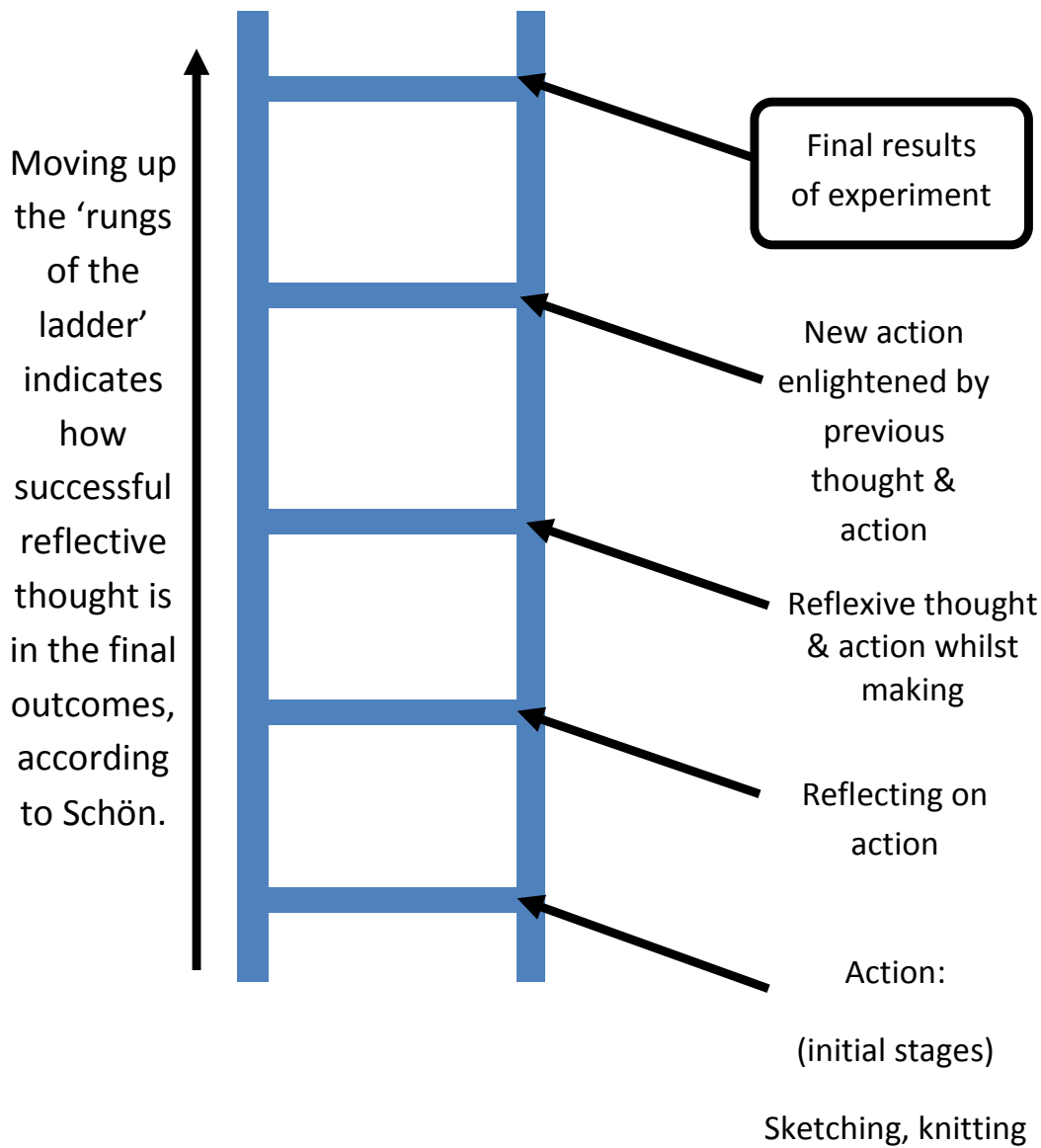
The example of the hem length 'evolving' can be noted as 'changing' from the first rung of the ladder.

Initially sketched as an idea on rung one of the ladder, then reflected on by rung two, and in rung three, whilst making, the hem length was altered. By rung four 'New action enlightened by previous thought and action' the hem length was changed again as it was deemed too long for desired the garment design. By rung five 'Final result of experiments' a final hem length was decided upon, and this length was taken through to the next stage for further designing, which was specific yarn integration of the garment.

Fig 2:5 'Evolutionary processes' in garment design. This shows a physical change in the garment where the hem length 'evolves' from 20cm in the first image, to 60cm in the second image, then finally to the desired length of 40cm in the conclusion of the design in the third image.



Fig 2:6 Schöns ladder of reflection:



Action Research

For the researcher-practitioner the process of action research is a valuable approach to progressing research through design in my work. Carr and Kemmis define action research as:

Simply a form of self reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practices, their understanding of these practices, and the situation in which these practices are carried out. (Carr & Kemmis, 1986, p.162).

This method of inquiry has informed the development of the modular approach to designing through a series of cyclic analysis. As each part of the designing process is broken down and reflected upon, it has allowed me to gain more insight into my work.

Archer, in his article *Design as a discipline* (1979) explains that the essential language of design is 'modelling' – a representation of something. This by experience allows the designer to research through making, as by making you discover limitations, capabilities and begin to understand the way in which you create. Archer's definition of design is also helpful to understand the relationship to other research disciplines:

Design is defined as the human experience, skill and understanding that reflects man's concern with the appreciation and adaptation of his surroundings in light of his material and spiritual needs.... It relates with configuration, composition, meaning value and purpose in manmade phenomena. (Archer, 1979, p.28).

With this understanding in mind the approach to design becomes holistic, as it is multi-faceted and intertwined with culture and trends. My design process is predominantly cyclic and reflective, as each stage in the research process corresponds to a portion of experiments concerning knitwear design. As this process is also technically based and is governed by the structure of the software programme. Hence why a modular structure is imperative in isolating the various processes, problems, effective combinations or the potential innovation of a certain design stage.

Tacit Knowledge

The tacit dimension is an intrinsic realm of prior knowledge which resides in the background of experience through activities by the designer and comes to the fore when we need to recall a certain skill, tool or method. This is learned either consciously or subconsciously through first hand creating, or by watching someone such as a 'master' through an apprenticeship to learn their skills and techniques. The philosophy of tacit knowledge can be regarded as a knowledge bank built through participatory engagement in the world around us. These skills are in described in the form of problems, hunches, physiognomies, tools, probes and denotative language (Polanyi, 1983, p.29). Polanyi writes:

Our body is involved in the perception of objects, it participates thereby in our knowing of all other things outside....Thus we do form, intellectually and practically, an interpreted universe populated by entities, the particulars of which we have interiorised for the sake of comprehending their meaning in the shape of coherent entities (1993,p.29).

'Tacit knowing' as coined by Michael Polanyi (1983) is correlated to Gestalt psychology. According to Polanyi (1983) Gestalt psychology is: "A physiognomy taking place through the spontaneous equilibration of its particulars impressed on the retina or on the brain" (Polanyi, p.6). Polanyi is approaching the philosophy of tacit knowing from the opposing view that "the outcome of an active shaping of experience preformed in the pursuit of knowledge" (p.6). This statement is formed on an intellectual framework, as opposed to the physical workings of the body.

This view of Gestalt's psychology is the foundation on which Polanyi claims all knowledge is revealed. The art of 'knowing' is expressed through German philosopher Gilbert Ryle's definition of "wissen" (knowing what) and "können" (knowing how), covering both practical and theoretical knowledge (p.7). Through Polanyi's exploration of 'tacit knowledge' he aims to combine "The higher creative powers of man and the bodily processes which are prominent in the operations of perception" (1983, p.7). By employing this form of 'knowing' as described by Polanyi I can exercise practical skills as well as intellectual knowledge that I have gained in my past years of experience as a designer. I have employed these conventions such as 'hunches' and 'denotative language', which are often used intuitively by designers, as tools to sift through and discover ideas and developments throughout the design process. By naming this form of inherent knowledge used by designers it enables me to confidently articulate my process in the form of academic writing.

Half scale experiments

The use of half scale garments have been used as test outcomes for the experiments and presentation of research in an exhibition setting. of the quasi experiments in an exhibition setting has been a useful way to test and demonstrate design parameters. This has a practical purpose as it takes less knitting time on the machine, and also limits yarn consumption. It also has an inherent experimental dimension, the half scale garments themselves take on 'specimen like' proportions: the garment is able to be viewed as a knitted product, where the craftsmanship is heightened, rather than a traditional 'fashion piece' in full scale. I produced the final garments for the November exhibition to the same half scale, which will be displayed on half scale mannequins in a gallery setting.

Half scale proportions are commonly used in fashion exhibition settings, as shown in the two recent examples listed below.

Dutch fashion personalities Victor and Rolf showcased a 2010 retrospective exhibition at the Studio Jobs Gallery in Antwerp. One doll representing each of their collections from the past 17 years was made to half scale, and displayed on half scale mannequins (see Fig 2:7). Senior lecturer Dr. Annie Shaw from the Manchester Metropolitan University in the UK recently completed her PhD in WholeGarment® knitwear in 2009, and also chose to display her garments as half scale. They were hung on a beam like structure, placed in the middle of the room for a final exhibition (see Fig 2:8).



Fig 2:7 Victor & Rolf retrospective show, Antwerp 2010. This image shows a model wearing the garments in a catwalk in the left image, and a half scale replica for the exhibition in the right image.



Fig 2:8 Dr. Annie Shaw's exhibition, 2009.

Concept Development:

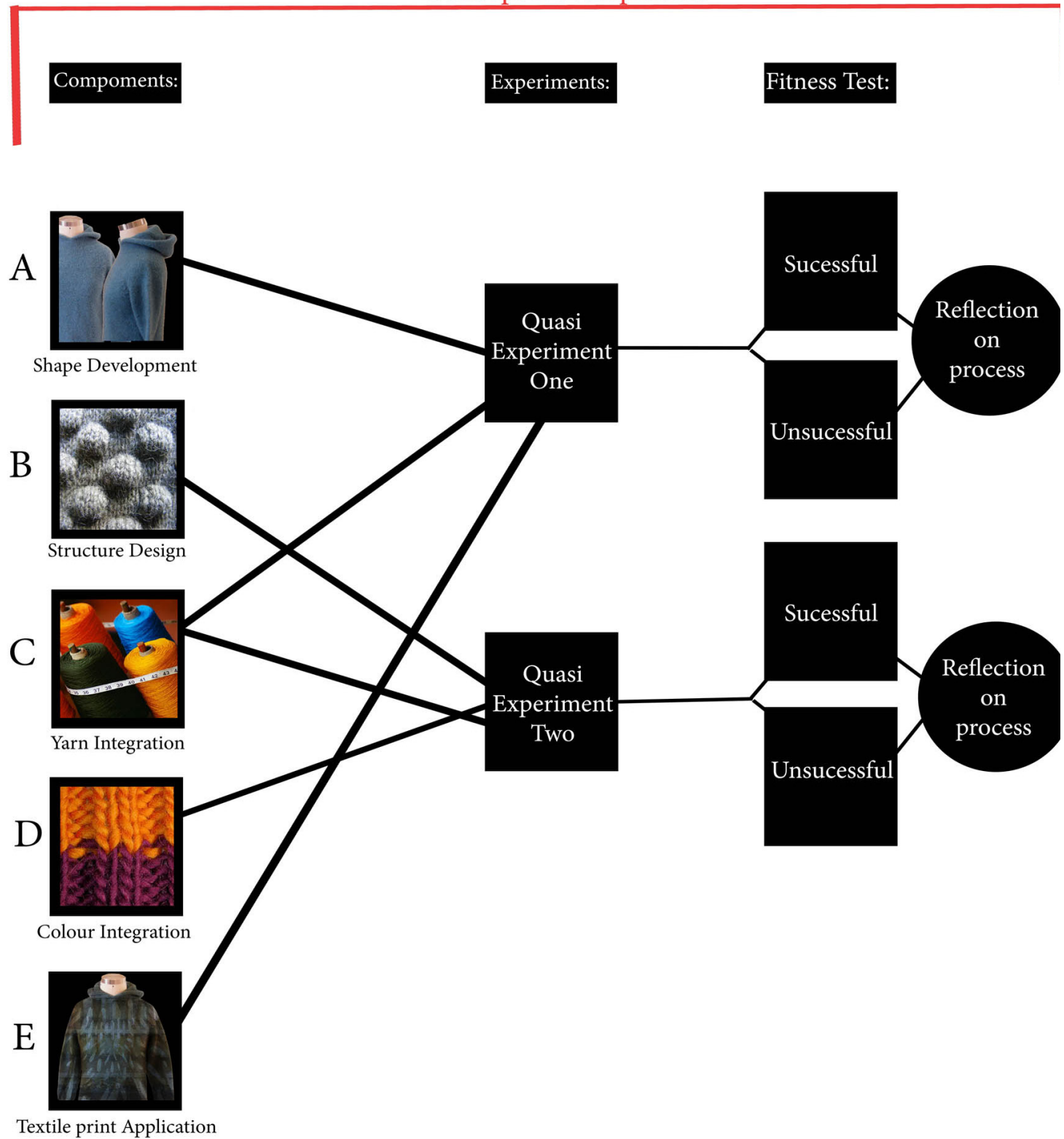


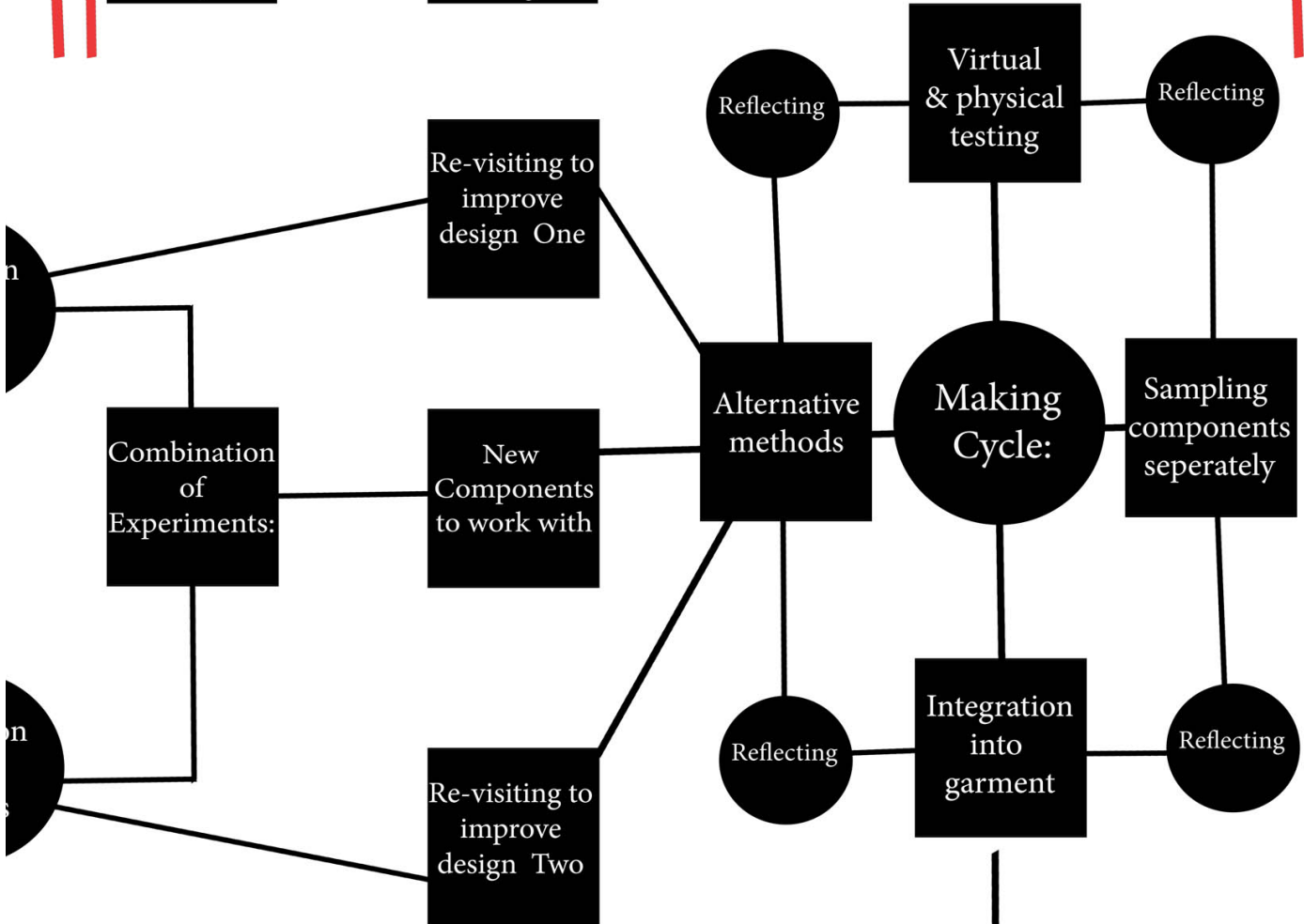
Fig 2:9 Practical designing process diagram

Making Processes:

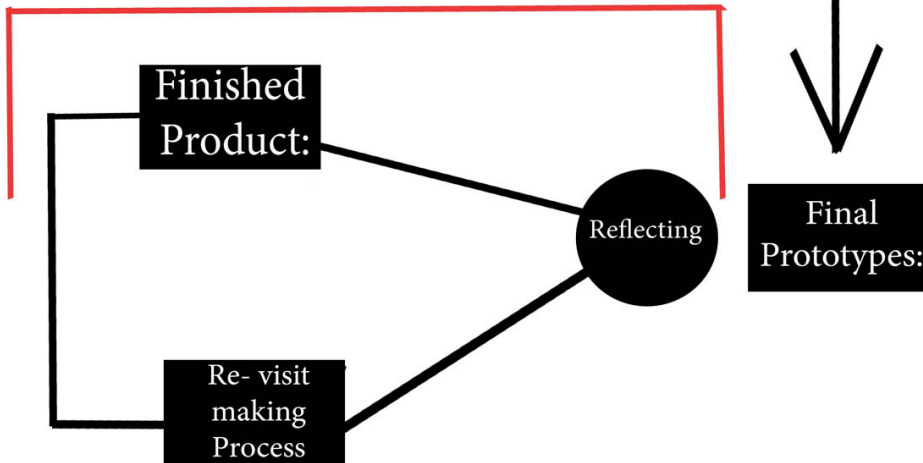
Hybrid Designs:

OR

Re-working Original Design:



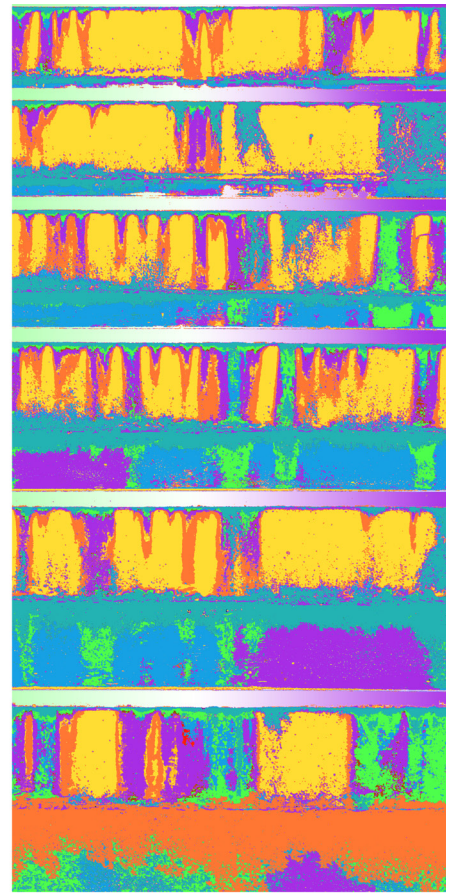
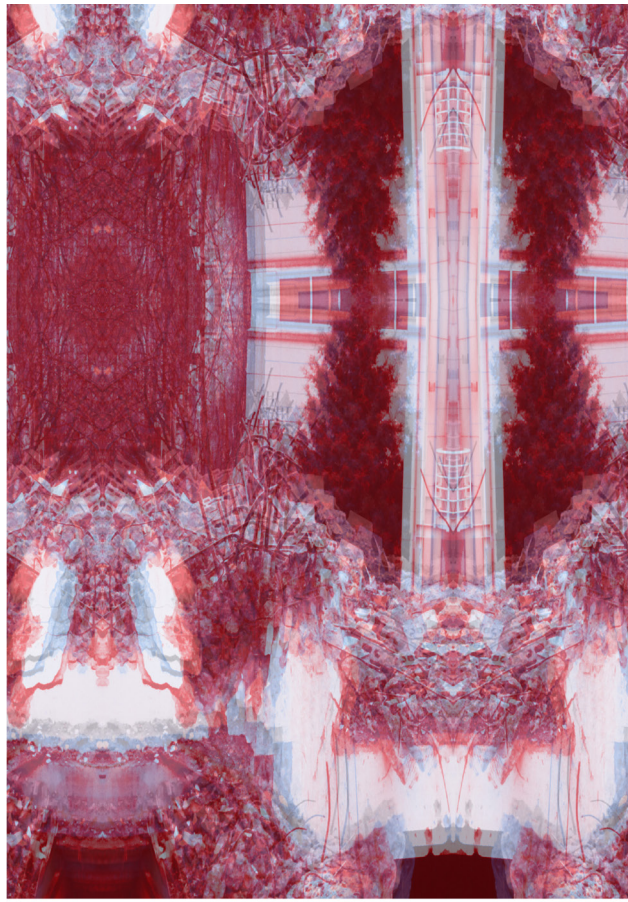
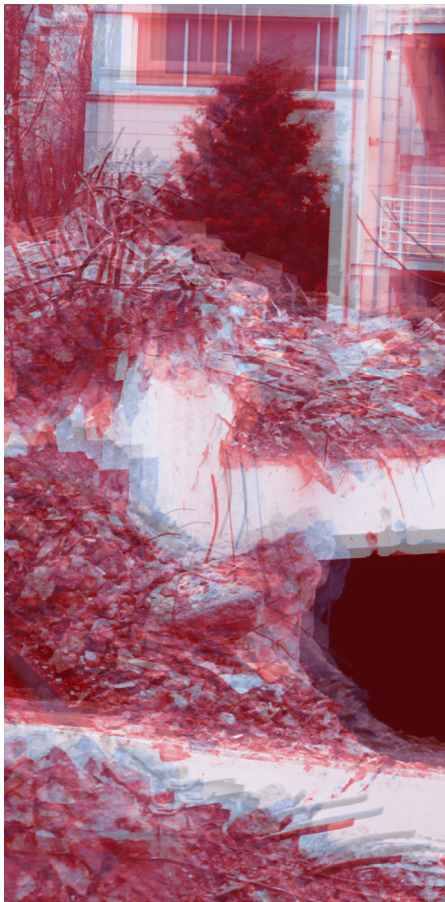
Analysis:



Methodology Conclusion

The methodology employed for this project fits under an overarching framework of hermeneutical research. This position relates to the design process in response to technology. As the two main areas of technical development and design development have to occur simultaneously, involving practice-led research a hermeneutical approach will successfully integrate both these approaches. The development of my project will be supported by action research, drawing on reflexive practice and tacit knowledge. The quasi-experiment process which involves genetic-like processes of parameterisation and combinatronics (seen in Fig 2:9) will utilise these methodologies throughout different stages of my work. Through an overview of a hermeneutical approach, the 'concept development' phase will be aided by action research, and tacit knowledge. The final phase, 'Analysis' will employ all of the fore-mentioned methods to wholly grasp the extent of my research, and further outcomes of my work.

Chapter Three: Quasi Experiments



Introduction

This chapter outlines the set of design parameters that formed the basis of the informal or quasi experiments conducted in this research project. These experiments were conducted to gain deeper understanding and to support the development of approaches that could lead to greater innovation in the field of WholeGarment® knit design. These experiments show the capabilities of the WholeGarment® machine through a creative lense. These experiments show the potential of what can be achieved by inventive design-based on algorithmic like processes via a knitwear technologist.

The practical research undertaken in these experiments discloses some of the limitations and possibilities of designing through new technology. These experiments are called prototypes¹⁰ and swatches¹¹, either fabric samples, or initial garments themselves, which could be developed into the form of a capsule collection, if taken further along the design and production process.

If some of the experiments undertaken were not successful in no means a 'failure' but rather they are important in terms of discovering additional knowledge about the design process and technological limitations by a designer who is using technology to inform the design process. Some of the experiments were further developed down alternate paths due to 'failures' in knitting execution. This has bought about an additional trialling of ideas to re-evaluate the problem at hand, or take a different approach. A diagrammatic approach to these quasi experiments can be seen in Fig 3:2.

Below are the terms which describe the factors that have been used as parameters in each experiment:

Shape Development:

This process defines the initial shape of the garment created. The designer needs to take into consideration whether the

shape will be that of a traditional knitted garment and therefore available or adaptable from the CAD pattern library or a unique shape. This shape will also need to work as a WholeGarment®, which will mean garment width consideration, sleeve width length, and so on need to be taken into account. If it is to be a draped garment, the overall shape cannot exceed the machine bed width. From past experience, if the shape of the garment is large and drapery, the sleeves, neck line and hem need to be designed with minimal detail to assist in quicker knitting time.

Structure Design:

This process defines the tactility of the knitted surface or any knitted structure applied to either the front or technical back of the fabric. This could include lace structures, cable structures, tuck stitches etc. Any stitch other than front and back knit (purl and plain) will add knitting time to the garment. Structures may also be used in certain parts of the garment, i.e. sleeves, front centre, neck lines etc, or they can be used all over the garment to create a whole textile. This can be problematic where the under arm seam intersection takes place due to the complex operations the machine has to undertake¹².

Yarn Integration:

This defines the various choices of yarn used in a swatch or garment. This initial selection of yarn is an important factor for knitting a successful product as all yarn reacts differently, depending on stitch length, gauge, fluffiness, weight and yarn composition. The appearance and shape of a garment can be altered by a simple yarn change.

Colour Integration:

This process defines whether the knitted product will be formed using two or more yarn colours. In the form of jacquard¹³ or intarsia¹⁴ this will create an interesting aesthetic in the garment, though can be a disturbance in WholeGarment® knitting. If I intend on using this parameter it needs to be intentionally thought through, so as to not interfere with other factors such as garment shape or structure design. The choice of either intarsia or jacquard adds labour time onto the knitting process, which can be reduced by considering specific placements of yarn colour or areas of the garment where the knitting is at a simple stage of the garment development i.e.: sleeve or cuff hem, or central placement below the armhole.

Textile Print Application:

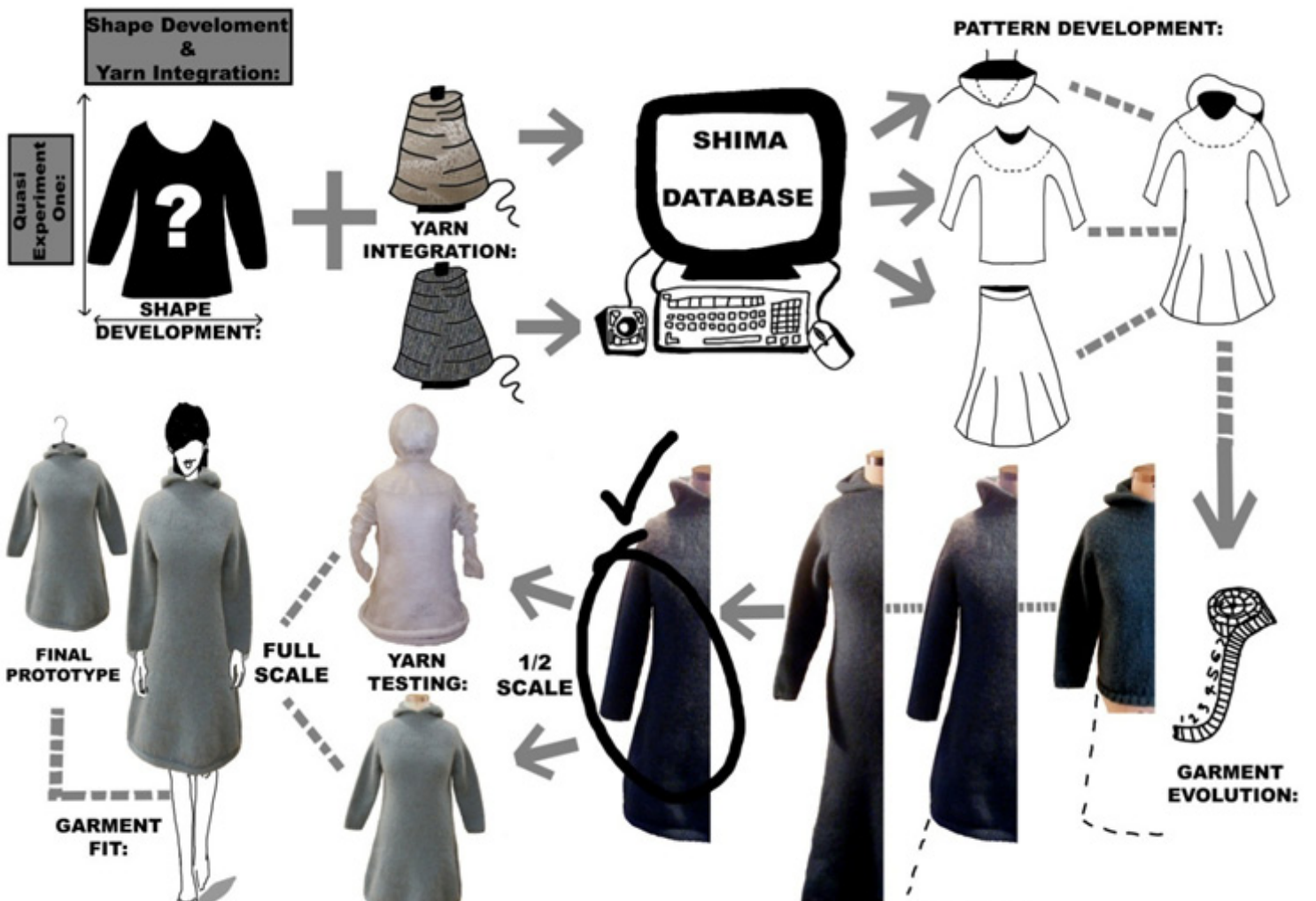
This parameter defines the use of digital textile printing post knitting process. It can be a clever way to integrate colour or pattern on a technically complex garment. This can be used as an aesthetic measure to give more 'life' and creativity to a product. It can be used as an engineered print, or a placement print, which is just positioned on a portion of the garment. If the garment or swatch consists of two or more yarns with different fibre properties, inks will need to be reviewed as to what type of dye is used, either pigment or reactive. Also some fibres don't bond well with dyes, so this will also affect the end result of the product. Although this parameter is applied post knitting, it is important to consider this process during the design stage.

Parameter's Table of evaluations and hypothesis' pre-and-post experimentation

Fig 3:1 Table of parametric features based on different knit design techniques.

Parameters:	Possibilities:	Limitations:	Hypothesis:	Reflection:
<u>Shape Development:</u>	<ul style="list-style-type: none"> -Innovative shapes -large areas of drape -Re-inventing traditional shapes -Possible accessories market -New knitting techniques 	<ul style="list-style-type: none"> -Shapes too complex for WG -Unable to change armhole/neckline areas -Bigger shapes can't be programmed into the pattern database 	<ul style="list-style-type: none"> - New shapes possible, but may be limited by machine width. Will need to consider compromising ideas to achieve knittable garment 	<ul style="list-style-type: none"> - Good in depth understanding about WG pattern database. - Gained skills about PACK-data for garments - Would continue further shapes next trial
<u>Structure Design:</u>	<ul style="list-style-type: none"> -Ability to create really textural surface -Transform knitting into sculptural art -Create stunning surface effects on garments 	<ul style="list-style-type: none"> -3D structures too complex for machine to handle -Only viable in certain areas of garments -May need to stick to lace and mesh structures. 	<ul style="list-style-type: none"> -This would be a great technique to make knitwear quite a conceptual product, though it could have various limitations depending on the structure I choose. 	<ul style="list-style-type: none"> - Trialled 3D structure, too complex for WG knitting. -Lace worked successfully, happy with outcome. -Will develop further
<u>Yarn Integration:</u>	<ul style="list-style-type: none"> -This use of yarns could create really interesting shapes and compositions if innovative yarns are chosen. -The use of non-traditional yarn could also be useful 	<ul style="list-style-type: none"> -The machine being able to knit with interesting yarns. -Gauge could also be an issue, as WG knits only 7gg. -Cost of the yarn vs. Commercial retail value 	<ul style="list-style-type: none"> -This could create a real note of difference in the garments I create. -It could also enhance the different parameters I choose to combine it with. 	<ul style="list-style-type: none"> - Great experimental parameter. Gave good indications of how yarn handles structures/shapes differently - Gained creatively interesting results
<u>Colour Integration:</u>	<ul style="list-style-type: none"> -The use of intarsia or jacquard in garments could work well in integrating colour. -Could become a renaissance of modern-style intarsia or jacquard. 	<ul style="list-style-type: none"> -As WG is already a complex operation this may be limited to only a portion of the garment -The use of 2 or more colours may distract from the other parameters. 	<ul style="list-style-type: none"> -This technique would create a great textural element to the garment, and could break away from the traditional intarsia/jacquard patterns, or sequences. 	<ul style="list-style-type: none"> - Great using contrasting yarns - Found exciting ways to incorporate this parameter into knitwear design -Enjoyed the possibilities it posed for further application
<u>Textile print application:</u>	<ul style="list-style-type: none"> -Effective way to achieve colour in highly technical garments -Ability to create a strong design aesthetic in a collection 	<ul style="list-style-type: none"> -Print placement will be a major consideration, as some placements may not be possible with difficult shapes -Seam matching and print engineering also has limitations 	<ul style="list-style-type: none"> -This could become a really useful way to save knitting time, but also can add substantial cost to a garment. It is important to use this feature to compliment the designs. 	<ul style="list-style-type: none"> - Created interesting 3D prints onto garments - Achieved vibrant colour results -Sophisticated, fresh designs achieved.

Fig 3:2 Diagram showing the physical doing and making process of a typical quasi-experiment in this project.



Quasi Experiment One: Shape Development and Yarn Integration

Experiment Introduction:

This experimental process enabled me to focus on the development of shape using the WholeGarment® knitting machine. As a designer it is difficult to know the full capacity of the shapes the machine is able to create. This is due in part to limited experience and specialised knowledge in this area. The trialling and incorporation of different yarns is also an important element in deciding on the shape and silhouette of the garment. Through this intersection of these two parameters (shape and yarn type) I aim to discover new possibilities using the Shima pattern library as a basis for creating innovative WholeGarment® designs.

Experiment Inspiration:

The way I approached this experiment was working with the idea to create a garment with traditional features but with more of a contemporary edge to it. This developed into the form of an A-line jumper dress with a parachute neckline and a two panelled hood. The Shima WholeGarment® pattern library already has an exhaustive source of patterns in the database, so with this in mind, the knitwear technologist selected aspects from three separate patterns (a hood pattern, jumper pattern, and skirt pattern) to create this one hybrid garment.

These patterns were all built together using PACK data¹³ to create the proposed dress, which was produced at half scale¹⁴. As I was using Perino¹⁵ wool (70% merino 20% possum 10% silk), which is fairly expensive I wanted to limit consumption and save on yarn. The knitting efficiency of producing a half scale toile as opposed to full scale is also faster in terms of knitting time on the machine, which also reduces cost.

The other yarn which I have used in this experiment as part of my shape development is a synthetic blend. It is made from 80% rayon 20% Viscose. This is used in the same garment shape, but

having changed knitting qualities due to the change of yarn fibre and thickness.

Experiment Aim:

The aim of this experiment was to produce a more successful result in terms of garment silhouette using different yarn types. It focussed on the intricacies of making the garment shape. It was also recognised that this approach would probably raise more issues about shape development to be addressed further in this research.

Experiment Testing:

In this stage of the experiment I focused on resolving the issue of the shoulder line in the WholeGarment® production, as problems often arise in the quality and finish of this region of the garment. As I learn more about the technicalities of the knitting process through the process of working with the knit technologist during these experiments, I began to understand the reasoning for this. This insight suggested ways that as a designer I could better resolve the issue.

Fig 3:3



Fig 3:4



Fig 3:5



Fig 3:6

Fig 3:3 (opposite page) Image of a WholeGarment® seam ‘peaking’ when joined in the machine. This is due to the heavy joining line and the number of stitches used. When sitting on the shoulder it draws attention to the eye due to the ‘bumpiness’ of fabric.

Fig 3:4 (opposite page) Detail of the implementation of the parachute neckline, which sits moulded onto the shoulder area. Through dart dispersion the seam line is eliminated creating a smooth finish. This is particularly useful for techniques such as digital print application, as there is no seam line to print across. This neckline also gives a cleaner silhouette around the shoulders, which looks more sophisticated than a traditional neckline.

Fig 3:7 B



Fig 3:7 A



Fig 3:7 c

Figures 3:5 & 3:6 showing the yarn integration portion of this experiment. During the shape development process the garment needs to be tested in different yarns. The clear Lurex yarn gives the shape 'armour' like structure. Double layered in both pictures, the garment shows considerable design development potential, being such a unique shape and structure. Due to the lightness of the yarn the hem of the garment rolls back on itself. This could be used as a design feature, as it is not completely un-desirable, or it could be further evaluated and looked into at the conclusion of this experiment, offering a different, or thick hem finish.

Throughout this experiential process it was important to assess the designs at each step. Even at the full scale toile phase (see Fig 3:7 A) the proportionate measures of the hood design were reconsidered (see Fig 3:7 C). This was too tight at full scale size. The knitting also burst around the neck line where the hood was being constructed as the components had different takedown qualities (see Fig 3:7 B). Due to the shift from half scale to full scale I needed to re-asses fit measurements and produce another prototype.

Conclusion on Quasi Experiment One:

This experiment was a useful way for me to evaluate and learn more about WholeGarment® knitting in relation to shape designing. The combination of trialling different types of yarn was an effective way to evaluate fit and shape using different yarn qualities. The use of the parachute neckline resolved many of the issues I have faced previously when using WholeGarment® integral knitting. This particular issue was related to the shoulder line of garments. The parachute shaping used on the upper body, or round yoke design is where the knitting is shaped to curve around the neck and shoulders, eliminating the traditional upper body seams. Using a traditional shoulder line (as opposed to a raglan or parachute design) the knitting would often cause uneven yarn tension or form a heavy row a stitching where the front and back shoulder seam joined. If the garment was going to be sleeveless, this issue would cause further problems as it 'peaked' on the outer shoulder point when it sat on the shoulder line. This was disconcerting as it happened in a number of styles I had previously tried to create. In making a closer inspection into how shape was created on the WholeGarment® machine, I addressed this problem by using the parachute neckline. This is created by shaping the shoulder line using eight small dart-like fashioning marks to create the rounding of the neck and shoulder line. This technique creates no shoulder seam,

which means the shoulders of the garment have a flat surface, 'moulded' to the shape of the body, relieving any shoulder seam intersection problems. The parachute neckline also creates a pleasant knitting line which could be used as a feature as part of a garment design.

Fitness Test Results:

Knitting efficiency: good

-This garment was time effective on the machine as it was just a plain knit. In a mass production environment this garment could work well.

Aesthetic qualities: good

-The aesthetic nature of this garment is pleasing to me as a designer. It is well designed, yet simplistic, and due to its simplicity it is able to transcend seasons, which adds value to the product as a long term fashion item.

Combination of design components: good

-These design parameters worked well together. By testing out each yarn type I was able to assess the shape of the dress, and the different look and feel of the end garment by using opposing materials.

Further possible testing:

This experiment would gain more insight through testing out different types of hood designs. There are three different patterns in the Shima data base which could be used in this design. The difference is that they are knitted using alternative knitting methods. Another possible object for further testing would be to trial a more diverse length of sleeves. The hem was trialled at different lengths, though the arms were left at one standard length. For styling purposes the longer sleeve length would add more character to the garment.

Experiment Two: Structure and Yarn Integration

Experiment Introduction:

This experiment enabled the exploration of technical and aesthetic qualities in yarn integration combined with knitted structures. These experiments can be regarded as being akin to architectural practices which create texture through materiality and technological production. By using the technology of stitch construction the physical surface of the fabric can be manipulated in knitted garments.

This experiment will investigate the success of various stitch structures to create texture in a Wholegarment® design.

Experiment Inspiration:

As a premise of an approach where knitwear might emulate architectural forms, I wanted to create a knitted structure which could be seen through both fashion and architectural lenses, and be appreciated from both design disciplines. The initial inspiration for this approach was taken from the subject of the natural degradation of buildings, in particular, the effect of rust. The small circular rust marks seen in Fig 3:8 create an intriguing pattern, which I saw as corresponding to the three dimensional form of garment engineering. Dutch designers Verharen and Ferdinand Sebastiaan Hartgers fashion brand 'Malousebastian' A/W 2010 collection has a similar textural aesthetic to that which I was looking to create through this experiment (seen in Fig 3:9).



Fig 3:8 (top right) Photograph of rust on an architectural structure (Gover, 2010).

Fig 3:9 (below right) The image shows Dutch designer's Malou Verharen and Ferdinand Sebastiaan Hartgers label 'Malousebastian' A/W 2010 collection, which uses leather and geometric hand pattern cutting to achieve a similar raised textural surface effect.

Experiment Aim:

This experiment aimed to explore processes of developing structures which work well with the garment aesthetic and WholeGarment® production process. I had several structures in mind, which were trialled through test swatches and prototypes. The results would be evaluated using the fitness test parameters.

Experiment Testing:

Different sizes of 'bobble' shapes were tested out to see which were the most successful, and also how bobble size changed the dramatic impact of surface structure. The use of different yarns was also taken into account with Perino working well in giving the bobbles a matted texture. This structure would have not had the same sculptural properties if it was made in the clear Lurex yarn due to the fibre weight and quality of the yarn texture.

Due to this bobble trial not being able to translate into WholeGarment® production effectively because of the complications in stitches being held, I decided instead to try another approach which was subtractive rather than additive – looking into the use of lace structures in WholeGarment® to incorporate further surface alterations in the fabric. Using Perino in this structure can give beautiful defined lines in terms of lace structures due to the fibre matting to create a defined edge.

3:10 Image showing the initial bobble trial, with the image on the left being the smaller bobbles, with fewer stitches held, and the right hand image showing a more pronounced bobble due to the maximum number of stitches being held before they were broken. As the bobbles increased in height they were prone to stitch bursting, which did happen on a number of occasions.



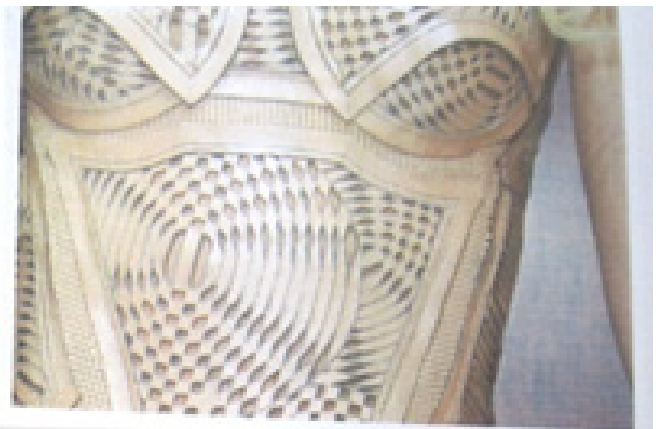


3:11 depicts the various half scale toile's (sleeveless round neck vests) to test out the bobble structure. The more needles that were held gave the most pronounced surface structure.

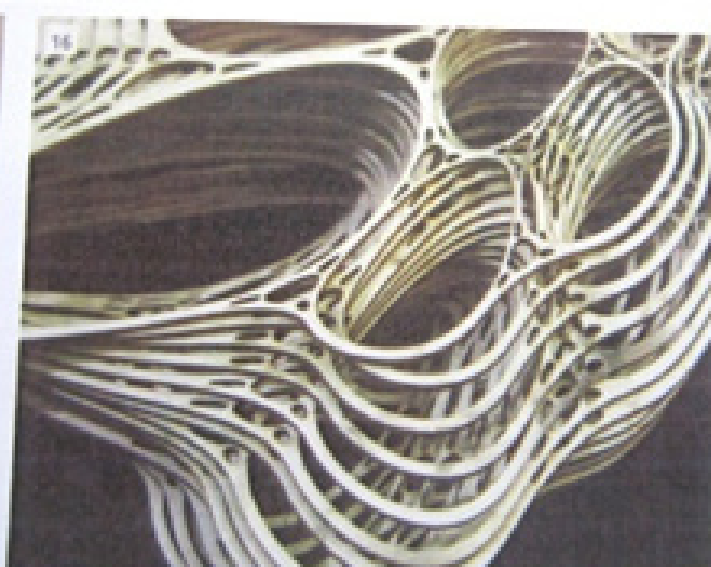
Fig 3:12 A (below) & 3:12 B (opposite page) Shows images that provided further inspiration in developing lace structures. The bobble structure did not work well for Wholegarment® production. The lace idea has been inspired by laser cutting patterns on wood and leather, seen in the latest trend magazines.



parametric lace



versace



Textile View #89
CUT OUT
INNERWEAR/
OUTERWEAR.

I started to virtually develop these designs by using the Shima SDS-ONE® stitch library database. By designing structures ‘virtually’ on screen I was able to rapidly generate and represent design ideas producing virtual samples of lace structures I wanted to work with. By working this way the design process is quickly visualised on screen, as you have the capability of seeing your ideas develop ‘clearly’ by using the computer as a design tool.

The type of lace used in this experiment is referring to is a pattern of small, random holes used to alter the appearance of the fabric. These could then be further manipulated on screen, or discussed with the knitwear technologist in terms of the potential for inclusion into WholeGarment® design.



Fig 3:13 A (below top) & 3:13 B (below bottom) Images of the design and technical on-screen views of the intended knitted structure. These are the two common views I work with whilst discussing the structure with the knitwear technologist.

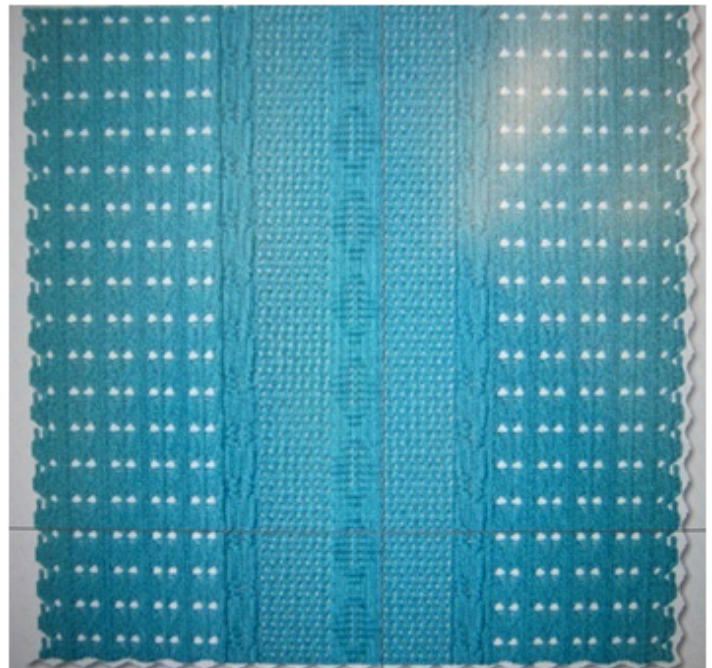
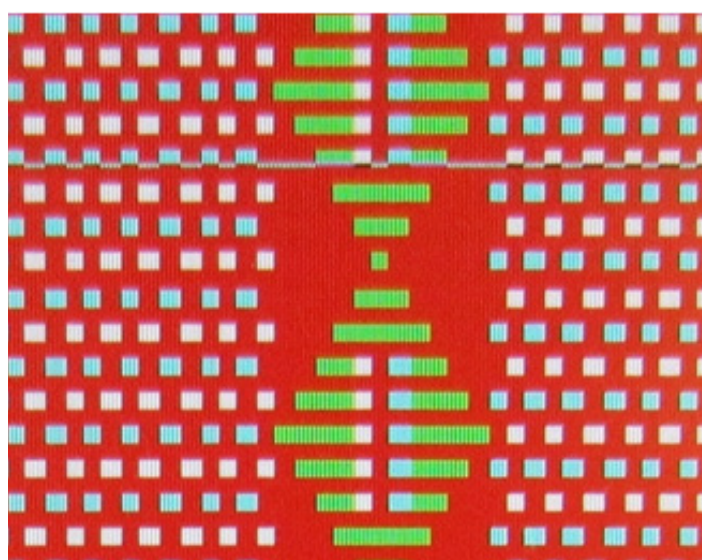
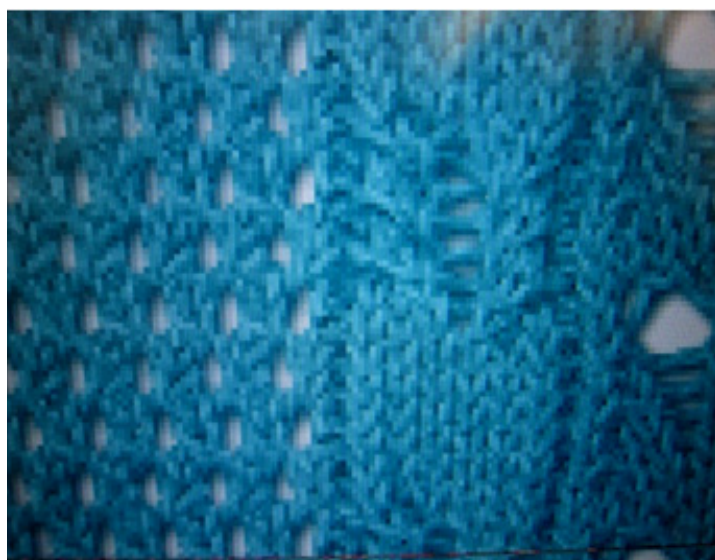






Fig 3:14 A (below left) & 3:14 B (below right) Shows images of the design and technical on-screen views of the intended knitted structure. These are the two common views I work with whilst discussing the structure with the knitwear technologist.



-  Colour #6: Lace stitch move one pitch left
-  Colour #7: lace stitch move one pitch right
-  Colour #2: Back bed knitting
-  Colour #1: Front bed knitting

This method of translating information through 'screens' helps the knitwear designer to technically understand the textile they're creating. Knowing the codes for the knitting colours improves communication with the knitwear technologist about the design you want to achieve.

Conclusion on Quasi Experiment Two:

This process of using stitch structures in WholeGarment® design was different from designing stitch structures for fully fashioned knitwear. The bobble structure could be achieved easily in fully fashioned knitwear as the front and back of the garments could be knitted out separately, which would not have caused many problems. Due to the complexities of knitting an integral garment, the needle bed could not cope with holding so many stitches to form the bobble. As this size structure would need to be doubled to take it to full scale garments, it was recognised that the machine would be unable to cope with this scale and form of texture.

Changing to the lace structure allowed many design possibilities, which meant I was able to be more creative with this outcome. I have trialled the lace structure in 'portions' of the garment, which have lead to some good design visualisations.

My aim was to create the lace structure in an 'organic' pattern to flow across the garment. This is always a challenge as knitted patterns are always formed in a grid pattern, so making them into a 'random' structure is always a difficult task.

By changing to the lace structure I was able to gain positive results in my fitness test, as these are the main rules used to determine a successful design. The lace structure did have intended cable structures throughout it, which worked well to a degree.

I worked on a variety of different cable designs, and picked one which looked more fluid rather than linear, due to the curving structure of the cables. There are a few lace details throughout the cable, though it was more of a minor detail, this added to the stylistic qualities of the garment. The downfall of the cables is that there is a clear 'start and finish' point, which is difficult work in well with the design aesthetic. The final design ended up having portions of cable design forming columns up the garment to the neckline. Though there were many cables which fitted with the architectural aesthetic of the garment (which were visually simulated) I decided on this style because of the curves the cable have.

The complications of this structure used in a WholeGarment® design was due to the garment shape. As the design is an 'A' line shape dress, the knitting needed to be narrowed in on the needles to create the 'A' shape. This was a difficult design for the knitwear technologist to programme as it took a long time to work this structure into the garment.

There were 2 different trials, and both had errors, though by

the final design the issues had worked out. This experiment was either going to work, or be unsuccessful, due to too many various knitting and programming factors interfering with each other.

Fitness Test Results:

Knitting efficiency: reasonable

-Due to the combination of a structure being incorporated into a garment it did extend the knitting time a short while. Though constructing lace on the machine, as opposed to cables is a far less time consuming job, which de-creases the knitting time.

Aesthetic qualities: good

-The inclusion of cables in this garment worked effectively, as it was used successfully in small portions of the garment.

Combination of design components: effective

-Though there were a few different trials in terms of structures, the cable style has proved to be the most successful, and meets the fitness test parameters well. It was beneficial to trial the bobble structure and cables as this gave good indications as to what was possible in integral knitting.

Further possible testing:

This experiment allowed many different ideas and possibilities to be trialled, which resulted in a good final outcome of the experiment. Though the first structure didn't work, it was not seen as a 'failure' as such, but rather the opportunity to try further ideas. This was a positive experience as I learnt a lot in terms of structure design for WholeGarment® knitting. For this experiment I would have liked to continue further with the integration of different structures in one piece, for example, lace and cable working together cohesively. Though this would put more time into knitting efficiency, it could achieve a much higher result in the aesthetic qualities portion of the fitness test. These tests could become endless, although experimentation is an important part of designing when exploring new design opportunities in knitwear.

The experimentation of cable structures gave a good depth in texture to the knitwear, and if further experimentation presented itself this would be a great avenue to explore for creating a successful depth in the fabric.

Experiment Three: Digital Textile Printing and Shape Development

Experiment introduction

This experiment focused on the use of digital textile printing to enhance colour and aesthetic appearance in knitwear. Digital printing can be used in collection development as a valuable aesthetic link between garments to show a continuation on theme or to develop a 'story'.

This process can be used to compliment yarn choices for bringing out 'accents' of colour in a collection, or to diversify the colour range. Often only pre-dyed yarns are available to the manufacturer and these must usually be purchased in large quantities (20kg minimum). Digital printing is a valuable and cost effective way to incorporate colour into the fabric. This is particularly attractive for small boutique companies who produce small-run quantities. The shape development portion of this experiment was conducted to specifically develop a textile print with a garment in mind. Though this may initially seem more of an 'aesthetic' as opposed to a 'technical' application, it is a relevant process for the knit designer to think through, as digital printing onto WholeGarment® knit requires a unique designing process¹⁷. Designing in a way which focuses on only two aspects of design in a single garment (shape and print), enables the designer to develop a better understanding of how the print can be executed. This particular experiment looked at a form of three dimensional, layered printing. This is particularly relevant to this project in that the use of WholeGarment® knitwear also involves three dimensional knitted forms. The aim was to produce anaglyphic¹⁸ prints onto clothing in the form of layered clothing and singular garments.

Fig 3:15 A and Fig 3:15 B showing the recent use of digital print in high fashion garments¹⁹. The array of colour is clearly demonstrated in these prints by Australian designers Josh Goot and Britten House.

Experiment Inspiration:

Through creating an anaglyphic print the colour intensity can be achieved in the form of a bold graphic design. This creates a sharp contrast with the clear colour of the yarn. As experiment five also has a digital print element, I worked with a more diverse colour range, with abstract patterns being used in this fourth experiment.

Fig 3:15 A Josh Goot, & *Fig 3:15 B* Britten House (right).



Fig 3:16 , Detail. Digitally printed dress by Australian Designers, Britten House.



garment. The shape of the garment can have a significant influence on the type of print applied. There can be two options of print onto WholeGarment® knitwear. Placement prints or engineered prints²⁰.

Experiment Aim:

This experiment set out to explore creative forms of printing in terms of how successfully anaglyphic images can be produced. It was understood that many small test swatches would need to be produced in order to develop a successful textile print on a garment

Experiment Testing:

After developing the shape of the garment from the previous experiments, I explored the use of digital printing onto the clear Lurex yarn. I firstly tested the intensity of the colours by printing a test swatch of all the colours onto the yarn using a pigment dye²¹ (See Fig 3:18, Fig 3:17, and Fig 3:19, opposite page).

The yarn which I chose to use for this experiment was clear Lurex. This yarn added an interesting dimension to the prints, as it absorbs the dye which penetrates both sides of the knitted structure, creating a unique effect. Being a transparent yarn, it also allows creative possibilities to be explored by focusing on both the technical front and technical back of the knitted fabric (See Fig 3:17).

Focusing on two areas of knitwear design development allowed me to concentrate on how digital printing can enhance the

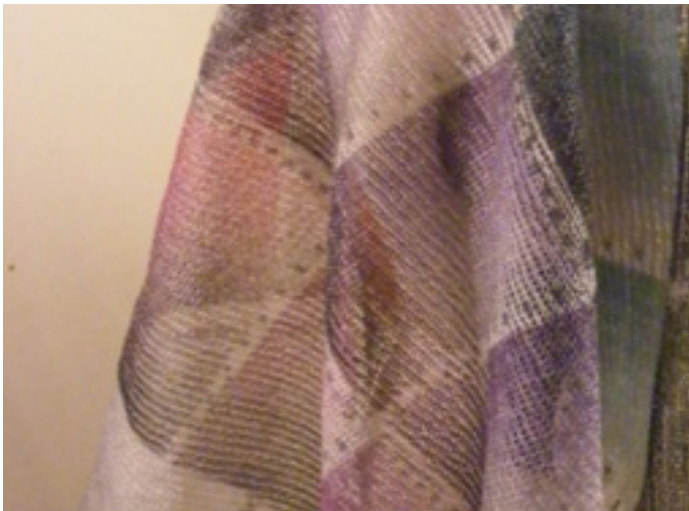


Fig 3:17 (above left) The pigment dyes have a unique transparent quality, being visible both sides of the fabric. The light is further dispersed to show the translucent nature of the knit.



Fig 3:18 (above right) show the digitally printed colour swatch onto clear Lurex. This colour chart shows the concentration of darker colours working successfully in the concentration of colour in the yarn fibres.



Fig 3:19 (below right) show the digitally printed colour swatch onto clear Lurex. This colour chart shows the concentration of darker colours working successfully in the concentration of colour in the yarn fibres.

Anaglyphic Images:

This process required the designing of a layered print by using a single image, and changing the tonal palette from magenta to cyan hues. This process was inspired by the visual language of anaglyphic perception. Commonly used in 3D cinematography, the anaglyphic image is seen through the lenses of tinted glasses. Each lens is filtered using a magenta and cyan tint, so the eye sees each coloured layer separately, then joins them together to create a three dimensional image (see Fig 3:20).

By employing the stylistic aesthetic of layering, there would be three layers of garments to express the layers of the print. This would be applied through each layer having the same image in the colour tones to make an anaglyphic print. This would consist of a black and white layer, magenta layer and a cyan layer. I was interested to see if these layers would move together as the wearer walked and create an interesting, three dimensional looking textile, with or without the tinted glasses. As the yarn is transparent, the three layers of fabric might create greater opacity making the garment more wearable.

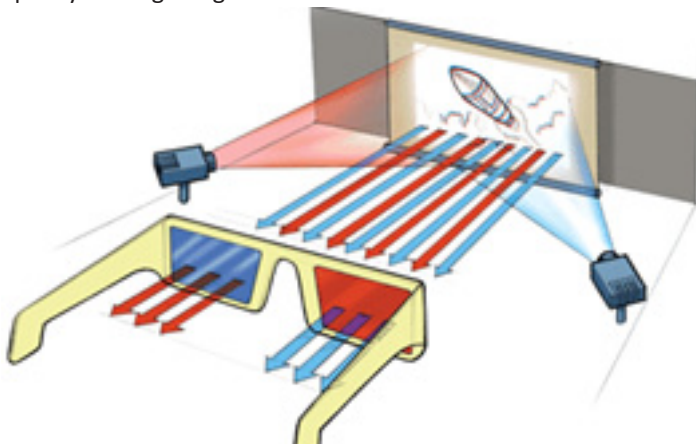


Fig 3:20 The red and blue lenses filter the two projected images allowing only one image to enter each eye.



Fig 3:22 , An example of an anaglyphic image. The image is duplicated into layers of black and white, magenta and cyan to create a 3D effect.



Fig 3:21 B

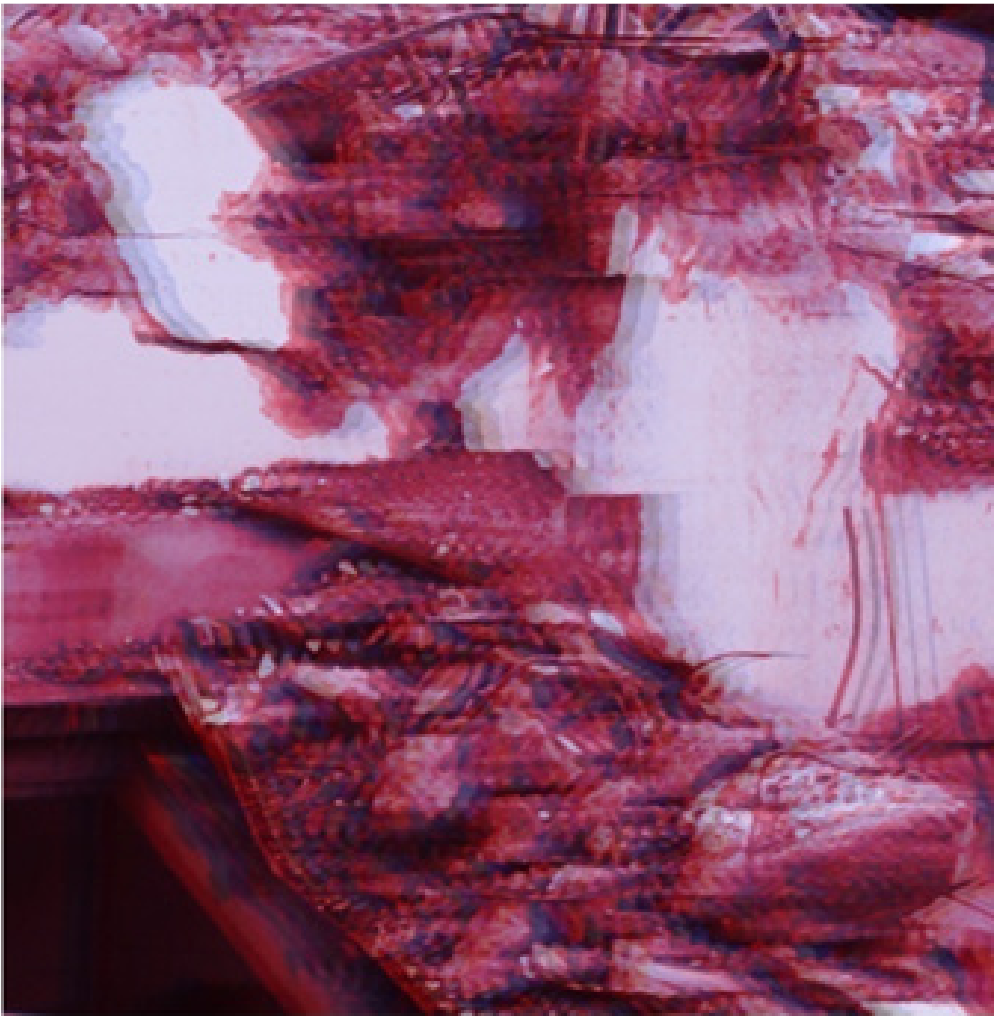


Fig 3:21 A & Fig 3:21 B Shows a small amount of anaglyphic printing being used in the 2010 Tokyo Fashion Week by Hidenori Kumakiri, designer of 'Beautiful People'.

After doing the initial colour testing using the digital printer, I developed a method for creating anaglyphic prints in Photoshop. The images I designed were both placement prints and engineered prints. The image photographed is of a dilapidated building site²², which has been the inspiration behind the textile prints.

Fig 3:23 shows the finished image, with the separate layers beneath.

From left to right: Full colour image (not used in the print), black and white image, cyan, magenta. The three layers will be used on each layer of a garment, or- used as a complete print on a garment instead. When viewed through correct filtered lenses the white of the image comes to the forefront, while the darker colours create depth.



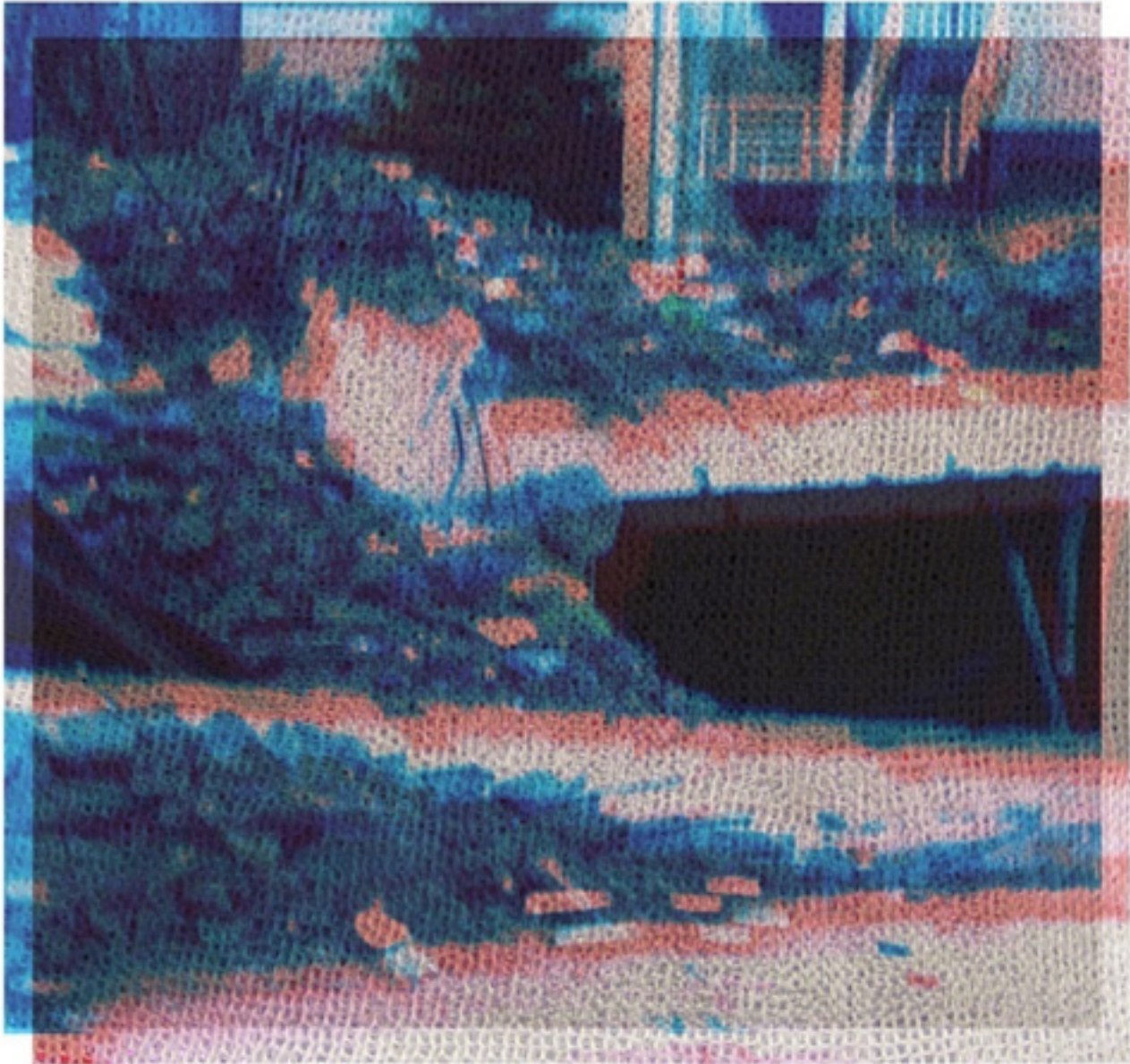


Fig 3:24 This visual simulation of an anaglyphic textile print shows the 'layering' effect of the cyan and magenta portions of the print. As the fabric moves it is envisioned that the layers will create a three dimensional effect.



Print and Shape Development

Fig 3:25 Shows the culmination of digital printing with shape development, the two outlined parameters of this experiment.



Fig 3:26 is a close up of the sleeve pattern created through virtual experimentation. The small image in the far left is the sleeve texture with no print; the larger image shows the print 'virtually' applied to the sleeve. Through this way of designing using virtual prototypes it gives a very clear indication of the look going to be achieved when physically produced.





Fig 3:27 Displays a placement print on the front of a Lurex garment. The anaglyphic print is slightly broken up which does not show the full visual effect and depth of the image. This effect is lost in this type of print.



Fig 3:28 This is a side view of the print dispersed over the garment. The dress on the left shows the print slightly off centre, and when viewed with the glasses is slightly 'off' as the image doesn't align and give the correct 3D perception. Whereas the print on the right is more aligned and gives a better anaglyphic effect.

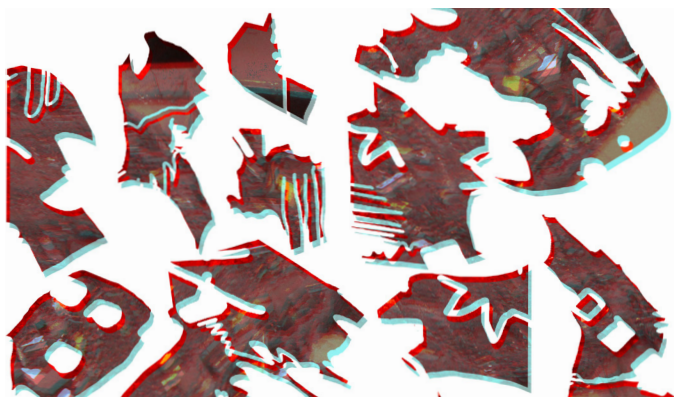
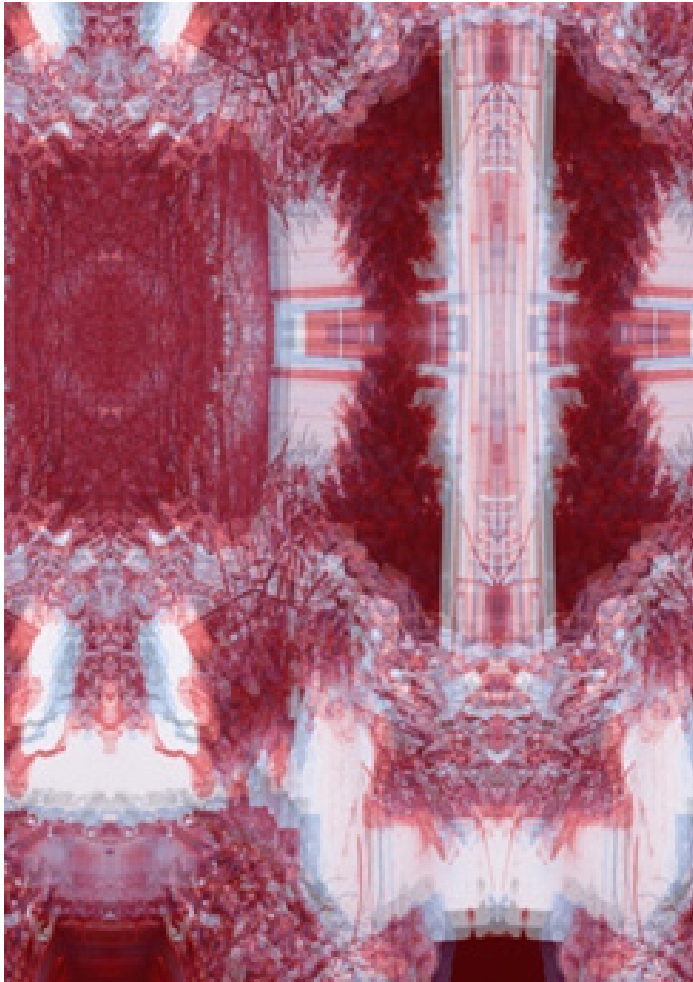


Fig 3:29 Another type of anaglyphic print I developed from the dilapidated building. This is a pattern repeat print, which can be engineered across the garment and seam lines. Seen as a continuous image it gives a good effect of the print.

Fig 3:30 Shows a trial placement print, based on an abstract anaglyphic print.

Conclusion on Quasi Experiment Three:

This experiment was successful in terms of exploring the process of digitally printing onto WholeGarment® designs. These design parameters investigated how print can be applied to an integral garment. The design process that followed produced different effects of print on knit. It was insightful to analyse how the specific use of anaglyphic print related to the garment in these different experiments. Although the anaglyphic print worked in the print visualisations, the image didn't take as well to the fabric, creating a blurred affect. This distorted the anaglyphic detail of the print which visually lost the effect I was trying to achieve. The colours also came out subdued, even though the colour test I had done previously worked well and vibrant colours were achieved.

Test one:

This test was created by printing three different colour ways onto three pieces of fabric. These are the three layers which form an anaglyphic print: Black and white base, followed by a red and a blue layer. The three fabrics printed were also subdued in colour. When all were placed together, to ideally form an anaglyphic print, the image was lost as the print was slightly too abstracted due to the nature of the knitted fabric. This test would have been successful if the fabric was of a flat, woven nature, though due to the knitted structure, the idea was lost.

Test Two:

This test was a single print of the three anaglyphic layers applied all together. This created a flatter, more visibly decipherable image, though the knitted fabric did create further distortion. This test could have been more successful than Test One if I had used a clearer more legible image.

Final print Decision:

For the final prototype of this experiment I had decided to resort back to a traditional image, rather than an anaglyphic image, as this did not really work in practice. I have used two different prints, each relating to architecture and rust, with more vibrant colours than the red and blue. These colours showed up well on the Lurex yarn, and were used in bold, repeating patterns to emphasise the colour.

Fitness Test Results:

Knitting efficiency: Very good

-Due to the garment being a plain knitted structure the knitting time was at its maximum efficiency.

Aesthetic qualities: interesting

-Though the anaglyphic prints experiment was unsuccessful, I think for the amount of colour achieved the alternate print was successful.

Combination of design components: Very effective

-Through the plain knitting and the use of digital print the garment was able to be transformed through the use of colour. This became the main feature, as the garment was a plain canvas to work with. In a commercial environment, this would be cost effective and could attract many buyers due to its striking unique qualities.

Further possible testing:

If I were to look further into the print application in combination with shape development I would focus on a feature area of the garment and build the print around that, rather than opt for an all over print. This could also be done using a draped, un-traditional shape of a knitted garment, and focus the print to feature the draped areas of the garment. The abstract placement print of the garment was not effective in terms of seeing an anaglyphic image. The clear Lurex yarn was very exciting to work with, and could lend itself well to other areas of knitted apparel. It is a very flexible, stretchy fibre when knitted, and though not too desirable to wear next to skin, it could be used in furnishing or interior designs. The use of anaglyphic prints was a good technique which could be successfully used in garment design, though on knitwear it was not successful due to the texture of the fabric.

Experiment Four: Colour Integration with Structure Design

Experiment Introduction:

This experiment focused on the use of intarsia/jacquard designs integrated with technical knitting structures. As these are both complex commands for the knitting machine to execute, this experiment explored the how the two processes can work together cohesively to be incorporated into a WholeGarment® product. This test involved working with both clear Lurex and Perino yarns to develop an intarsia/jacquard design which also allowed a technical stitch structure such as lace to be worked into the design. Different variations of this combination through virtual simulation²³ and physical test swatches were trialled. Good communication with the knit technologist was required in order to understand more of the technical issues related to realising this approach.

Experiment Inspiration:

These two approaches were used intentionally to show off the technical capabilities of the WholeGarment® knitting machine. It was intended that the product produced from this experiment would be an attention grabbing knitted textile and could add commercial appeal as clever structural engineering is a unique selling point for knitwear.

Knitwear seen in the trends forecast of 2010/2011 shows a lot of technical knit structures being used, but none using more than one yarn integrated in the garment. Through trialling this experiment I hoped to discover the possibilities and limitations of these two parameters working together. The success of this quasi experiment was evaluated through a formulated set of factors in a fitness test. The conclusion draws on future possibilities of applying these aspects to WholeGarment® products.



Fig 3:31 Directional trend Images showing different knitting structures to give textural elements to the work. These only have one yarn colour, and does not have any intarsia or jacquard design.

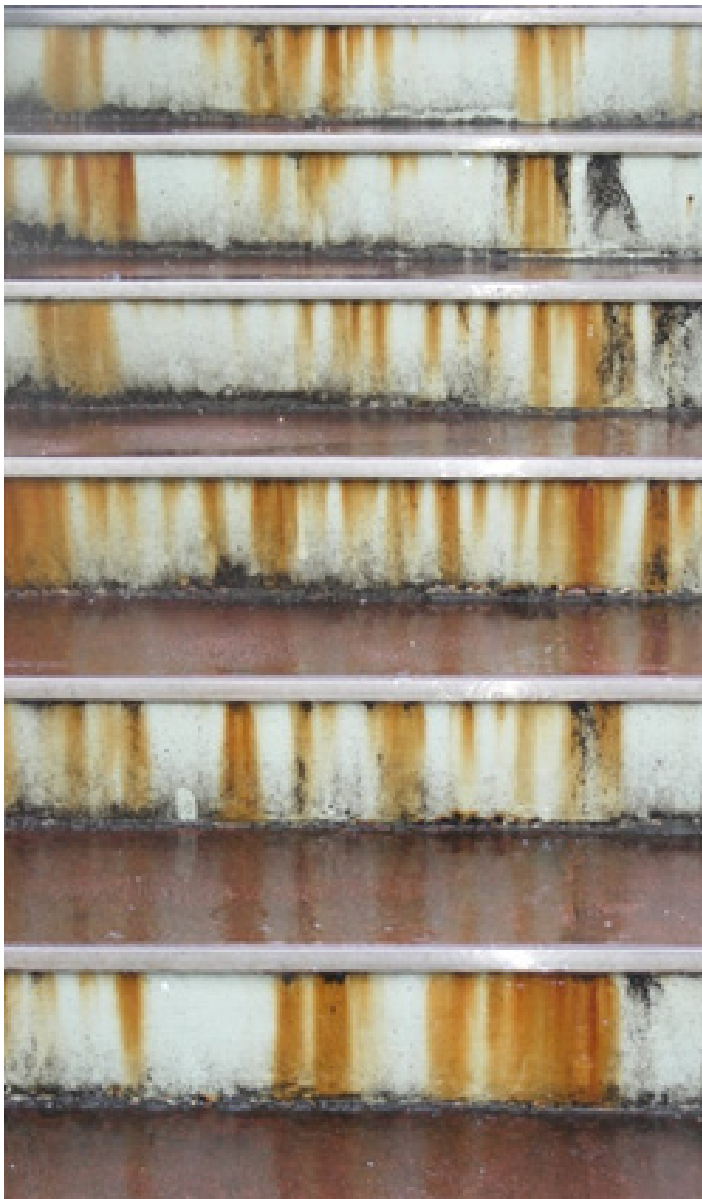


Fig 3:32 A & Fig 3:32 B This image is the inspiration for the colour integration and structure design. The rows of rust lend themselves well to stripes, and the small portions of other decay could become a beautiful lace structure, or cable (See close up, Fig 3:28 B). This design aesthetic will be explored throughout various trial swatches.

Experiment Aims:

The experiment involves two highly technical factors which can be difficult to simultaneously incorporate into one garment. This process worked through a number of preliminary tests to identify a workable outcome. The experiment aimed to include both these approaches in a WholeGarment® design.

Experiment Testing:

Firstly I started off virtually designing some test swatches using Perino and Lurex blends. I designed a jacquard test swatch, and quickly found out that due to the clear nature of the Lurex, the yarn could not be floated along the back side of the fabric as it would be visible. This was a profound discovery, which cancelled out the use of jacquard altogether. Intarsia, the other option was comparatively slower and more labour intensive for the machine. Because of the yarn choice however, this was the only option available. As I knew I wanted to test the use of stripes I discussed the design idea with the knit technologist. When using stripes on WholeGarment® designs the use of an intarsia or jacquard programme isn't strictly necessary. The stripes can be achieved just by changing of the feeders after each block of colour. Doing this cut down on knitting time and as each colour changes only at the end of the row, the intarsia method is not necessary. Though this technique is neither intarsia nor jacquard the process saved both time and money by using this alternate and innovative method. The other issue arising in this experiment was stitch quality. Because the Perino and Lurex were substantially different fibres in terms of diameter, weight and chemical makeup, the inclusion of both yarns in the one garment could cause problems. A few knitting trials were conducted to get the tension of the loops forming correctly for both yarn types.

Fig 3:33 & Fig 3:34 shows an initial testing of the stripes to evaluate if the 'feeder' idea would work. This is using scrap yarn, to just experiment with the production process. The stripes were designed to gradually get bigger as they worked up the garment to the neckline. This test was successful, as you can see the stripes flow evenly across the body onto the arms. An issue which may have arisen would be the stripe joins at the underarm section. This will be seen more in detail in the following images.





Fig 3:35 Shows the stripes matching evenly across the underarm section of the garment. As many complex technical processes are taken place when joining the sleeves and the body together, this is a success, in the form of the stripes matching up evenly.

This design can now be tested using the intended yarn, as the structure is correct and working.

Fig 3:36 and *Fig 3:37* (opposite page) Show the Perino and Lurex yarns working together in the striped dress. The yarns seem to be working well, and create smooth, crisp stripes. *Fig 3:34* shows the stripe continuing over the arm intersection with even stripes. The clear Lurex yarn did tend to have some twisting in the formed loops, which distorted some of the rows. This yarn was still held stable due to it being knitted with the more sturdy, Perino yarn.



Fig 3:36



Fig 3:37



Fig 3:38 (above) & Fig 3:39 (below) Shows the stripes on the body of the garment lining up correctly with the sleeve stripes. This is technical as well as aesthetic, as when the hands are rested by the side, the stripes will align. Once the stripes have been correctly programmed, then the inclusion of the structure design can be used.

Conclusion on Quasi Experiment Four:

The inclusion of stripes into the garment gave the dress an interesting texture and aesthetic. The method of achieving stripes suggested by the knit technologist, makes the production cost of this garment a lot cheaper, as multiple feeders can be used instead of 'fields' of intarsia. Though this was initially time consuming to programme, the outcome was successful.

Getting the stripes test working well, I could now apply the use of structure in the garment. This was an exciting possibility, though very technically challenging. There were many parameters that were restrictive to the designing process. The lace structure could work front and back but only in certain areas. There was also the factor of the lace structure reacting differently when knitted in the Perino and the Lurex.

I decided to have the lace structure placed in certain areas of the garment, rather than all over as a random structure. The developments I went through were all subtle lace designs, using the simple stitches of number 6 & 7 (lace transfer stitches).

Structure Trial:

This test worked well trialling out the structure on the CAD system, and the pattern of the 'random' lace holes was successfully achieved, which was designed to dither off to make it not look too structured and 'placed' on the garment. When this structure was knitted out however, it worked well in the perino, though did not look too aesthetically pleasing in the Lurex knit. Due to the elasticity of the knit the lace holes weren't forming properly, and the stitches become distorted. This produced a 'messy' looking structure when the lace was knitted into the Lurex.

The messiness of the lace in the Lurex structure was something I did not initially think about, and was a surprise to me when it was knitted. This would have worked better if I were to only use the lace structure on the perino areas of the knit. The compromise in design ideas would have lead to a more visually

pleasing garment if I had further time to experiment.

Fitness Test Results:

Knitting efficiency: Moderate

-Due to the lace structure being added this slowed down the initial stripes knitting time.

Aesthetic qualities: Unsuccessful

-Though both parameters worked well separately, due to the yarn integration the lace structure did not knit well in the Lurex. This lead to a visually unsatisfying result.

Combination of design components: Unsuccessful

-This was due to an unsuitable structure being knitted in a yarn which was far too springy for this use. If using a different colour of Perino in the stripes, this would have turned out well.

Further possible testing:

I would like to have experimented further with this test, as it could be resolved successfully after a few more trials. If a different yarn were to be used, this would have also made the lace structure more successful. Another option could work by being 'selective' with the lace knit, and only using it on the Perino in certain areas. With further testing, I believe this experiment could work successfully.

Experiment Five: Digital Textile printing with Colour Integration

Experiment Introduction:

This experiment assessed the use of digital printing onto one or more different yarn types in WholeGarment® design. As digital printing requires various inks for different fibre types, the aim of printing onto two differing fibres will be an informative experiment using WholeGarment® designs. The usual protocol when using two variables of yarn types is that they are printed separately, and then joined together post-printing. Such is the nature of WholeGarment® that the product is made up in its entirety, so a different printing strategy needs to be formulated. This quasi experiment focussed on this method of printing to produce a series of prints to trial different possible approaches to this medium.

Experiment Inspiration:

The inspiration for this experiment is taken from the use of applying colour to knitted products. This can often be a unique selling point of the product, as traditionally knitwear has been limited as to colour choices as only a certain number of yarns could be used in one garment. The other drawback was the incompatibility of screen printing onto a knitted garment. This produced a rough surface texture, and damaged the inherent stretch capabilities of the knitwear. As digital printing is a recent technology development, the use on knitwear comes as a novel and innovative approach of the inclusion of colour. Following the theme of an architectural nature, I used images of dilapidated building sites as inspiration. The use of line thickness and bold graphic shapes are inherent to this print. The use of colour integration is introduced through the stripes design used in the previous experiment. This allowed a print to be applied in areas where a structure design may not work due to machine limitations. I aimed to create a free flowing print which can wrap around the garment and bring vibrant colour to the design.



Fig 3:40

Experiment Aims:

Experiment five explores an aesthetic balance of print and stripe integration.



Fig 3:41

Experiment Testing:

I started developing print designs which used a lot of lines and bright sections of colour to enhance the print. Due to the nature of the perino fibre it is important to remember the surface texture of the fabric. The Perino fibres are long and hairy. This surface can distort the image if the detail is too fine. This aspect needed careful consideration as the combination of Perino and Lurex will effect different areas of the print.



Fig 3:42 Shows the work of Textile Designer Maija Louekari, who designs simplistic graphic prints for design boutique Marimekko, often inspired by urban settings. I really relate to her line work and naivety of the drawing. This image was a link to the building prints I have been designing, and would work well as a placement or engineered print.



Fig 3:43 Shows the development of the initial garment simulation on the CAD design system. This print when draped onto a garment works well, though the line work is too fine to show up effectively onto the Perino. The portions of colour work effectively, though I would include more colours into the design, along with some graduated areas.

Fig 3:44 Shows the initial workings of a sample print, void of colour. Progressing from the image in Fig 3:43, the line work is an integral part of the print, which works far better once the thicker lines were added. Through this style of print I wanted to create structure, yet abstract shapes simultaneously.

This design when sectioned up using colour could provide a bold graphic print for both fibre types. You can see the thicker lines are referencing architectural floor plans, while the thinner lines are that of a building site, following the exterior of the building ruins. The aim of these prints is to have a sophisticated yet fun and simple aesthetic to the design.

Fig 3:44

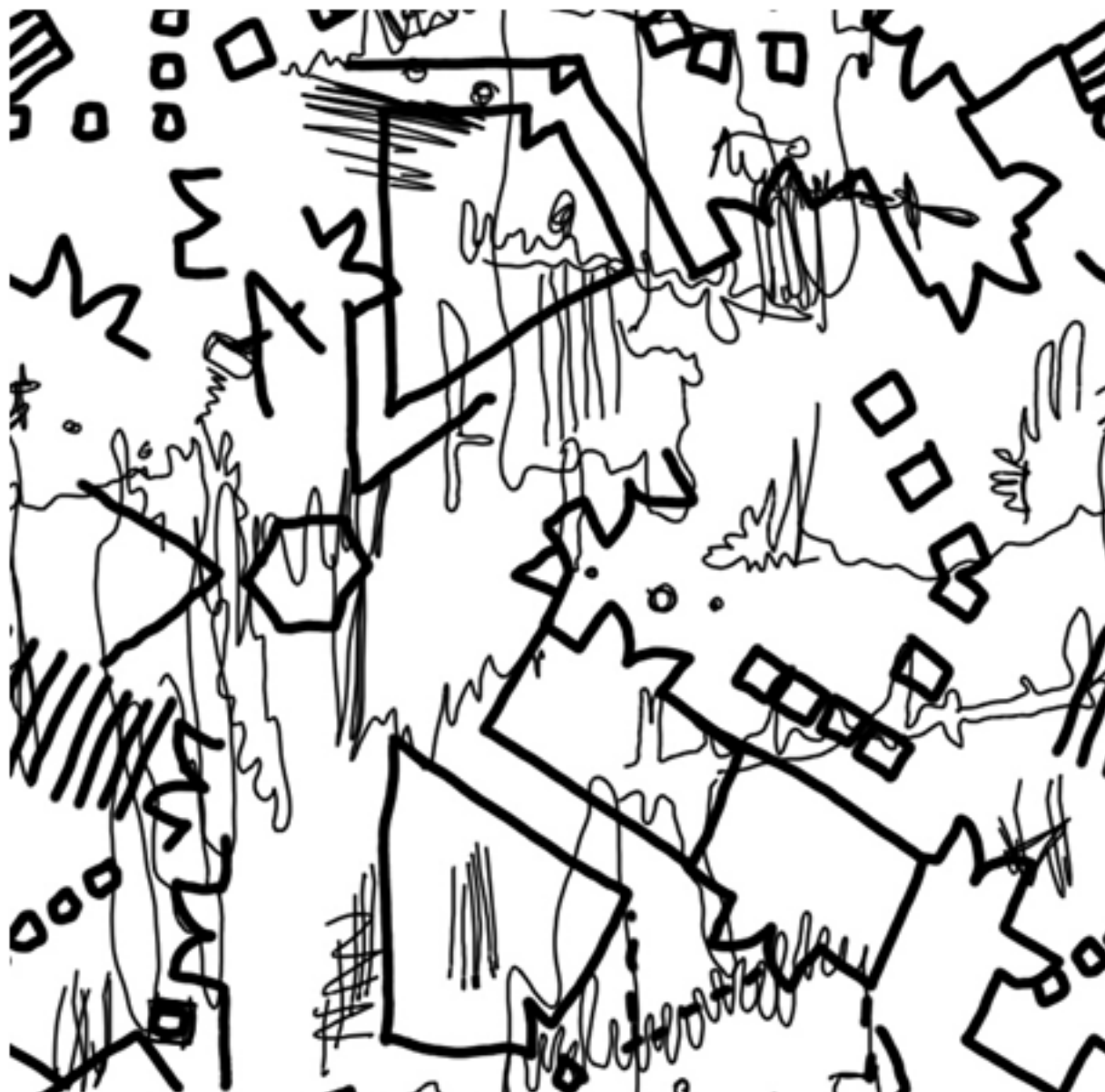


Fig 3:45 & 3:46 These print developments show the inclusion of colour and gradient designs.

Fig 3:45

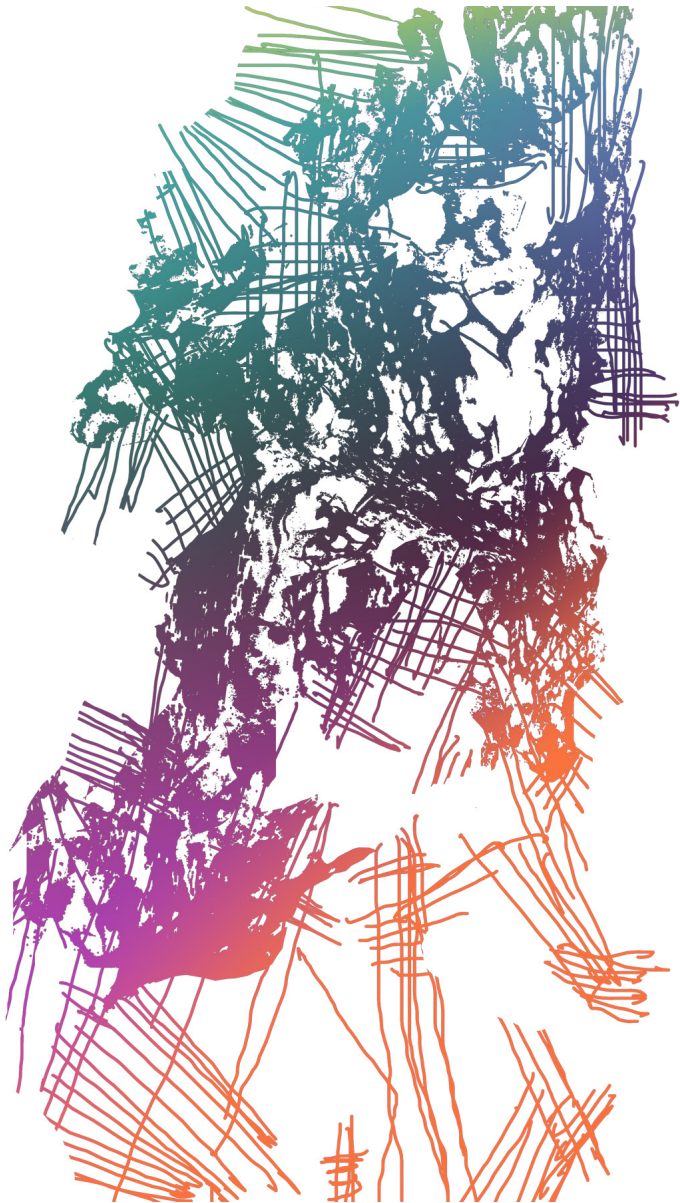
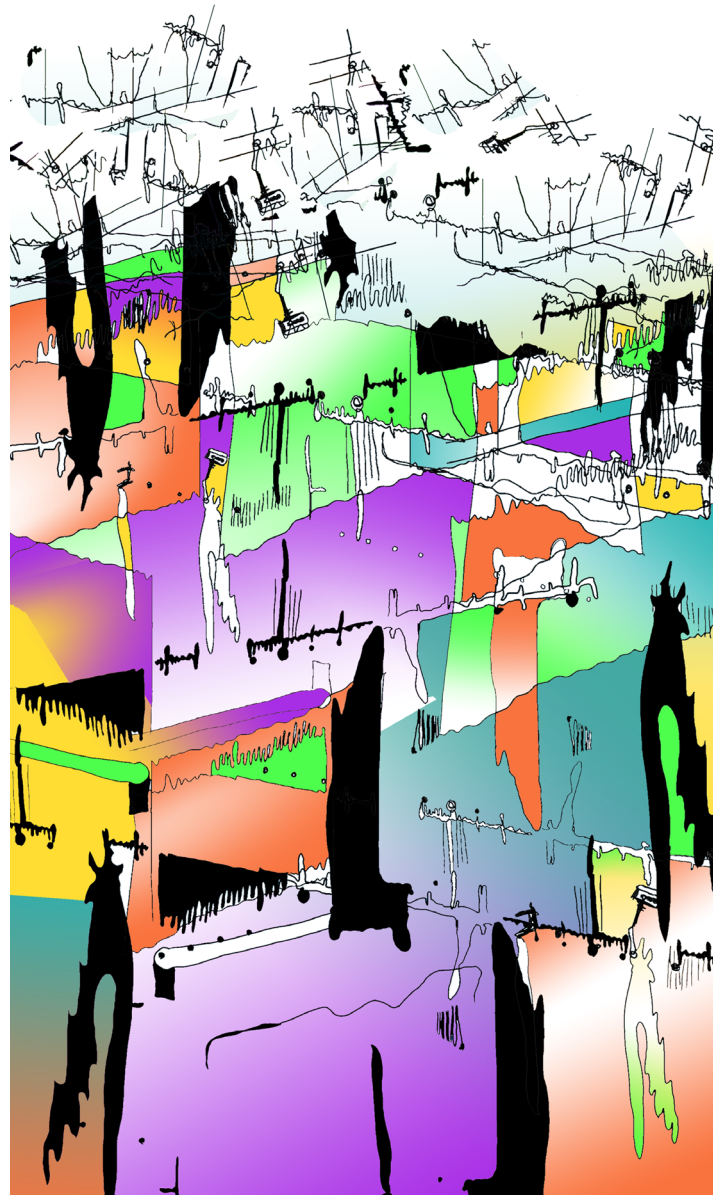


Fig 3:46



Conclusion on Quasi Experiment Five:

This experiment worked well in combining print and knit in a Perino/Lurex blend. This experiment worked well to use a placement print for the garment, as not to lose the aesthetic qualities of the stripes. The main focus was on incorporating organic line work in the print, reminiscent of architectural plans. A gradient feature used in the print also highlights one of the advantages of using digital printing.

This test was carried out producing a few different sample placement print visualisations, to decide on the most successful design. After a design was chosen it then was made into a final garment and printed before washing. This experiment was a relatively simple process, and there were not many factors which threatened the final outcome of the test. One issue could have been the pre-treatment chemicals applied to the garment. A reactive bonding chemical was used, as this is what is used on natural fibres (Perino). Though this garment had both natural and man-made fibres in it, it could not have both chemical bonders applied to it. My hypothesis was that the printing may not adhere to the Lurex part of the stripes, with the colour only picking up on the Perino.

Final Outcome:

This garment looked very effective having the print applied to the striped fabric.

I was surprised that the dye did adhere to the Lurex striped areas, even though it was not the correct chemical bonder to use on man-made fibres. This gave the print more visibility in the garment, while creating an interesting pattern. I am happy with this outcome, and I feel I have resolved it successfully.

Fitness Test Results:

Knitting efficiency: Very good

-Due to the garment being a plain knitted structure the knitting time was at its maximum efficiency.

Aesthetic qualities: Very pleasing

-Adds great textural elements to the knitwear, bringing colour and vibrancy.

Combination of design components: Very effective

-The combined parameters work well together, complimenting each other.

Further possible testing:

This print would be great to develop across different portions of the garment, knowing that the Lurex yarn absorbs the dye colours. The scale and energy of the print could be adapted to many other garment shapes, as it has an 'organic and growing' nature to it. If there was further testing to be experimented with, I would like to manipulate the shape and colours of the print, though still including the colour gradient in the design.

Conclusion of Thesis Project

This research is an investigation into technical and aesthetic directional choices made by the designer in WholeGarment® knitwear design. It has led to the identification of a set of design parameters and an exploration of combinations of these features through a series of practical, informal, experimental processes. By isolating each design parameter I have been able to concentrate on methods and production processes of creating WholeGarment® knitted products and textile prints via the technical interface of the Shima Seiki SDS-ONE® CAD system.

These experiments have been creative and technically informative in the production and creation of knitwear. This has in turn given me a wider technical understanding and the capability of more confidently employing this technology. While the range and scope of these experiments was not comprehensive (I did not attempt to explore every possible aspect of every parameter, or the full range of combinations of all the different parameters, as this was a creative rather than scientific process), the findings have led to new insights and understandings of the WholeGarment® design process and raised further questions to be explored in the future. While the outcome of this research includes designed artefacts, these should be recognised as the result of experiments to understand successful design strategies for innovative knitwear design, rather than as a traditional fashion “collection.”

As quoted in my introduction, Sayer et al (2006) have recognised that this technology requires a conceptual shift and a reassessment of how knitwear has been traditionally made. As an isomorphic textile the application and concept of WholeGarment® knitting requires a new methodology for application in the knitwear market as a three dimensional, engineered form. It is hoped that the findings of this research will assist designers in the industry and that the apparel business sector will adapt and change to recognise the opportunities for

innovation through this unique approach to knitwear design and manufacturing in fashion and apparel areas.

As a research-practitioner I have found the communication to the knitwear technologist quite clear and accurate. This could be an account of two things, firstly, an approach inspired by genetic algorithms, and secondly, the use of the Shima Seiki CAD system, where both our languages and communication issues are nullified through the use of a ‘split screen’ view where the designs are discussed whilst both technical and design information can be viewed simultaneously.

As my designing has been centred on quasi experiments it has allowed me to isolate the intricacies of WholeGarment® designing to focus on the individual elements of the knitting process. This has led to a greater understanding of the individual elements in knitwear designing, and knowledge based on a technical understanding of the knitted product.

As a research-practitioner I have been fortunate to work closely with a highly skilled and communicative knitwear technologist, Gordon Fraser, at AUT’s Textile and Design Laboratory whilst conducting my experiments. It is recognised that this sort of experimental development and open communication is not often supported in an industry situation, where the focus is on commercial production rather than research. In addition there are some technical factors which tend to limit the type of communication between designer and technologist in relation to WholeGarment® knitting. The interface of the Shima Seiki SDS-ONE® CAD system aids design and technical communication because design information is translated into technical information by the software and the information viewed simultaneously through ‘split screen’ views.

This research has led to a greater personal understanding of

the individual elements in knitwear design, the way different elements might be combined, and an increased knowledge-base in technical understanding. This has given me greater confidence as a designer working through WholeGarment® technology.

The existing body of knowledge about design-centred approaches to WholeGarment® technology and creative application is still limited. It is hoped that the body of contextual research, informal experiments and analysis undertaken in this project and documented in this thesis will be to be a useful in educating and informing designers, technologists and educators in some of the practical applications, opportunities and limitations of using this technology.

Though the experiments themselves have lead to better understanding and knowledge, they have also helped identify further technical and aesthetic aspects of integral knitting which require further investigation to be resolved, built upon, and refined to allow the designer greater understanding and creative freedom in the use of this technology.

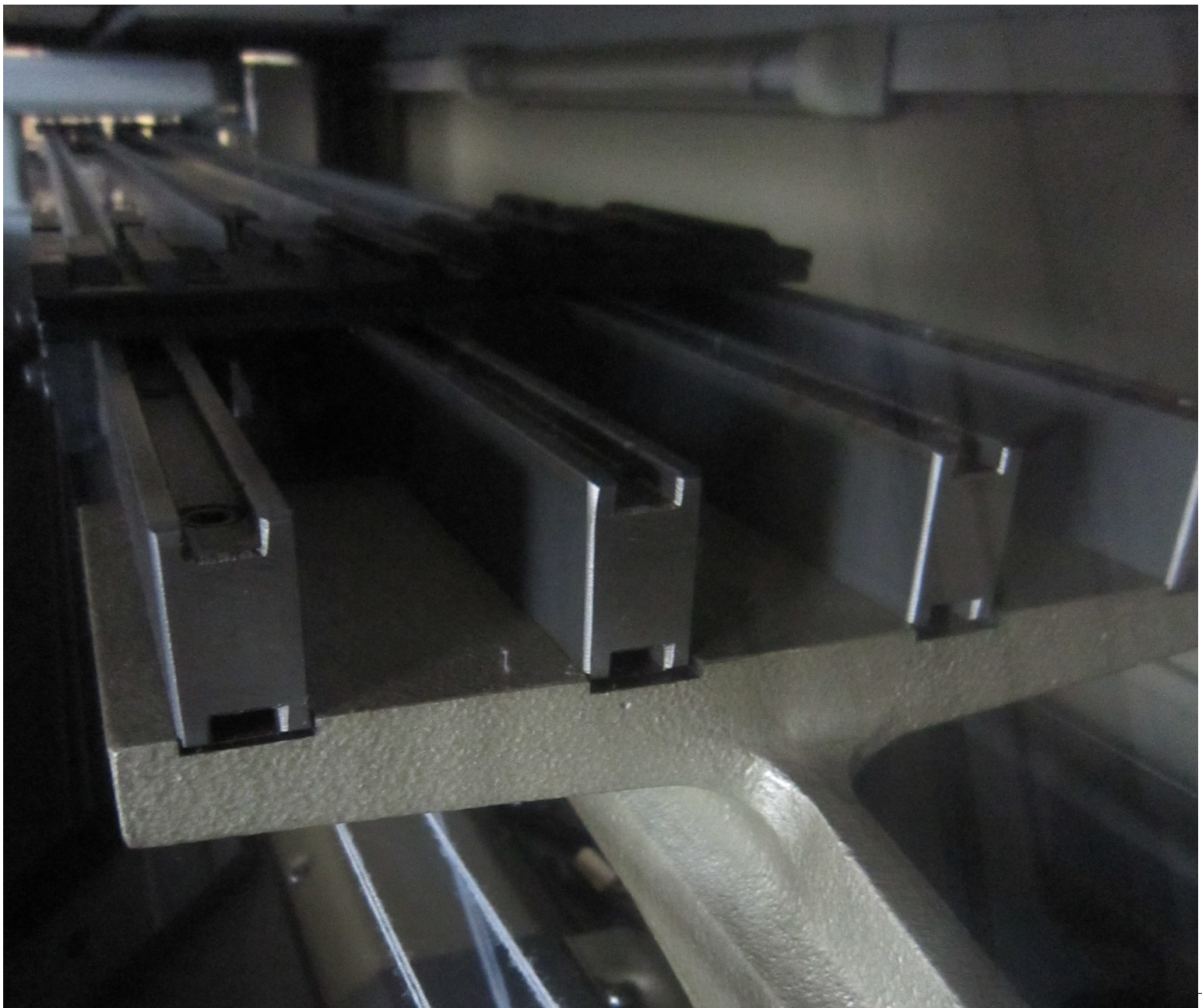
Appendix 1:

Analysing the New Zealand Fashion Market: New Opportunities for Knitwear Design.

In association with the Textile & Design Laboratory, AUT University

This research was funded through a TEC Postgraduate Summer Studentship

By Alysha Gover



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Fig 2:31 Gover, A. *Post printing process* Digital photograph, 2010.

Part Three: Collection Photographs. *Defining Flight A/W 2010/11*

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Photographer Amy Yang

Model Sarah Davidson

Makeup Artist Christina Cai

Fig 3:1 Gover, A. *Knitwear Exhibition* Digital photograph, 2010.

Fig 3:2 Gover, A. *Knitwear Exhibition* Digital photograph, 2010.

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Fig 3:4 Gover, A. *Knitwear Exhibition* Digital photograph, 2010.

Part One



Introduction

This project was an investigation into design innovation and marketing opportunities for digitally printed merino knitwear within the New Zealand fashion sector. It has involved a review of current uses of digital print on knitwear both internationally and in New Zealand; the development of a range of digitally printed knitwear which utilises and demonstrates a range of print on knitwear approaches to be shown to industry as a promotional kit; and consultation with NZ designers and design companies to ascertain levels of understanding, interest and opportunities for the use of these technologies to add value to NZ apparel production. The project was carried out between December 2009 and June 2010. An interim report on the project was presented by the author at the “Digital Strategies – Innovation through Apparel and Textile Technologies” symposium held at AUT University in April 2010.

The research conducted through this project has identified and consolidated a body of contextual material that will inform ongoing research and teaching at the Textile and Design Lab (T&DL) and the author’s own Master of Art & Design research project. The design development process has led to the production of some innovative and sophisticated design applications which are the basis of information and promotional material for industry. Additional research into NZ industry extent of use approaches, understandings and future needs for these technologies has provided valuable information to inform ongoing research, development and educational initiatives at AUT’s Textile and Design Laboratory (T&DL) to support NZ industry.

Part One: Abstract

The aim of this project was to collect information, gain feedback and analyse the state and potential of digitally printed textiles in the NZ fashion industry. In particular, the study was focussed on digital printing onto knitwear. This research firstly involved an investigation of the use of digital printing in the knitwear field. The next stage was the design and production of a capsule collection to fit into the high end knitwear sector of the fashion market. After releasing the collection at an exhibition evening, attended by academic staff & post graduate students from AUT along with industry personele. A general survey of New Zealand knit wear manufacturers, knit design companies and designers was conducted using the online 'Survey monkey' system. This was to gain insight into broader industry perspectives on knitwear design and manufacture in NZ. Particularly in relation to the use of print on knit. This process was followed up with a series of interviews with a selected group of eight designers and two knitwear companies presenting some of the collection pieces, along with an Autumn/Winter 2010-11 look book, and asking a short list of questions to gather their feedback on the response to digital printing in these garments and their potential within the New Zealand fashion market.

After this questioning and gaining of perspectives and opinions the information was collated and the project concluded in relation to the identification of factors that may limit or effect uptake and application and the current and potential uses for digital printing in the New Zealand fashion knitwear industry.

The general response was that designers interviewed were a lot more open to the idea of adopting digital printing, compared to knitwear makers and producers who tended to hold more traditional views of production methods and applications. The main barrier to uptake is initially the cost, followed closely by lack of knowledge in the industry about this form of digital textile application.

The designers interviewed who already had their garments situated in the middle to high end knitwear sector indicated the most positive response to the uptake of the idea of digital printing, because they were already working within a price point that would cover the additional cost of this innovative printing method. A few NZ companies have already adopted this method of printing onto knitwear, and have produced innovative products which the market has seemed to warmly receive.

The conclusion regarding the overall response to this research project from industry were extremely positive in relation to the uptake of new technology; however the uptake has been sluggish due to the additional costs and also because of limited knowledge in this area. Given more education on the industries behalf and a more favourable economic climate it is suggested that there will be a stronger demand for this point of difference in knitwear collections, as companies overseas are already seeing this take place.

Contextual Review A: Innovative Knitting

1 . The New Craft of Machine Knitting:

The use of new technologies within the knitting industry has been healthily adopted in the southern hemisphere. The interest in these technologies has also been well received as fashion is becoming a digital industry with methods of production and assembly are shifting from old to new technologies and supply chains are becoming more integrated. A display of such innovation was seen in an exciting knit-focused exhibition held at the RMIT Gallery in February 2010. The Endless Garment: the new craft of machine knitting assembled a group of 12 International and Australian designers who are all using knitting technologies to create innovative modern garments. It focused on showcasing the bright future of machine knitting, and had high profile designer garments being exhibited by Issey Miyake, Sandra Backlund, and Walter Van Beirendonck.

Their work showcased the creativity through the use of machine knitting. Aptly called the new craft of machine knitting in the exhibition title the work presented showed the deliberate artisanal feel these designers put in their garments through high-technology focused processes.

Fig 1:1 Nikki Gabriel's garments. Knitted on domestic and computerised machines .



Fig 1:2 (Left) Nikki Gabriel was a past student at RMIT university where the exhibition was held.

Fig 1:3 (Below) Swedish born Sandra Backlund's collection displays sculptural elements in knitwear.

Fig 1:4 (opposite) Walter Van Beirendonck's collection 'Sun King' displays textured knitted yarns showing conceptual ideas.







Fig 1:5 (opposite) London Based designers 'Sibling', with their dramatic men's knitwear collection.

The Australian newspaper article '*The seamless dress, the golden mean and the machine*' Turcu, K (2010) discussed the exhibition and public perception towards 'machine' knitting which often have negative, mass produced connotations. In comparison to notions of 'craft', and 'workmanship' associated with traditional hand knitting, which is more warmly received. Co-curator Ricarda Bigolin stated that the exhibition was to enlighten people on the changing forms of knitting due to technological progress and to show that machine knitting is interesting, artisanal and creative.

2. Tokyo Fashion Week Autumn/Winter 2010/11:

Experimental, yet highly wearable knitwear was seen on the catwalks of the iconic Tokyo fashion week Autumn/Winter 2010-2011. Renowned for its investigative, conceptual clothing, the shows presented Japanese viewers with an immense and varied range of knitwear as accent pieces in collections, adding texture and body to other simple pieces. There was a resurgence of knitwear taking a masculine form, with strong silhouettes shown in some Men's wear collections. In 'Quesorvel', designer Yoshiyuki Iwagishi used warm colours with chunky cabled cardigans to compliment his outfits.



Fig 1:6 and 1:7 'Quesorvel' at Japan Fashion Week, 2010.

A geometric feel was seen in the more modern knitwear shapes of 'Sise', by designers Seishin Matsui and Takatoshi Hirokawa. Geometric styles are also evident in the label 'Lorinza's' collection, as well as chunky cables.

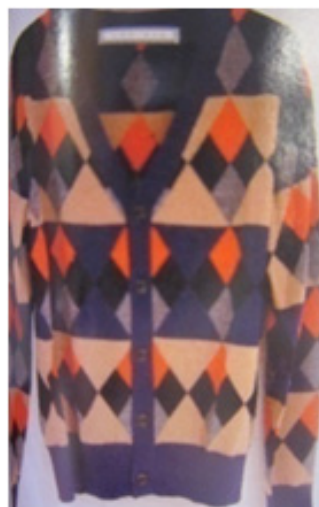


Fig 1:8 (above) 'Lorinza' at Japan Fashion Week, 2010.



Fig 1:9 (opposite) 'Sise' at Japan Fashion Week, 2010.

Deconstructed knit took on a 'grunge' aesthetic in the collection 'Talking about abstraction', with the knitwear laddering and fraying at the hem of the garment.

Women's wear in Tokyo Fashion week took on sculptural yet elegant forms contrasted with chunky knits.

Nozomi Ishiuro's 'Haute couture' show displayed colourful abstract digital textile prints, with chunky crochet-like knitted eskimo jackets. Keita Maruyama also used crochet in her collection, giving the garments a more three dimensional fabric.

Fig 1:10 Detail (opposite) 'Talking about Abstraction' at Japan Fashion Week, 2010.

Fig 1:11 (Below left) 'Talking about Abstraction' at Japan Fashion Week, 2010.

Fig 1:12 (Below middle) 'Nozomi Ishiuro' at Japan Fashion Week, 2010.

Fig 1:13 (Below right) 'Nozomi Ishiuro' shows digital printed knitwear at Japan Fashion Week, 2010.





'Akira Naka' showed delicate knitted structures juxtaposed with a sculptural silhouette. 'Cosmic wonder light source' Fashion Company also used circular silhouettes in their garments, contrasted with the strong lines of the cable structures. 'Mihara Yasuhiro' designs also referenced a deconstructed knit but in a rather elegant, lace-like manner. The stitch structure let the skin peek through the garment, referencing laddered or ripped stockings.

The underlying themes of deconstruction, sculptural knitting, and androgyny were seen in many knitwear pieces, which mirrored the fore coming trend directions shown in the trend forecasting magazine 'view' and directional fashion websites.



Fig 1:14 and Fig 1:15 (Top left and right) 'Keita Maruyama' uses crochet to give texture to her fabrics at Japan Fashion Week, 2010.

Fig 1:16 (Below left) 'Arika Naka' shows at Japan Fashion Week, 2010.

Fig 1:17 (Below right) 'Cosmic wonder light source' shows at Japan Fashion Week, 2010.

Fig 1:18 (Opposite right) 'Mihara Yasuhiro' shows a deconstructed style of knitwear at Japan Fashion Week, 2010.



3. Saverio Palatella & Shima Seiki Collaboration:

Italian knitwear designer Saverio Palatella who displayed his collection pieces at RMIT's gallery exhibition in Australia, also created a capsule collection titled 'Bianco' in collaboration with leading knitwear specialists Shima Seiki, specifically showcasing the potential of the WholeGarment® designs in the high fashion market. Shown at the 2008 New York fashion show, Palatella created stunning white whole garment pieces void of any colour to display the technical mastery achieved in knitting an integral garment. 'Bianco', literally translating in Italian to the word 'white' was an intentional namesake for the collection, to give designers, technologists and consumers alike the endless creative possibilities of WholeGarment® knitwear.

Reviewed on the website www.altaroma.it (2009), the author comments on the exciting innovations made by the creation of WholeGarment®:

WHOLE GARMENT® knitting is not only a novel alternative to existing production methods. Its technological breakthroughs have also led to the development of previously unknown knitting techniques that expand the range of knitwear as fashion. New shapes, new patterns and new textures can now be knitted using a wider range of new materials.

This gave the public a good indication of how technology has progressed knitwear into the forefront of cutting edge garment engineering. Palatella has his own established Italian label using cashmere yarns to form modern high fashion knitted garments. Images of Palatella's garments shown at 2008 New York Fashion Week are shown in *Fig 1:19, 1:20 and 1:21*:

Fig 1:19 (Opposite right), 1:20 & 1:21 (over page) Saverio Palatella's 'Bianco' collaboration collection with Shima Seiki knitting manufacturers, shown at new York Fashion Week, 2009..







4. Stoll and AWI Collaboration:

German based knitwear manufactures Stoll recently paired up with Australian Wool Institute (AWI) to create a technically-focused knitted collection featuring their version of integrally knitted garments, called 'Knit and Wear®'.

Focusing on using a merino fibre, the collection was a nomadic, intrepid themed sportswear range which used specialised stitch structure and yarn integration. The technicality of the knitting structures allow breathability of the body, combined with the excellent wicking capabilities of merino wool making this collection notable in terms of technique marrying machine knitting skills with a sustainable natural fibre. The design consultant for the range 'Richard Goodstein Inc' comments on this combination:

The concept of building 'smart' garments, using truly innovative knitwear techniques, and capitalising on the benefits of the Merino natural fibre have been brought to fruition with the Modern Nomad collection, specifically for the outdoor active-wear market. (2009).

By creating specifically designed knitted panels to cater to the body's needs such as moisture retention, heat retention and odour control, these garments have a functional edge as well as a novel aesthetic that appeals to current trend driven markets. opposite are some images from Stoll's A/W 2009/10 'Urban Nomad' collection:



Fig 1:22 and 1:23 (Above) Stoll and AWI's 'Nomad' collaboration collection, A/W 2009/10.

Fig 1:24 (Opposite) Stoll and AWI's 'Nomad' collaboration collection, A/W 2009/10.



Fig 1:25 Stoll and AWI's 'Nomad' collaboration collection, A/W 2009/10.



Contextual Review B: Digital Printing

1 . J R Campbell

In 2009 researcher and textile artist J R Campbell from Glasgow School of Arts visited New Zealand to attend AUT's Textile Design Symposium as a key note speaker.

Researching the fields of digital textile printing and the possibilities of two dimensional and three dimensional prints, this use of technology to produce textiles has propelled it into an area where almost anything is now possible. Using bright colours and 'planetarium-like' space age prints Campbell's work showcases the ability to distort garment silhouettes and display interesting shapes on the body. Speaking from an interview with journalist Melanie Cooper from AUT, Campbell compares the differences in printing techniques used only a few years ago:

We have come from reduced colours, large scale production in which a few designs get produced in multiple millions to a stage where any colour is almost possible and it is just as easy to produce multiple millions of design ideas as it is to make multiples of one idea. (Cooper,2009)

This use of technology in the area of textiles has encouraged the collaboration of other digital areas of design, moving from a fashion context, to a product and furniture focused areas of design as well. Digital print doesn't abolish the use of traditional screen printing methods, rather it extends the use and aesthetics of point applications through technology.

Fig 1:26 "Summer" by J R Campbell (2009):

This was a collaborative piece with Jean Parsons and Susan Strawn. There are two layers of digitally printed silk; silk broadcloth below, silk gauze above. The transparency of the gauze creates an amplification effect with the imagery. Susan cut extra digitally printed silk into strips and created the knitted hood, cuffs and hemline.



Fig 1:27 Detail "Summer" by J R Campbell.



J R Campbell believes that the context of New Zealand is the perfect environment for digital printing technology to flourish and become a commercial possibility, and also an experimental area full of potential:

Like Scotland, New Zealand will not be able to sustainably manage mass production of textile products. We are no longer 'manufacturing' countries. Instead, we need to use approaches like the one I described above (digital textile printing) to circumnavigate the mass production supply chain. This will allow for more meaningful design to occur and will result in more valued products, which people will retain for longer. None of these products will have to be produced in advance; instead they will be created on-demand. As a result, as smaller countries, we will be able to take advantage of a more responsive, more appropriate, more creative and more sustainable means for textile product consumption. (Cooper, 2009)

2. Walter Van Beirendonck

Other designers such as Walter Van Beirendonck have taken a quirky approach to digital printing, using a photographic image of a man's chest which has been digitally printed onto a sweater. This type of 'gimmick' use of digital printing showcases the various marketable possibilities the application of this medium can have.

Fig 1:28 Walter Van Beirendonck's digitally printed sweater.



3. Cathy Pill

Cathy Pill, a designer from Brussels, uses colour gradients, and large scale images to highlight the point of difference digital printing can give textile design. Her garments sit in the high fashion price point and are currently being sold in the UK in Brown's department store.

Fig 1:29 Cathy Pill's Digitally printed kid mohair garments.



4 . Blue Area

Blue Area is a company established in Germany in 1996. It is sold exclusively to Browns Department store in the UK. The cashmere knitwear is printed reproducing artists artwork as placement prints over and around the garment.



Fig 1:30 and 1:31 Blue Area's digitally printed cashmere garments.

5 . Hussein Chalayan

The world renowned designer Chalayan has also included digitally printed garments in his collection. These prints boast photo generated images which can be duplicated onto fabric due to the technology of digital printing. The texture of the concrete can be seen coming through in the print, which would be very difficult to achieve using the traditional screen printing methods.



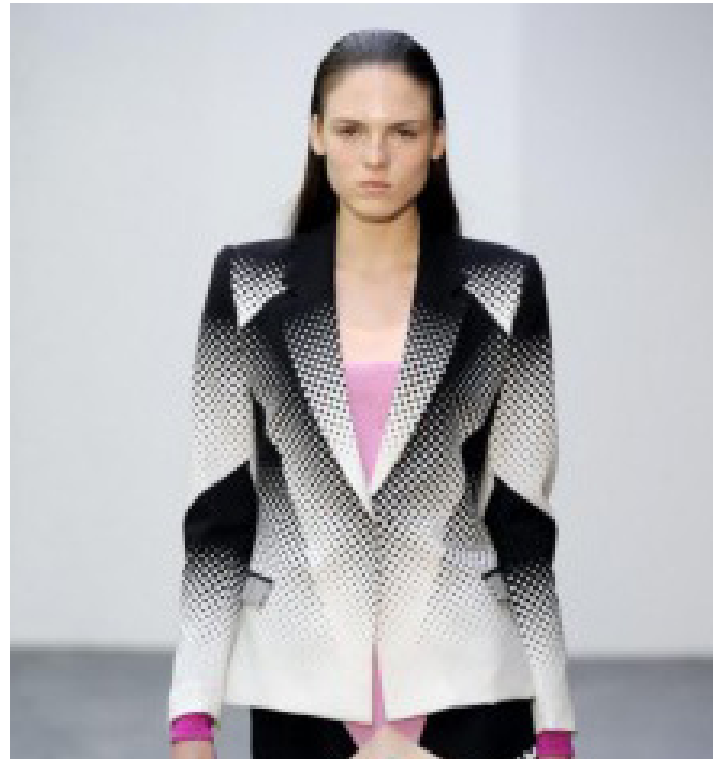
Fig 1:32 and 1:33 Chalayan's Digitally printed concrete-like leggings and bodice dress.

6. Josh Goot

Australian Designer Josh Goot also uses digital printing to create bold graphic surfaces on his garments, as well as abstracted, blended colour patterns.

The most expensive digitally printed garment identified during research in the over sea's fashion market was from designer Cathy Pill. This was for 5,890 pounds (\$12,696.70 NZD) for a digitally printed garment. The cheapest international garment price was 60 pounds (\$120.30 NZD), from a company called Kaliko.

Fig 1:34 (Below) and 1:35 (Above right) and 1:36 (Below right) Josh Goot's Summer collection, all digitally printed in bright vibrant colours.



The most expensive digitally printed garment identified during research in the over sea's fashion market was from designer Cathy Pill. This was for 5,890 pounds (\$12,696.70 NZD) for a digitally printed garment. The cheapest international garment price was 60 pounds (\$120.30 NZD), from a company called Kaliko.

Within a New Zealand context digital printing is being used by designers such as Lonely Hearts, printing onto mohair sweaters, socks and gloves with a vintage floral print. The price point in the New Zealand 'high fashion' market would allow the expansion of digital printing to offer exciting new cutting edge prints in this market. As J R Campbell said we have the ability to offer 'on demand' printing in NZ to cater for small production runs, and Lonely Hearts is a perfect example of this application.

Fig 1:37 Detail and Fig 1:38 (Above right) Lonely Hearts digitally printed floral jumper.



Digital Printing Methods

Digital printing allows for a greater variety of print approaches than traditional screen printing methods. While there are specialised machines for the roll to roll digital printing of fabric lengths, there are two methods of print application that are most relevant to digitally printed knitwear, which are well supported by the T&DL's print technology. These are:

Placement Prints:

The placement print is the simplest method and has a high success rate when running a large quantity of prints for commercial output. This is due to the print generally being placed in the centre of the garment, which has no effect on any seams, or prints wrapping around the body. As it is generally a simple print, it can be used on a variety of different shaped or size graded garments with the motif being scaled accordingly, and printed either front or back.

Engineered Prints:

This form of printing requires a lot more precision and also requires allowances to be made for the garment shape, size and seam interference. Due to the high amount of accuracy involved this type of printing significantly affects the price of the garment so it is generally used in high end products where price is not an issue.

The technique of engineered prints allows designers to create patterns to the exact shape of their garments which flow over the seams, or join a design at the seams for a focus of the design. This pattern is made on Photoshop or Illustrator and exported in a TIFF file format. As this method requires moving or flipping the garment for printing, some seam overlap in printing can occur. With this in mind it is better to create a 'forgiving'

print, so the design will not be compromised if there is any slight inaccuracy. In this form of printing 'formers' are placed inside the garment to ensure it is held flat with minimal movement of the garment taking place.

Conclusion of Part One

It was recognised that the current state of print on knitwear was still at an experimental stage. While some outstanding international examples were identified, in general digital print is still often being used in a similar way to screen printing, even though the new technology has significant potential for innovation in print design. Innovative combinations of print on knit are more limited. The technologies within the TD&L offer significant opportunities for New Zealand designers and knitwear companies. The main issue is to develop greater industry awareness of these opportunities.

Part Two



Design Development of a Collection

Within the New Zealand context I started the development of a collection which used digital printing and knitwear technology to explore and show some of the possibilities of the successful combination of two innovative technologies: digital print and digital knit. This stage of the project involved several steps:

- 1) Consideration of fashion and textile trend forecasts to ensure stylistic relevance to the high end fashion market
- 2) The development of print design concepts
- 3) The development of garment shape concepts
- 4) Tests of knitting and printing experiments
- 5) Virtual prototypes of garments
- 6) Collection cohesion for sample range

The first stage of this part of the project involved looking at trend guides on line, current overseas trends, and directional forecasting magazines to see the prevailing trends.

Due to the envisaged collection using high quality merino wool and digital printing, it was imperative it was developed for the high fashion bracket of the NZ apparel market so that the price point would fit into this demographic of fashion retail.



Fig 2:1(Opposite) This image is from a Trend directions magazine, showcasing some of the upcoming trends for A/W 2010/11.

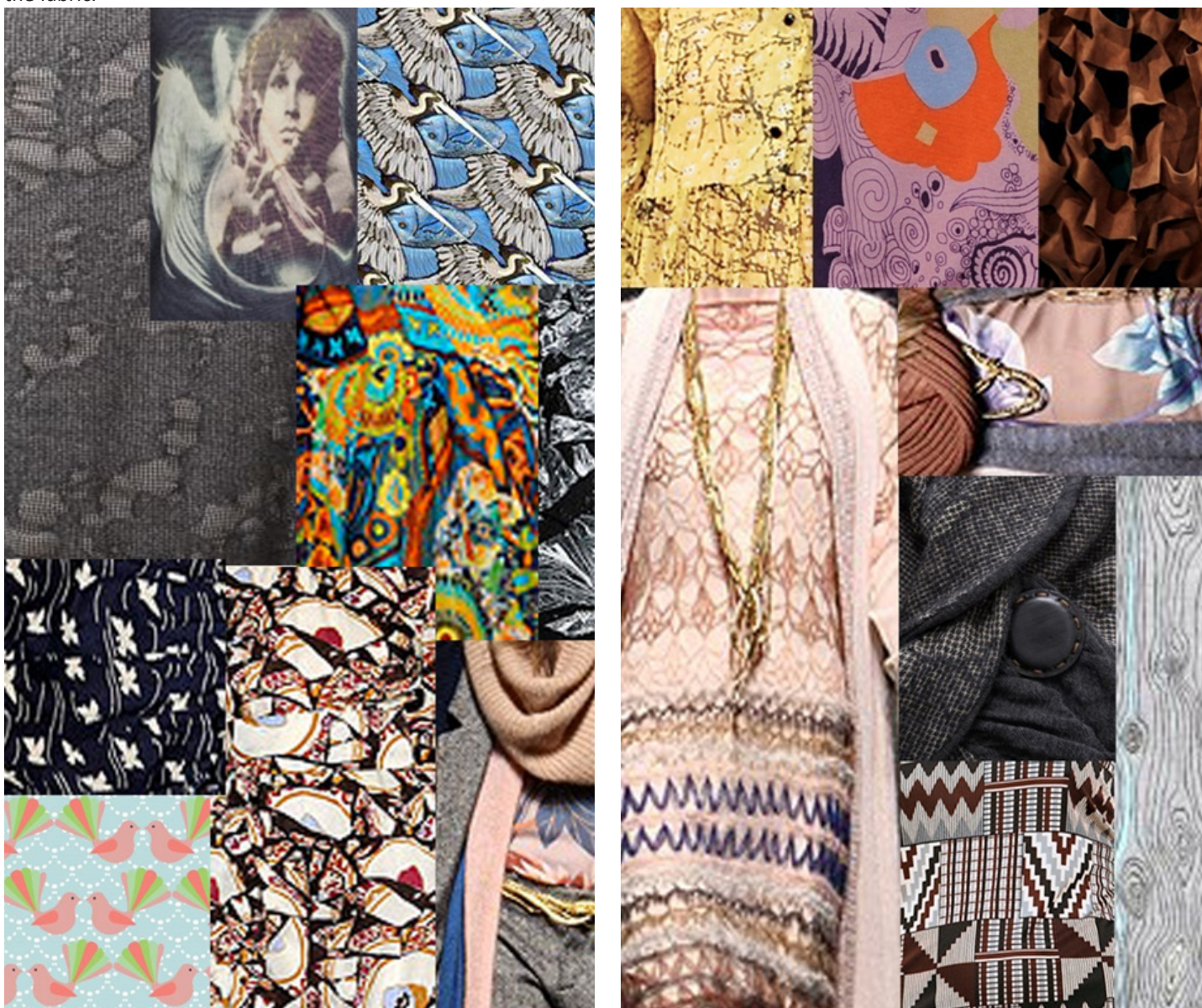
Fig 2:2 This image shows a trend forecast of fabric textures and surfaces.

Fig 2:3 This image shows the trend forecast seasonal colours of A/W 2009-10.

These Images show fabric surface manipulations and the forecasted colour palette for the season I was designing for. This is all important information to gather prior to designing a collection, as this information will determine in what style and aesthetic garments will be marketed in.



A sub theme of the print direction from forecasting magazines was identified as the print 'slipping out of control'. This idea sounded like an interesting path to take, and I discovered a designer called Talbot Runhof who uses digital printing technology. His hounds tooth prints are digitally manipulated to make them flow around the wearer's body, giving the prints a 'slipping' notion of falling off the fabric.





Looking further into the idea of prints 'slipping out of control' I came across the Dutch graphic artist M. C Escher (1898-1972) who bases his work around symmetry and geometry concepts that work well in textile design in terms of repeating patterns.

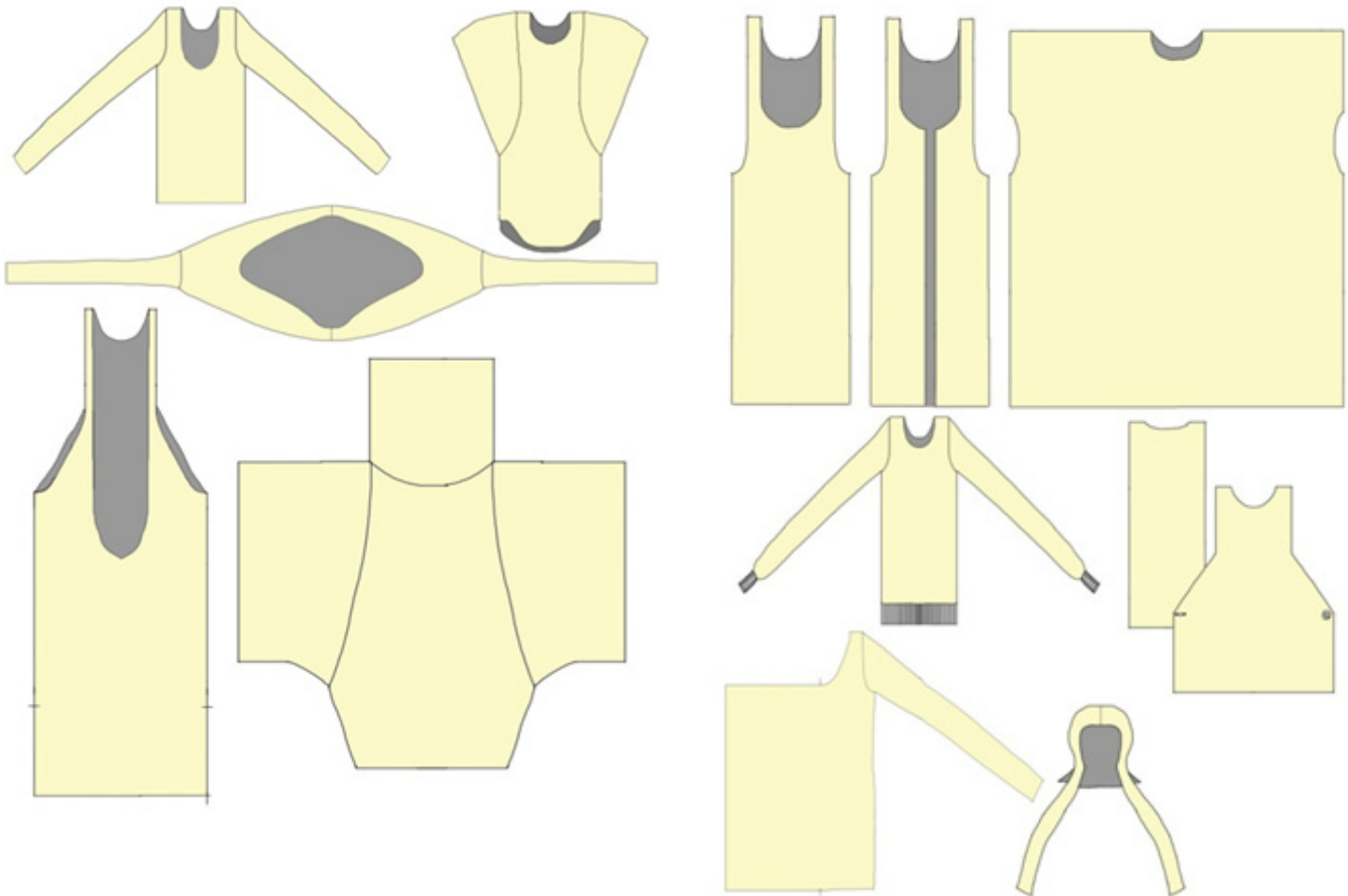
Fig 2:4 and Fig 2:5 (Opposite page) Show print samples are taken from New Zealand and overseas designers from current and past collections.

Fig 2:6 Talbot Runhof's garments are made from stretch wool and silk mousseline. The prints of these garments have been cleverly designed to follow the bodies' curves to give movement and energy to the print.

Initial Garment Shape Development

The garment shapes below are a few that I chose from the many I had developed. The silhouette was a relaxed fit, drop shoulders, lowered armholes, with a slimming silhouette following the body. Most of these garments incorporated drape into the body and sleeves. I chose to do a six piece collection, five women's garments and one menswear piece.

Fig 2:7 These initial garment shapes were planned to be either 7 gauge or 14 gauge merino knitwear. Some of these shapes would be fully fashioned knitwear, and some would be whole garment knitwear that is integrally knitted.



Initial Print Development

The textile prints I developed were based on the theme of flight. Referencing the notion of 'slipping out of control' from something structured, to an organic image which flowed over the garment, I focused on a graphic hand sketched illustration style, using a contrast of bold and thin lines.

This aesthetic works well in digital textile printing as lines can be fluid and free flowing, using varied thicknesses of pen. The use of colour gradation is an additional distinction between digital printing and the traditional screen printing technique. Another design factor to consider was hue in relation to the application of colour onto already dyed merino. The base colours selected - 'bone' and 'grey' would affect the brightness of the dyes applied through printing.

I initially started designing on computer and then once some of the sample prints were ready to be made a colour swatch print using my fabric as a knitted swatch. This indicated how the colours would show up on the fabric colour. I then assessed the on screen colour to the physical printed colour, and usually changed the saturation of the colour on screen to one or two shades brighter, so as to show up more vibrantly on the fabric.

Fig 2:8 and Fig 2:9 These initial prints were developed after deciding on the garment shapes for the collection. This was because the type of prints I wanted to do - as placement prints, or engineered prints required consideration of the shape/print relationship.



These prints are some of the final developments for my range. The use of gradients within the prints is an effective way to communicate depth and a tonal range of colour.

The final colour palette (see below) is used as further cohesion within the collection. Although digital printing is not limited to a set number of colours (unlike screen printing, where each colour requires one screen), it is still important to intentionally choose the range and number of colours for maximum visual impact.

Fig 2:10, Fig 2:11 and 2:12 Showing final developments of digital textile prints and colour palette.



Final Print and Shape Development

Fig 2:13 (Below left) Showing fashion illustration I drew to communicate the 'mood' and 'feel' the collection would have.

Fig 2:14 (Below right) Showing final print and shape developments combined into garments.

These are some renditions of the final garment shapes and prints. This selection was not an individual decision, as I had weekly meetings to consult with a team of my supervisors and technicians who helped direct and input into the design and production decisions to be made. A 2/28 count merino wool yarn, in a bone and a grey hue was used as a background for printing on. This visualisation was produced before the knitting process was started. The next stage of this design development was to move into 'virtual' design and prototyping on the Shima SDS one design programme to enable better visualisation.



Technical Garment Development

The technical specification of the garments was the next important phase in the development of the collection. I worked on this with Gordon Fraser, the T&DL's knitwear technologist to create the final garments. The collection uses two approaches: WholeGarment® designs, which eliminate side seams, and fully fashioned garments, which require a post knitting construction process. This construction choice was to show the different methods & techniques that can be used with a digitally printed, knitted garment, as the construction of the garment is a factor influencing the placement of the print onto the garment. Specification sheets are used in industry to communicate between the designer and machinist, or designer and knit technologist. They are important tools of communication between departments, and hold key 'physical' information, such as size, shape, yarn type etc.

SIZING SPECIFICATION SHEET		Season: W 10/11	Date: 09/02/10	Gauge: 78	Machine: SES WG	02W10h
Style: Drop Armhole singlet Dress	Size: 12	Specification Drawing	w/w	m/w	Yarn Count: 2/28	Yarn Colour: natural
1 shoulder width	4cm					Fabric/Yarn Swatch
2 neckline width (front)	15cm					
3 neckline depth (front)	20cm					
4 neckline width (Back)	15cm					
5 neckline depth (Back)	9cm					
6 upper Garment width	17cm					
7 upper Garment length	30cm					
8 slope of Armhole (F+B)	10cm					
9 split length	15cm					
10 hem width	59cm					
11 length from split-underarm	35cm					
12 waist width	58cm					
13 arm hole depth	25cm					
Trims/Comments: neck line/Arm holes: 2x1rib hem: tubular welt split? no welt??	3cm 4cm					

Using the Shima interface, the garments were then created as packages and exported to the design CAD interface to virtually simulate the knitted garment view. This is an area of knitwear technologist specialisation, involving the programming of the machines to create the desired garments. As some of the shapes weren't traditional garment shapes already in the machine, CAD garment shape library the technologist had to create these manually by building 'packages' for the knitting machine to understand.

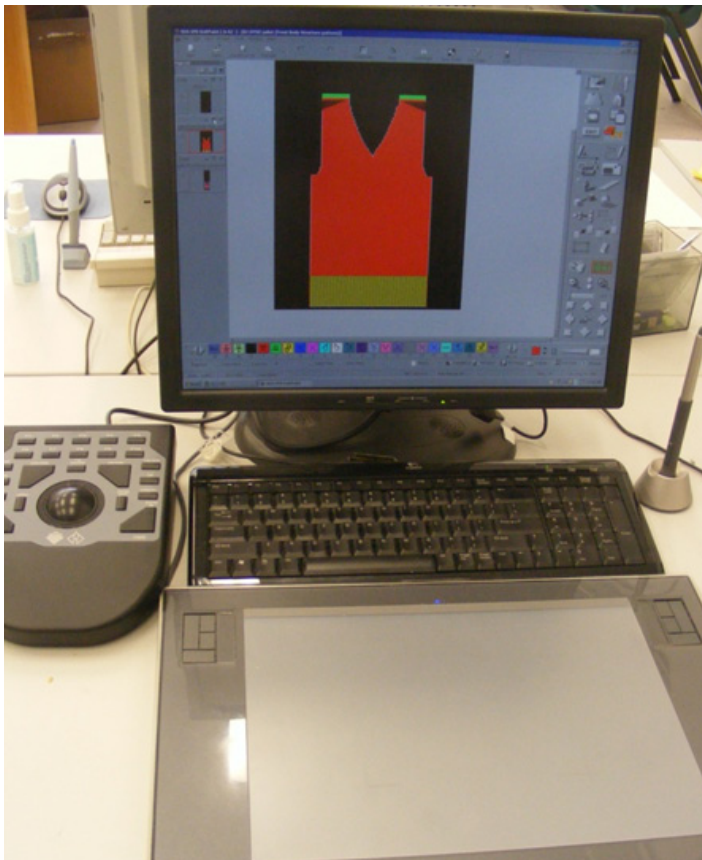
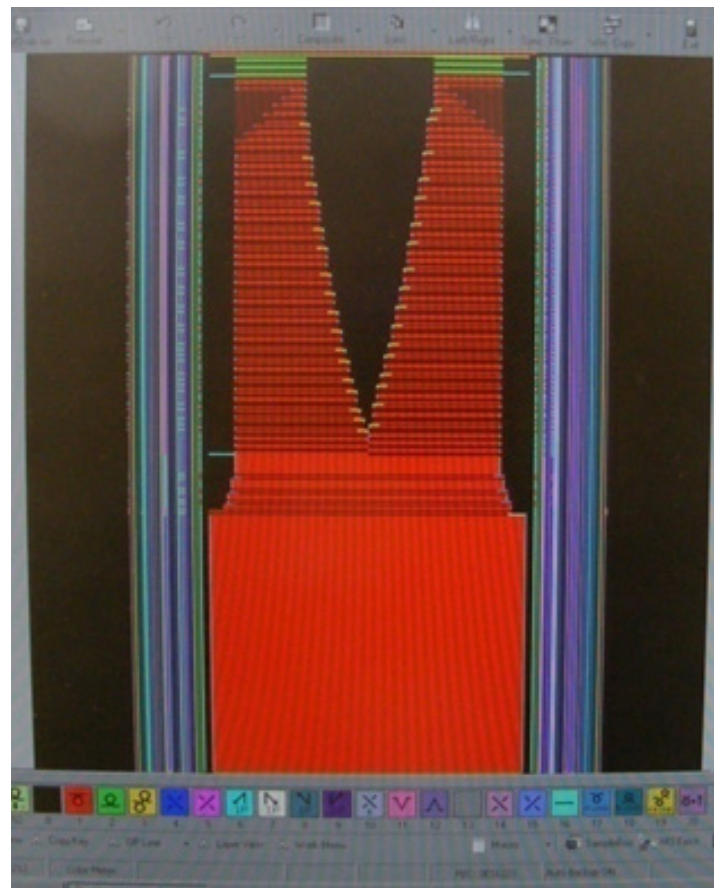


Fig2:15 (Opposite page) This image shows the communication of the technical garment information between designer and technologist.

Fig2:16(Below left) and Fig 2:17 This is the technical view of the Shima Seiki CAD programme, which is where technicians build the garment shapes for knitting.



After the garment is processed by the computer the designer can use the same software (Design CAD) which gives you a virtual view of the garment. The programmed designs can then be taken into the design CAD program and can be virtually simulated with the correct yarn colour, gauge and yarn count, to show a finished knitted image of the garment, even before it has gone to the machine to be physically knitted. The textile print can then be 'virtually' applied to the garment through a technique called 'mesh mapping'. This places the print onto the garment by taking the shape, gauge and texture of the knit into consideration.

I produced a lot of designs in this way, using the design interface of the Shima Seiki software to help visualise the end product. Though design and technical development changes were made along the way, this was a really useful process to help to determine how the garment would look, without knitting a stitch. This process had some drawbacks when it came to simulating fuller, draped garments, although for print placement it was an effective tool to use as this work was being designed and created in a digital medium.



Fig2:18 (Above right) and Fig 2:19 (Opposite page) Here you can see a photo shop design I created on the left, and then the quality of the virtually knitted garment with the print applied which shows a lot more depth and texture of the print, below.

This was a useful way of working, using the Shima design interface in combination with the Shima knitting machine, as information could be easily transferred.

The use of the Shima Design CAD can emulate knitted fabric to a fuller extent - even down to gauge and yarn type. This would be a difficult process to achieve in Photoshop, which would take several stages to complete.





This virtual simulation of the garment on a mannequin is also a useful technique which Shima design CAD offers. It is used through the 'template mapping' technique, which allows the garment to be fitted to the mannequin. With this version of the software I was unable to see a 'draped' version of this garment, though with the new Shima Seiki 'Apex' Design CAD interface this virtual view is now possible.



Fig 2:20(Above left) and Fig 2:21 (Right) Shows the flat image being translated into a virtually simulated garment which wraps around the body.

Garment Design Visualisation

The following images show the steps of creating a design visualisation using a print swatch which is then placed using mesh mapping onto a virtual mannequin retrieved from the Shima database. This is then mapped onto a real model, also from the Shima database, using another technique called template mapping.



This technique is helpful for designers to get a more comprehensive idea of the completed design. Being able to apply the print and texture of the garment is a lot more accurate than the two dimensional sketches traditionally used in this process.

This method is also an important tool in communication to other people involved in the garment design process. Ideas can be abstract and hard to explain in words so these visual representations give a clear indication of the shape, colour and scale of the print the intended garment is to have.

Fig2:22 (Above left), Fig 2:23 (Above right), and Fig 2:24 (Below right) Shows the mesh mapping technique available on the Shima Seiki SDS-ONE® design CAD.

Digital Printing

The next step was the physical production of the garments. They were knitted, then pre-treated ready for print to allow binder chemicals to adhere to the yarns. Once completely dry, they were placed on the print bed in a cardboard former (visible in the picture below) to keep the garment flat for a digitally printed design to be accurately applied. This particular garment used panel printing and was printed all over front and back. I designed the print in such a way that the abstraction of the background image was forgiving if a margin of error occurred across join lines in the garment.

The garment was then taken through a heat setting process in a tunnel dryer so that the dye can set and the reverse side of the garment can be printed. This technique of printing is similar to an engineered print, as the print comes together at the seams. As mentioned earlier, this print was designed as a 'forgiving' print as, due to the stretch and tension of knitwear, it can be difficult to get exact matches over seam intersections.

The other garments were either printed as placement prints, on front or back, or they were printed over seam lines. This happened on the fully fashioned garments, which were linked together on the shoulder seam and around the arm hole, then laid flat for printing.



Fig2:25 (Above) This image shows the garment half assembled ready for the printing process. The print has been designed in such a way so that the print will continue across the shoulder seam to the back of the garment. The print orientation is an important consideration when making prints for the front and back of the garment

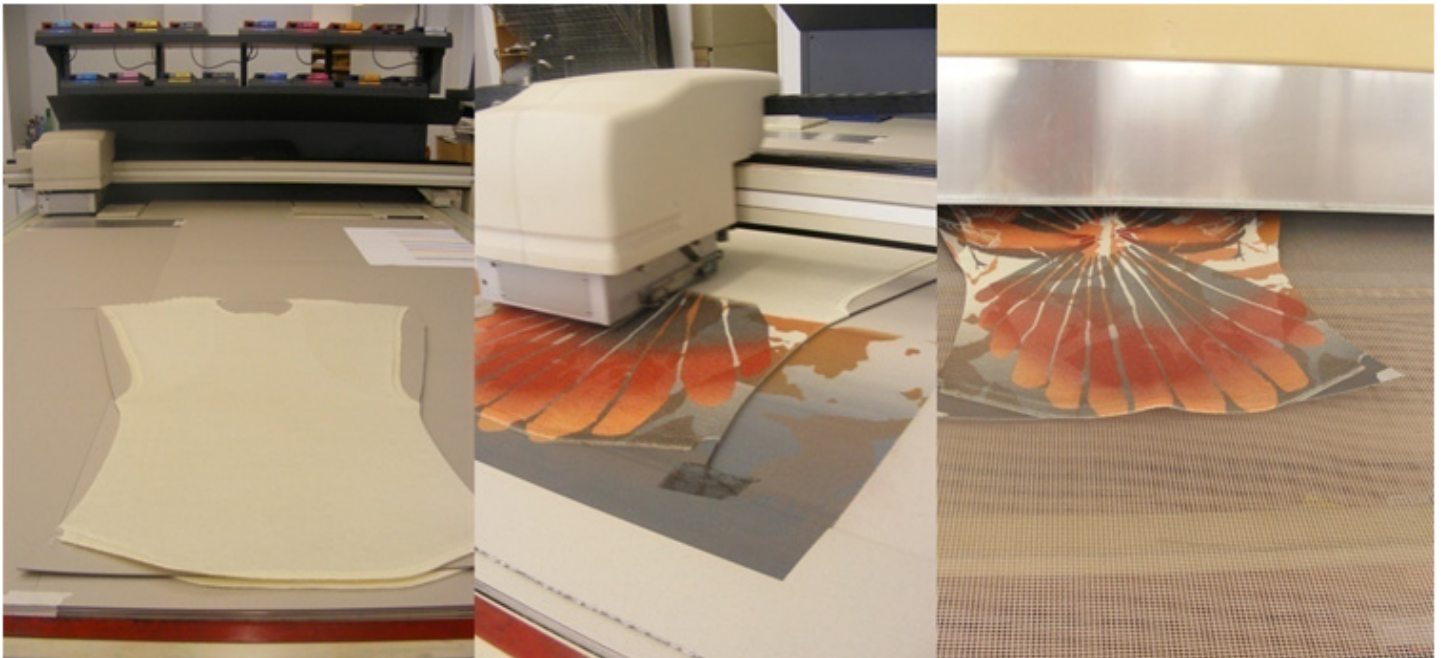


Fig2:26 (Above) This image shows on the left, the cardboard former used to keep the garment flat for printing, the middle image is the SIP 160F print head traversing across the bed width printing fine particles of dye over the garment.

Fig2:27 (Right) Shows the seam line printed over when sewn up pre-printing.



Post-Printing treatment:

After printing, the garments went through the tunnel dryer and then into the steamer to set the dyes. They are then washed by being put through gentle rinse cycles to expel any surface dye that may not have adhered to fabric. Depending on the size of the garment and the print, this can take up to 3-4 wash cycles. They are then dried either in the tumble dryer, or laid flat to dry in room temperature.

Due to the yarn being a natural, protein fibre the post printing treatment was different to that of a synthetic yarn. This is due to the type of dye that is used in the printing of the garment. Wool is most commonly printed using a reactive dye which needs a more through post treating process. This is in contrast to pigment dye, which bonds better to synthetic fibres. The post-printing process for pigment inks is usually tunnel drying so no washing needs to take place. This difference in fixing processes effects the production costs of printed garments, due to extra time and processing acquired for reactive dyes. However the 'handle' of reactive dyes is usual softer and fabrics feel more luxurious.



Fig 2:28 (Top right) Tunnel Dryer.

Fig 2:29 (Middle right) Industrial Steamer.

Fig 2:30 (opposite) Washing Machine.

Fig 2:31 (Opoosite page) Shows the linking machines used to complete the two fully fashioned garments. Over locking was also used in the assembly of the neck ribs.



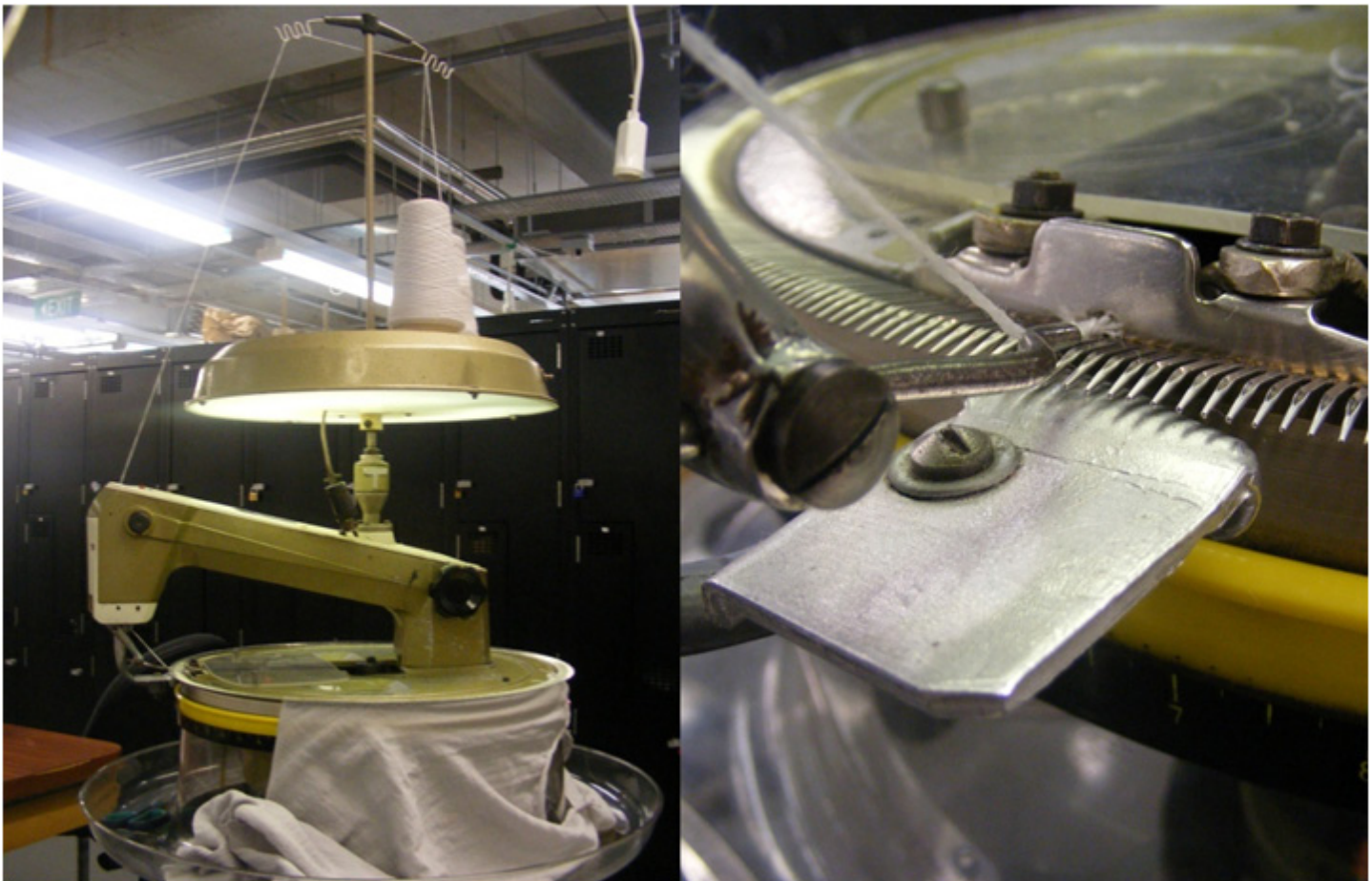
Garment Construction

The two fully fashioned garments were first linked over the shoulder seams and the crown of the armhole, to get a more accurate print placement on the garment. They were then taped down onto cardboard and printed as usual, then afterwards sewn up down the side seams, also using a linker.

The other garments were whole garment designs, which came off the machine with no post-knitting construction required.

Final garments completed:

My final collection was then styled with other winter merino garments and accessories to create six outfits, and a photo shoot was conducted to produce professional photos for research and promotional end uses. The next stage in the research process was an exhibition evening to which industry professionals and education staff was invited to. This is discussed in part three of the report.



Part Three

Photoshoot of Promotional Collection



Defining Flight

A/W 2010/11





































Exhibition of Collection

Presentation at Design Symposium

Part way through the project I was invited to speak at the T&DL Design Symposium: Digital Strategies. I was asked to give a presentation on the different aspects of this project and the results gained so far. This was useful as it gave me some good indications of response to the project in terms of the New Zealand industry, as the majority of people attending were working within this arena. It also gave me an indication of the importance of the design process, costing and the commercial application of the project as businesses are very concerned

Fig 3:1 (Below) Knitwear Exhibition evening at the T&DL.

with 'price'. In response to this feedback a costing sheet was developed for each garment (see page 167).

The final part of the project utilised this collection from a commercial perspective to form a promotional tool to educate and evaluate industry feedback on digital printing, specifically about print on knitwear in a New Zealand context. After the collection was produced it was then set up in the display area of the T&DL at AUT University with fashion industry, post graduate students, and academic teaching staff was invited to view the collection and give feedback on the results.





This was a successful evening, with the garments being displayed in an exhibition setting to showcase the innovative and practical application of this technology. Though it did not gather enough feedback to draw conclusive results.

Another, more individual assessment was conducted with the collection pieces, professional look book, and a questionnaire which was taken out to selected knitting companies and designers to gather fuller, more comprehensive feedback. The following information was provided to the participants:

Fig 3:2 (Opposite page) Knitwear Exhibition evening at the T&DL.

Fig 3:3 (Below left) Knitwear Exhibition evening at the T&DL.

Fig 3:4 (Below right) Knitwear Exhibition evening at the T&DL.



Industry Survey

As part of the research conducted through out this project a survey was electronically sent out to thirty business around New Zealand. This was done via 'Survey Monkey' and was a preliminary questionnaire to gain feedback from the industry about thier ideas, perception and knowledge of print on knit.

This was sent out whilst the collection was being completed, then afterwards the comanies which resopned positively to the survey could then view the collection and answer additional questions.

The survey questions were as follows:

1. Company Details:

2. Are you responding to this survey as:

A Free lance designer

Representing a company with five or less full time staff

Representing a company with ten or less full time staff

Representing a company with more than ten full time staff

Representing a company with more than twenty full time staff

3. Do you or your company create your own print designs for garments or accessories?

4. What methods do you currently use to produce textile prints?

Screen printing in New Zealand

Screen printing off shore

Digital printing in New Zealand

Digital printing off shore

5. Why don't you create your own print designs for garments?

It's too expensive

Not part of our style/look

Do not have the expertise

Do not have the facilities

It is too difficult to access

Happy using commercial stock fabric

6. Are you interested in learning more about digital print?

7. What aspects of print would you like to learn more about?

Placement prints on garments or accessories

Engineered prints (on pattern shapes)

Developing pre-production samples

Digital textile design

8. Do you ever include knitwear in your collections?

9. Do you have knitwear manufactured?

10. Which construction techniques do you use for knitwear?

Cut and sew

Fully fashioned

Whole or seamless knit

11. We do not include knitwear in our collection because:

Does not suit our style/design approach

Do not have knit design expertise

Difficult to access manufactures

Too expensive

Available scales of production are too large

Have never considered including knit

Not interested in knitwear

12. *Have you ever used print on knitwear in your collections?*

13. *How would you describe the result of using print on knitwear?*

Highly satisfactory

Satisfactory

Unsatisfactory

14. *We have not used print on knitwear because:*

We do not produce knitwear

Was not aware this could be done

Concerns about garment handle with print process

Additional cost involved

Could not access expertise could not access technology

Print does not fit in with our style/ design approach

15. *Are you aware of the WholeGarment® knitwear capability at the TDL at AUT University?*

16. *Would you be interested in finding out more about digital print on knitwear at the TDL?*

17. *What areas would you be interested in learning more about?*

Design approaches for digitally printed knitwear

Wholegarment® knitting

Knitwear design using Shima Seiki CAD system

Knitted accessories

18. *Would you be interested in seeing a range of digitally printed*

knitwear especially developed at the TDL by AUT Master's student Alysha Gover to showcase some innovative applications of print on knitwear?

Survey Summary

There were nine responses out of thirty companies or individuals contacted. Of these six companies were based in Auckland and one each from Rotorua, Christchurch and Dunedin. Of these respondents three represented companies of five or less staff, one was from a company with more than ten staff and five were from companies with more than twenty staff.

Eight companies used some printing in their products. Of these six had used screen printing in NZ. Three had used screen printing off shore. Three had used digital printing in NZ and two had used digital printing off shore.

When asked why companies didn't develop their own original print designs for garments, three said it was too expensive, two said it was not part of their style. One said they did not have the expertise and two added that they did not have ease of access to facilities. Seven companies were interested in learning more about digital printing. Two were not interested.

Four companies were interested in learning more about placement prints on garments. Two were interested in engineering prints, three in pre-production sampling and two in digital textile design. Eight companies used knitwear in their ranges. Five companies have knitwear manufactured in NZ, four have it manufactured internationally. In relation to garment construction techniques eight companies used cut and sew, five used fully-fashioned and three were also using whole or seamless garment technology.

One company did not include knitwear in their range because available scales of production are too large. Six companies had previously used print on knitwear in their collections; two had not tried to do this. Four of these companies were very satisfied with the results of print on knitwear, two were satisfied. Two companies had not used print on knitwear because of the additional cost involved.

garment knitwear development capability at the TDL at AUT University. Four companies were interested in finding out more about digital print on knit at the TDL, three companies were not interested. Three respondents were interested in design approaches for digitally printed knitwear. Two were interested in knowing more about whole garment knitting. One was interested in learning more about knitwear design using Shima Seiki CAD system. One was interested in learning about knitted accessories.

Five companies were interested in seeing the range of digitally printed knitwear specially developed at the TDL by AUT masters student Alysha Gover to showcase innovative applications of print on knitwear.

The initial feedback gained from this survey helped me to gauge the level of usage in print on knit in the industry and how my promotional collection could be applied effectively for industry visits.

After this questionnaire I then developed a set of questions to ask on my visits to the industry to gain further feedback and opinions.

Costing Sheet*

STYLE	YARN	KNITTING TIME	PRINT	+25% T&DL	TOTAL
<i>Men's round neck jumper</i>	265g @ \$60.00 = \$16.00	37 minutes \$24.70	\$60.00	\$25.00	\$126.00
<i>Women's round neck jumper</i>	265g @ \$30.00 =\$8.00	51 minutes \$34.00	\$60.00	\$25.00	\$126.00
<i>Women's singlet</i>	250g @ \$30.00 =\$7.50	27 minutes \$18.00	\$60.00	\$21.50	\$107.00
<i>Women's drop shoulder dress</i>	300g @ \$30.00 =\$9.00	51 minutes \$34.00	\$60.00	\$26.00	\$129.00
<i>Women's drape dress</i>	350g @ \$30.00 =\$10.50	48 minutes \$32.00	\$60.00	\$25.50	\$129.00
<i>Women's kimono top</i>	570g @ \$60.00 =\$34.20	67 minutes \$44.70	\$60.00	\$34.70	\$174.00

*All costing of the collection is calculated on 20 units.

Presentation to Industry Businesses

The following questions were asked across all interviews conducted, whether they were designers, or knitting industry employees. These questions were asked in the same sequential order after garments from the collection and the look book had been viewed.

1. Were you aware print on knit could be used in this way?
2. Do you see potential for print on knit in your own collections?
3. Do you think the industry may adopt this method of printing?
4. Any other comments?

These questions were asked to the following people/companies:

Designers: 8

Knitwear manufacturers: 2

The responses to these questions are detailed in the following information tables:

<u>Business One:</u>	
<u>Background:</u>	Designer
<u>Company Information:</u>	Knits with whole garment as well as fully fashioned knitwear. Knitwear comprises 90% of range. Uses cashmere, merino, alpaca. Markets knitwear in high fashion sector. New Zealand made products.
1. <i>Were you aware print could be used on knit in this way?</i>	Yes.
2. <i>Do you see potential for print on knit in your own collections?</i>	Yes, sees potential. Main issue is price. Can screen print for \$2.50 per garment, as opposed to \$18.00 per garment for digital print.
3. <i>Do you think the industry may adopt this method of printing?</i>	Yes. Could create garments that are marketable in Scotties, which could be the high fashion price point. Could use luxury fibres such as cashmere.
4. <i>Any other comments?</i>	-Likes the idea. -Programming of printing is the main time constraint. -Like the nice joins intarsia has- would lose this if garment was printed intarsia instead. -can achieve bigger areas of print using digital, as opposed to the limitations of a screen. -Likes the idea of the use of technology.

<u>Business Two:</u>	
<u>Background:</u>	Designer
<u>Company Information:</u>	Produces high fashion knitwear. Shows at New Zealand Fashion Week. Designs are created in NZ, off shore manufacturing. Mainly 90% knitwear collections. Cut and sew, and fully fashioned. Uses a variety of different yarns for each season
1. <i>Were you aware print could be used on knit in this way?</i>	Yes.
2. <i>Do you see potential for print on knit in your own collections?</i>	Price- First main concern. As industry how would you go about creating a digital print (unsure of process-lack of knowledge). Dates of delivery of garments- would need to coincide with off shore production.
3. <i>Do you think the industry may adopt this method of printing?</i>	Summer collections- use lighter yarns, so more viable to print on a lighter colour. Winter collections- use mainly heavier yarns for texture, printing would be lost.
4. <i>Any other comments?</i>	<ul style="list-style-type: none"> - This company usually gets colour in by the use of stripes, or yarns dyed to specific colours. - Use of plaiting to also get colour in. - The T&DL needs to become recognised as not just a 'university institution'. Needs industry folk involved. - Would require more people to be aware of this to bring the price down. - Industry needs to gain more knowledge on this technology in order to see the possibilities of it as a printing method. - The time to also have the skill and ability to make the print well- often big time constraints when working on a collection.

<u>Business Three:</u>	
<u>Background:</u>	Designer
<u>Company Information:</u>	Shows in New Zealand fashion week. Collections have a graphic 'edge' to them. Highly print focused. Produces some knitwear pieces in collection- cut and sew.
1. <i>Were you aware print could be used on knit in this way?</i>	Yes. Has printed on knitwear before.
2. <i>Do you see potential for print on knit in your own collections?</i>	Yes. Viability of where you can get it produced. Prices? Timelines?
3. <i>Do you think the industry may adopt this method of printing?</i>	Yes. This company designs their own prints on woven fabrics already through the use of screen printing large lengths of fabric.
4. <i>Any other comments?</i>	<ul style="list-style-type: none"> - This company incorporates colour into their collection by the use of accessories/ - Digital printing looks too 'computer generated'. - Likes the look of the prints being done by screen prints. Appreciates the craftsmanship in a print, and therefore finds digital printing too removed from an artistic perspective. - Liked the promotional collection as even though it was digitally printed, it still looks like it could have been screen printed- has drawing elements in it, which look artisanal.

<u>Business Four:</u>	
<u>Background:</u>	Knitwear Manufacturer
<u>Company Information:</u>	Produces Knitwear in New Zealand, mainly for the tourist market. Sells in medium-high price bracket. Sells to older demographic. Knitwear is 100% of their label. Produces whole garment and fully fashioned pieces. Uses luxury fibres such as fine gauge merino and Perino.
1. <i>Were you aware print could be used on knit in this way?</i>	Yes. Has printed on knitwear before.
2. <i>Do you see potential for print on knit in your own collections?</i>	No. Price point would be too high. Achieves getting colour into garments through intarsia and jacquard. Would slow down production time as all knitwear gets produced in house. Would mean garments would have to be sent elsewhere for printing.
3. <i>Do you think the industry may adopt this method of printing?</i>	Yes. Only in the high end fashion driven market, aimed at younger consumers.
4. <i>Any other comments?</i>	<ul style="list-style-type: none"> - Likes the fact with digital printing you can achieve. - sweeping fluid lines- can't do that with intarsia/jacquard. - Knitting in the colour is the most cost effective way for this company. - Might possibly look at this technology in the future when the cost isn't so high. - Like the promotional collection, has great direction.

<u>Business Five:</u>	
<u>Background:</u>	Designer
<u>Company Information:</u>	New Zealand based fashion company, designs and produces on shore. Shows at new Zealand Fashion Week. Produces basics and occasions wear, with 'fashion pieces' as a sub theme to collections. Mainly uses cut and sew knitwear in collection. Has six stores throughout New Zealand.
1. <i>Were you aware print could be used on knit in this way?</i>	Yes. Had attended the Digital Strategies textile symposium (2010). Had been aware of print on knit before this.
2. <i>Do you see potential for print on knit in your own collections?</i>	Looking into the possibility. Would like to start off with placement prints to show in Fashion Week this year.
3. <i>Do you think the industry may adopt this method of printing?</i>	Depends on the market. Cost would need to be reduced.
4. <i>Any other comments?</i>	<ul style="list-style-type: none"> - Uses digital printing to test screen prints out before hand. - Thinks digital printing for promotional purposes, like Telecom- who would only need 15-20 promotional shirts printed. - Achieves colour in the designs by zips, buttons and ribbons. - 40% of fabric is already patterned, polka dots, stripes etc.

<u>Business Six:</u>	
<u>Background:</u>	Designer
<u>Company Information:</u>	Strong knitwear producer with multiple ranges. New Zealand based fashion company, designs and produces on shore. 90% of garments are knitwear. Uses fully fashioned and cut and sew techniques. Sells basics, not too trend driven. Middle to upper price point. Has older clientele.
1. <i>Were you aware print could be used on knit in this way?</i>	Yes, has been to the T&DL (has seen the promotional collection already).
2. <i>Do you see potential for print on knit in your own collections?</i>	No. Seems too expensive for the commercial companies in their price bracket. Price needs to come down before they think of using it.
3. <i>Do you think the industry may adopt this method of printing?</i>	Yes. For higher price points though, like Karen Walker, Kate Sylvester.
4. <i>Any other comments?</i>	- If they did use digital printing, would outsource the work.

<u>Business Seven:</u>	
<u>Background:</u>	Designer
<u>Company Information:</u>	Well known High fashion company. Shows at fashion week. Has 20% knitwear in range, fully fashioned and cut and sew. Uses a lot of texture and patterns in collection. Has three other labels operating under the namesake label.
1. <i>Were you aware print could be used on knit in this way?</i>	Yes, has been to the T&DL. Was not aware however that digital printing could be used in this way (printing onto knitwear).
2. <i>Do you see potential for print on knit in your own collections?</i>	Yes.
3. <i>Do you think the industry may adopt this method of printing?</i>	Yes. A very progressive technology based medium, could catch on quickly in New Zealand. More people in the industry need to be educated about using this method of printing (awareness, education).
4. <i>Any other comments?</i>	<ul style="list-style-type: none"> - Excited about the potential of print on knit. - Like the idea that more colours can be used in printing.

<u>Business Eight:</u>	
<u>Background:</u>	Designer
<u>Company Information:</u>	Designer and creator of fashion company. Creates handmade as well as whole garment 'bespoke' knitwear pieces. Uses alpaca and cashmere yarns. Sells largely to Australia.
1. <i>Were you aware print could be used on knit in this way?</i>	Yes, has been to the T&DL and had work done there.
2. <i>Do you see potential for print on knit in your own collections?</i>	Yes.
3. <i>Do you think the industry may adopt this method of printing?</i>	Yes. In the high end, designer goods market.
4. <i>Any other comments?</i>	<ul style="list-style-type: none"> - Digital printing is great that it doesn't compromise the handle of the knit. - Can see limitations in the means of seam overlaps and print matching.

<u>Business Nine:</u>	
<u>Background:</u>	Designer
<u>Company Information:</u>	Designer and creator of fashion company. Shows at Fashion Week. Well known NZ label. Produces a range of menswear and women's wear. Has 20% of collection as knitwear. Cut and sew and fully fashioned.
1. <i>Were you aware print could be used on knit in this way?</i>	Yes.
2. <i>Do you see potential for print on knit in your own collections?</i>	No. Is not the right aesthetic for our collections.
3. <i>Do you think the industry may adopt this method of printing?</i>	Yes. Not until the price is lowered. This will only happen by educating the industry. Maybe in five to ten years it will become more freely accessible and available on the main stream market.
4. <i>Any other comments?</i>	- Other companies are doing digital print really well, good examples of it out there.

<u>Business Ten:</u>	
<u>Background:</u>	Designer
<u>Company Information:</u>	Shows at Fashion Week. Produces a range of menswear and women's wear. Has 10% of collection as knitwear. Cut and sew and fully fashioned. Sells worldwide.
1. <i>Were you aware print could be used on knit in this way?</i>	Aware of digital printing, but not onto knitwear.
2. <i>Do you see potential for print on knit in your own collections?</i>	Yes, possibly next season.
3. <i>Do you think the industry may adopt this method of printing?</i>	Yes. For the high fashion sector, boutique ranges of the collection. Have seen a lot of it overseas.
4. <i>Any other comments?</i>	- Usually use screen prints for textiles, but would be open to digital printing.

Feed back From Industry

Visiting New Zealand based fashion companies and presenting the T&DL promotional range was a very exciting and beneficial aspect of this project. As well as being an academically based project which informed the development of my Masters study, it was a great marriage between post graduate research and industry application. This was a practical ‘bridging’ of knowledge which allowed my research to be shown, speculated and evaluated by the industry itself.

I was surprised by how many businesses were not aware this technology was available in New Zealand and though many had heard of ‘digital printing’ they often had no idea of the process, or application involved in producing digital textile prints. This shows a chasm between the investment of new, cutting edge technology and investment in industry education about the technology to be able to confidently use it as a viable textile printing option. This is in spite of the T&DL’s efforts over three years to publicise and involve industry in training sessions for both print and knit design and production. As the ‘set up’ of a digital print is fairly different to that of a conventional textile print, many companies were unsure of the way to go about designing prints let alone producing them. In such cases out sourcing to a designer would be necessary which would increase costs even before the actual printing.

Cost was the issue most businesses bought up as the first initial factor as to why they wouldn’t use digital printing at the moment. This issue goes hand in hand with the lack of education of this product, which means that many place it in the realm of ‘speciality applications’ which means less people use it which consequently affects the cost of production. In the future, hopefully there will become more awareness of digital printing, and the cost will be lowered due to more demand for the machinery and scales of production.

This is a different response to the use of digital printing in

an educational and research context. As students aren’t as limited by cost or time efficiency, digital printing has taken on a highly experimental form of printing by university students¹. The limitless possibilities have appealed to fashion and textile students, who have produced many inspiring products to show the industry the commercial application of digital printing in the years to come. These technologically informed and capable students going out into industry is one of the best ways of challenging this lack of industry awareness and many projects have been brought to the T&DL by these graduates working in industry. There has also been interest in digital print technology for spatial design students, graphic design, visual arts, and product designers. Local Artists and costume designers have also employed the facilities at the T&DL for print replication onto fabric for further extension of their work to a digital medium.

As shown in the contextual review of digital printing technology used overseas earlier in this report, it is apparent that the market is picking up on this recent textile technology. In terms of the use of printing in a New Zealand application and information gathered through industry feedback, Interest is already building in this area. In a few years there will be a wider, more common use of this textile application, which would mean production prices would be lowered due to higher customer demand. As Universities like AUT are producing more students who are capable of using this technology, the change of traditional textile applications will start to shift into technology based applications. This will help the integration of technology to become more natural as future graduates are employed in the industry.

Conclusions on TEC Research Project

This project was undertaken to try and identify why New Zealand companies had been slow to develop innovative applications of digital print on knitwear, given the relative strength of the NZ knitwear sector in relation to other NZ apparel sectors; the exciting work that is beginning to be produced internationally using these technologies; and the opportunities offered at the Textile and Design Laboratory at AUT for industry learning and product innovation support. This research has been valuable in beginning to identifying levels of interest and specific issues effecting use and understanding of digital print and knit technologies in the New Zealand apparel industry. While the level of industry response to the general survey was not high enough to do any statistical analysis, this was only one aspect of a multi-stranded project that also involved an international and national review of current uses of digital print and knit, the design and development of a demonstration collection of printed knitwear with follow up viewing and interviews with selected designers and companies, and a conference paper presentation at a symposium with industry feedback.

The enthusiasm that the NZ fashion industry has towards new technologies was evident in the research. Eighty percent of companies interviewed clearly indicated that they could see the value of uptake in this technology. However cost factors inhibit use – production costs are always a factor in the NZ apparel industry where smaller scales of production means that overheads have to be tightly controlled. This would seem to be exacerbated by the current economic downturn which is making companies reluctant to pursue commercial applications of these new production methods.

As the questionnaires indicated, the majority of companies contacted would be interested to learn more about these areas of digital textiles in relation to their work. The Textile and Design Laboratory offers educational facilities and expertise

to industry through short courses about these technologies and introductions to the process of digital textile design. While knowledge of the T&DL was widespread, understanding of what was available regarding training and support for product development was not as high, indicating that despite considerable publicity and profile there is still work to do in making industry aware of how the T&DL can support fashion and apparel design companies, and the opportunities offered by these new technologies. The T&DL also functions as an experimental laboratory in running initial print samples, or trying innovative ideas. Through this medium of 'on demand' printing at the T&DL, businesses can try out ideas and print development, without a large cost of time or money to see how these applications may fit into their company aesthetic.

Producing tangible examples of how these new technologies can be innovatively used to provide distinctive knitwear design – as developed in this project- allowed designers to see and feel the potential of these new approaches. It also helped educate designers about the different ways print can work with a range of construction techniques, and how these different approaches effect production time and cost, as well as the distinctive aesthetic effects that can be developed. It is anticipated that the information provided to designers through the specially designed knit and print collection, and the knowledge gained about the concerns and understandings of industry towards these technologies will lead to an uptake of interest in the coming years regarding these textile applications.

Appendix 1 End Notes:

Digitally printed silk dresses by Debra Laraman & Donna Dinsdale, Bay Of Plenty Polytechnic, 2007.

Image retrieved September 17, 2010, from <http://www.tdl.aut.ac.nz>



Karen Chen, AUT University, 2007.

Image retrieved September 17, 2010, from <http://www.tdl.aut.ac.nz>



Natalie Allingham, AUT University, 2008.

Image retrieved September 17, 2010, from <http://www.tdl.aut.ac.nz>



Nadeesha Goddumanne, AUT University, 2008.

Image retrieved September 17, 2010, from <http://www.tdl.aut.ac.nz>

1. These Images above are some work of University level students undertaking digital print in interesting, innovative ways. If these ideas are applied and adopted into the industry, there could be some exciting innovations and textile direction taking place.

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Appendix 2: Viva & Exhibition



The final exhibition was made up of the five final outcomes of each quasi experiment. These half scale garments were displayed on five mannequins positioned around the exhibition space on white plinths. Macro images of different areas of each garment on display were also shown in A3 size behind the garments. There was also a table at the edge of the exhibition displaying various test swatches and other working experiments. This tactile table gave viewers of the work a good idea as to the experimental nature of this work.

The Master's exhibition was in collation with AUT's 'AD2010' Exhibition, held for a week over the 9th to 14th of November 2010.





Quasi Experiment One exhibition piece: Shape and yarn integration.



Quasi Experiment One exhibition piece: Shape and yarn integration.



Quasi Experiment Two exhibition piece: Structure and yarn integration.



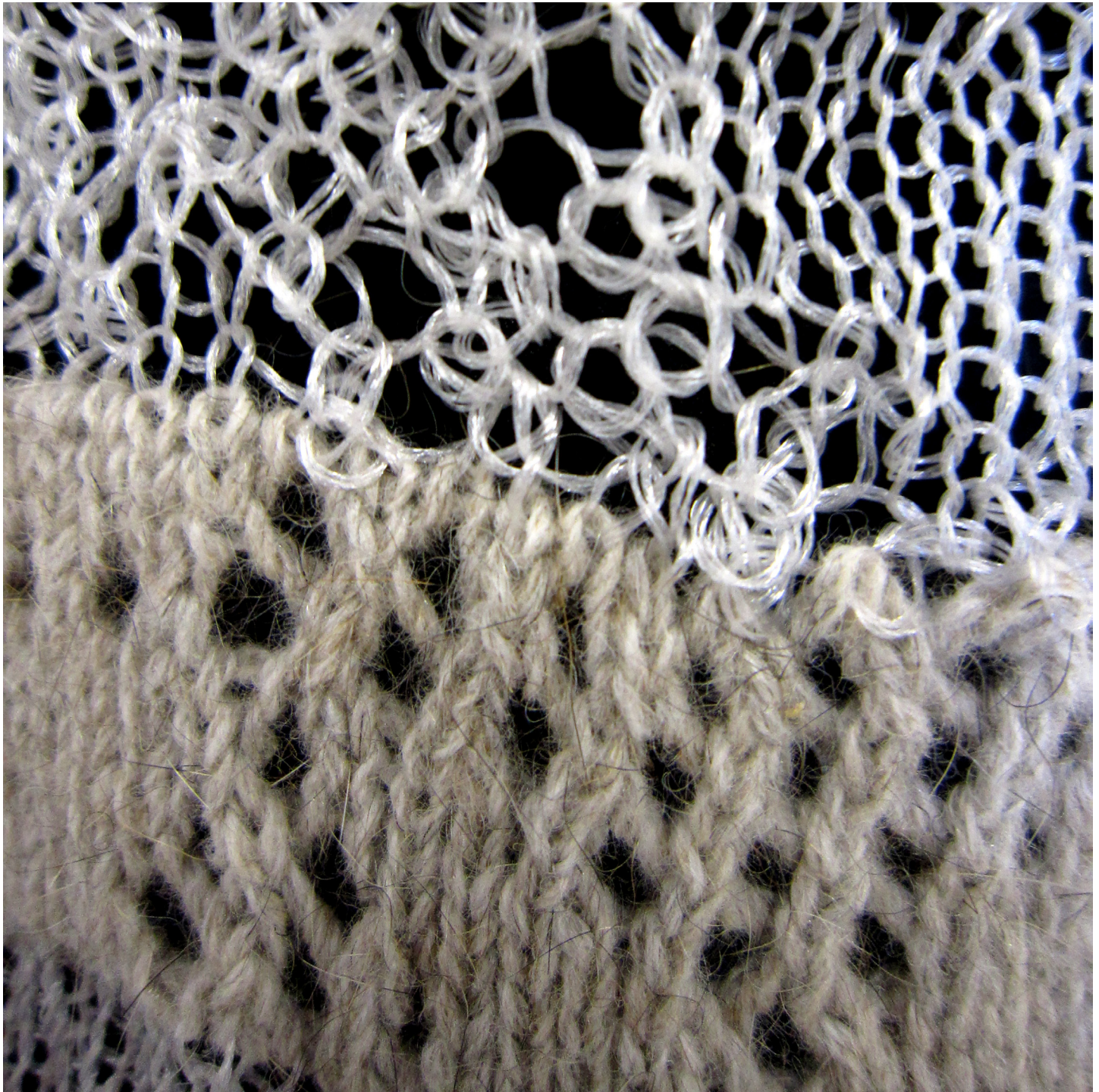
Quasi Experiment Two exhibition piece: Structure and yarn integration.



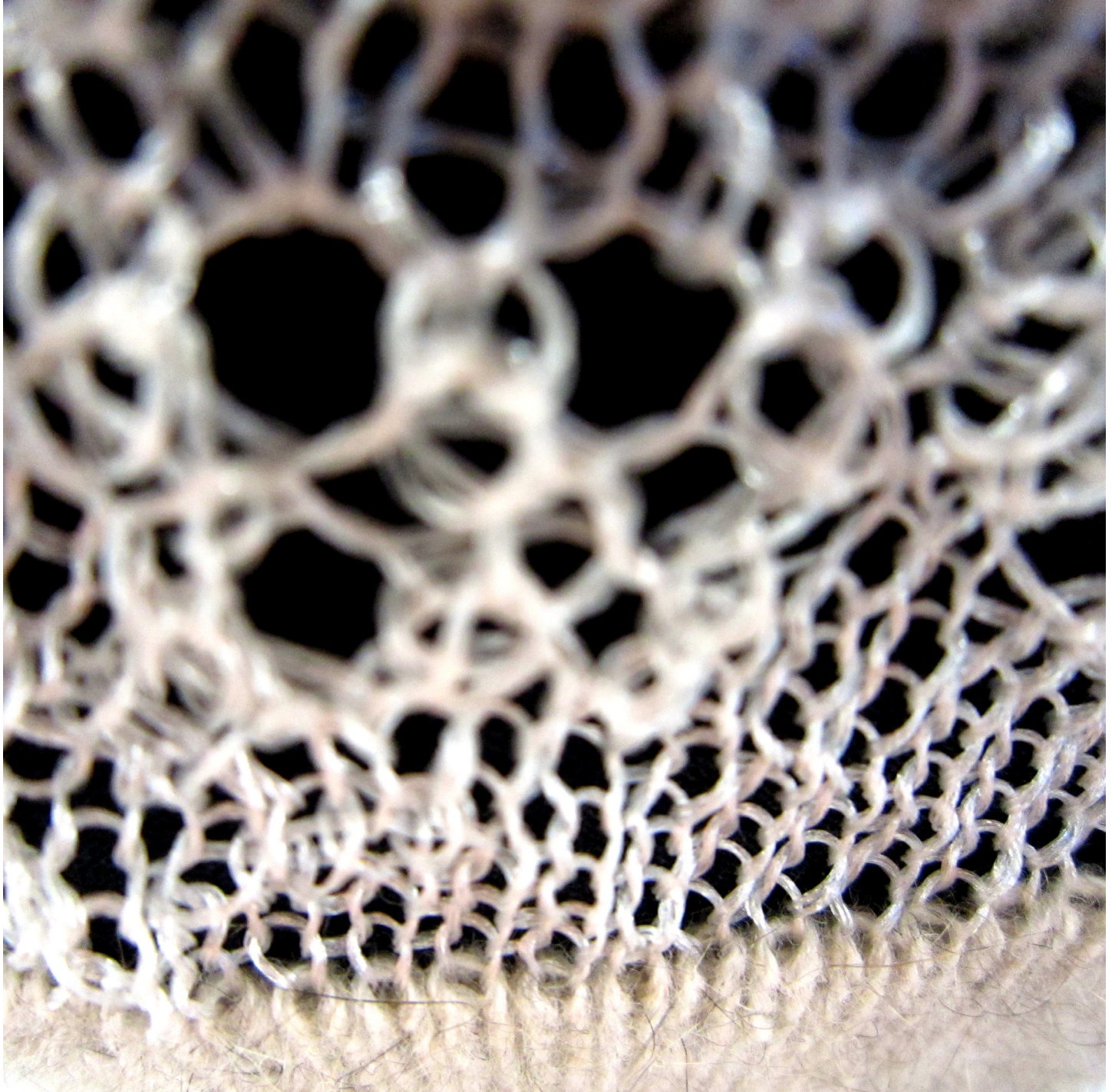
Quasi Experiment Three exhibition piece (A): Digital textile printing and shape development.



Quasi Experiment Three exhibition piece (A): Digital textile printing and shape development.



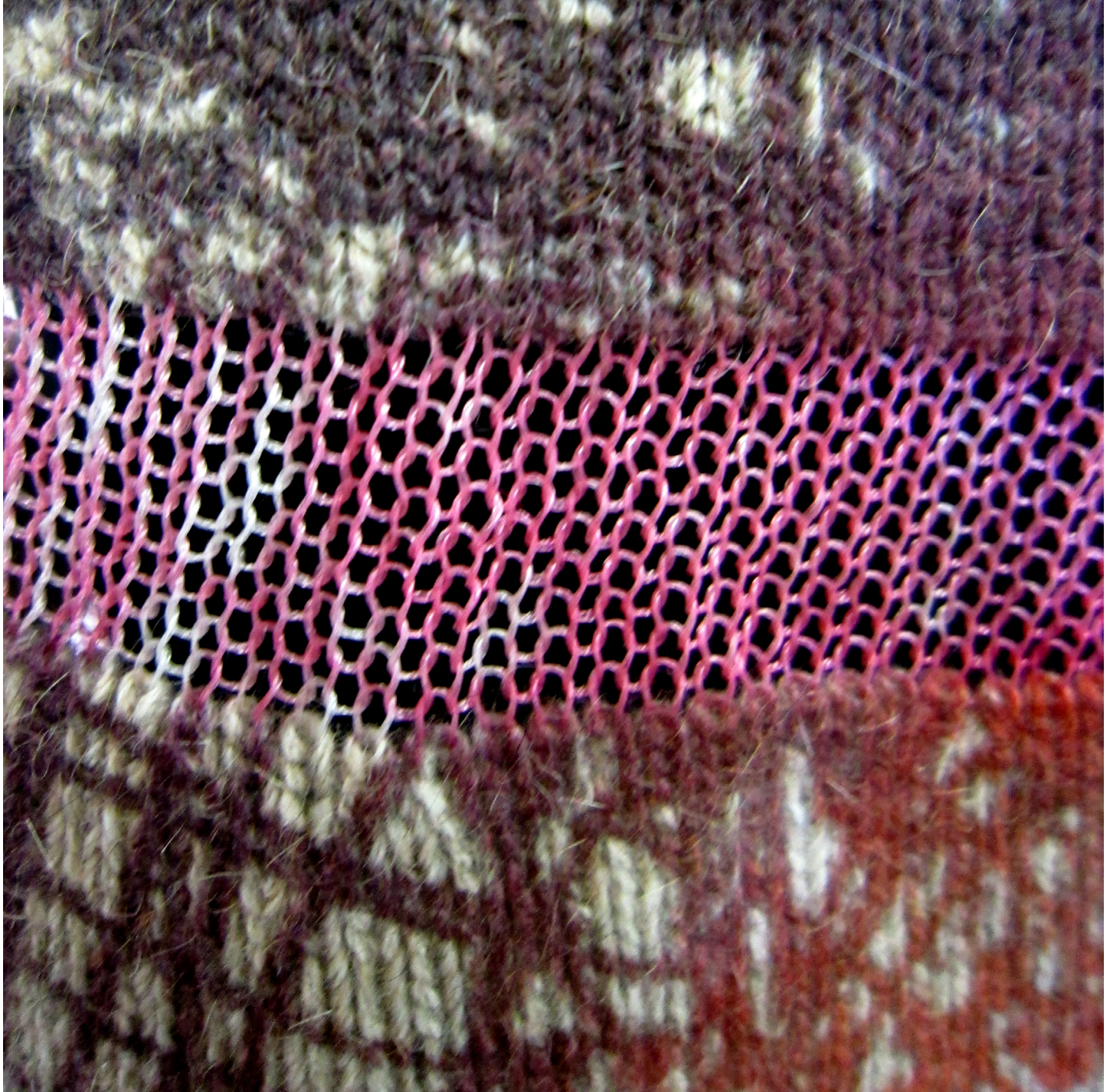
Quasi Experiment Four exhibition piece: Colour integration with structure design.



Quasi Experiment Four exhibition piece: Colour integration with structure design.



Quasi Experiment Five exhibition piece: Digital textile printing with colour integration.



Quasi Experiment Five exhibition piece: Digital textile printing with colour integration.



Quasi Experiment Three exhibition piece (B): Digital textile printing and shape development.



Quasi Experiment Three exhibition piece (B): Digital textile printing and shape development.

End Notes

1. The first knit machine was patented by William Lee of Nottinghamshire, in 1598. Supposedly he invented it as an efficient contraption so his lover could spend more time with him instead of knitting (Chapman & Millington, 1989).
2. This is in comparison to the initial linking of front, back and sleeves of a fully fashioned garment. Followed by sewing on trims, ribs, facings or strapping to then complete the garment.
3. "A fully fashioned method of knitting in which trims, such as pockets, plackets, and button holes, are included in the initial knitting process. Minimal garment assembly is required" (Donofrio-Ferrezza & Hefferen, 2008, p.295).
4. Prior to releasing whole garment technology onto the market there were many technical issues to overcome. The main problem had to do with takedown, which required even pressure on all the stitches to transfer correctly. This was accomplished by the development of the presser foot, which was licensed to Swiss flat machine builder, Dubied (Hunter, 2004). As described by Hunter (2004) the presser foot is:

A suitably bent piece of wire placed between the beds to allow the clearing of the last formed loop and the holding of this loop until it had begun to close the latch of the needle as the needle returned into the bed (p.20).

This development allowed for an even amount of pressure to be applied on the take down of the fabric, with the creation of shaped panels and garments being able to be knitted.
5. See glossary of terms.
6. An 'expert system' refers to the tools used in industry in computer design such as CAD programmes, which are often used in online gaming simulation of clothed mannequins.
7. To read more on the 'Endless Garment' exhibition and for designers who showed in the exhibition along with images, see Appendix: Analysing the New Zealand Fashion Market: New Design opportunities for Knitwear Design.
8. A more comprehensive feedback and conclusion from this survey can be read in the Appendix 1: *Analysing the New Zealand Fashion Market: New Opportunities for Knitwear Design* (Gover, A. 2010).
9. This is referring to the garment designs of Kawakubo's company Comme des Garçons, which was displayed in the 1982 exhibition Hodges curated called 'Intimate Architecture: Contemporary clothing design', Held at Hayden gallery, Cambridge.
10. See glossary of terms.
11. See glossary of terms.
12. This is due to the three 'tubes' (Body and two sleeves) becoming joined at the underarm point to knit the upper body of the garment. This can cause a weak point in the garment due to the amount of stress applied to the underarm seam area.
13. See glossary of terms.
14. See glossary of terms.
15. See glossary of terms.
16. See glossary of terms.

17. This is in relation to designing prints for garment which are printed in the dis-assembled state, then sewn up. When printing onto WholeGarment® products which are made up in their entirety, special consideration has to go into print placement, print designing and print implementation. This is a different approach which is needed to understand when working with Wholegarment®.
18. See glossary of terms.
19. See Appendix: Analysing the New Zealand Fashion Market: New Opportunities for Knitwear Design for more images of digital printing being used in fashion.
20. To read a detailed description about this type of print refer to the Appendix: Analysing the New Zealand Fashion Market: New Opportunities for Knitwear Design
21. See glossary of terms.
22. The choice of this 'Architectural theme' and inclusion of buildings for the textile prints was to continue on the relationship of seeing knitwear as an architectural, engineered structure.
23. Working through Shima Seiki SDS-ONE® CAD systems is a beneficial medium to test the stitch structures for knitting capabilities. This can be seen through a virtually simulated swatch, as any holes, laddering or stitch cross over's are clearly seen in real-time when your designing the textile.

Glossary Of Terms

Algorithmic: A term used in explaining the nature of the experiments which were used in this thesis. They were loosely based on Scientific ‘genetic algorithms’.

Anaglyphic: Also called ‘stereoscopic’, this form of visual images is most commonly seen in cinematography. Through separating a single image into cyan and magenta tones, the eyes only read one colour at a time, and put them together to create a single ‘three dimensional’ image. The image consists of three layers: Firstly a black and white image, then a cyan image, then lastly the magenta image. The black and white image is centred, then the cyan and magenta image are placed slightly off centre to the left and the right. The dimensionality cannot be seen first off, but needs tinted lenses to separate the two colours into each eye. If seen without glasses, the image looks blurry.

Architectonic: “adj. 1. Of or relating to architecture or architects. 2. Of or relating to the systematisation of knowledge” (Oxford concise dictionary, 1991, p.56).

Design CAD: “Computer aided design (CAD) is a recognised tool in the clothing industry, with many commercial systems available to assist in the design process. Essentially, these systems provide the designer with two separate environments for conceptual design or pattern cutting, grading and marker making. Both of these are 2D and while integrating well into their respective stages of the design process” (Hardaker & Fozzard, 1998, p.114).

Expert System: A computer programme to convert data from an image or sketch to turn into information the computer system can read and translate into a CAD programme. (Hardaker & Fozzard, 1998).

Genetic: A word used in relation to the type of experiments

undertaken in this thesis. It refers to the modification and ‘building on’ of different experiments undertaken.

Integral garment: A garment which is formed wholly in one piece. The word ‘integral’ is used to describe WholeGarment® knitwear.

Intarsia: This knitting term is referring to the use of two or more colours included in the knitting of the garment. This is a labour intensive process on the knitting machine, and requires a different feeder for each field of colour. Complicated designs (such as argyle patterns) can use up to 14-22 feeders at a time. A similar look can be achieved through using a jacquard technique, which doesn’t require as many feeders.

Isomorphic: “something is different in ancestry but has the same form or appearance” (Oxford concise dictionary, 1991, p.629).

Jacquard: This technique is similar to intarsia design, though it does not require as many feeders. Instead of using a new feeder for every area of colour, it ‘floats’ the yarn in behind the design until that colour is needed again. Floats can often be held for only a limited number of stitches until they become a risk for being caught on other garments. Another alternative to this is ladder backing, which is not loose threads, but is a knit structure created to hold the threads in place.

Knitwear Designer: This title refers to the research practitioner writing this thesis. It is also a generic term used in the fashion industry for the employers designing the knitwear for companies.

Knitwear technologist: This title is also known as ‘knitwear technician’, which can be used interchangeably. In relation to this Thesis it refers to the person programming the technical intended garment into the machine using the special technical CAD interface of the Shima Seiki software.

PACK data: Refers to: “Stored modules of knitting data which hold specific information relevant to a particular knitting technique. Each PACK is stored as a programming colour which can be retrieved and inserted into a programme when required. Using PACK data is claimed to speed up program creation, which is important for complex knitting techniques such as integral knitting”. (Hunter, 2004, p.27).

Perino: This is the type of yarn I am using in my thesis project. It is a special blend of possum fur with merino and silk. The fibre has a light weight ‘plush’ feel to it as well as having the warmth of the merino.

Pigment Dye: This type of dye is used in digital textile printing for synthetic fibre fabrics. A pre-treatment chemical is applied to allow the dye to adhere to the fibres in the yarn. The fabric is then printed and put through a post-finishing process of tunnel drying to set the inks in place. No wet finishing treatment is needed.

Prototype: This term refers to the trialling of garment designs to check for size, shape and proportion. They are not finished garments, but physical representations of what a final garment could look like.

Reactive Dye: This type of dye is used in digital textile printing for natural fibre fabrics. A pre-treatment chemical is applied to allow the dye to adhere to the fibres in the yarn. The fabric is then printed and put through a post-finishing process of tunnel drying to set the inks in place. The fabric is then washed up to three to four times to allow the dye to permanently set into the fabric. This wet finishing treatment allows any surface dye to disperse in the wash.

Rule Table: This is used in the Shima Seiki pattern database system for grading garment sizes. The rule table is a documented list of all the size changes/adjustments you can alter a garment by. You are also able to create a customised rule table for specific garments if needed.

Seamless knitwear technology: Established and founded by Dr Shima over 50 years ago, Shima Seiki Corporation is a leading Japanese knitwear machine manufacturer who supplies machines to the industry worldwide. Shima Seiki also produces CAD SDS-ONE® interfaces in the form of desktop programme packages for designers and technologists to use, which correspond with the knitting machine technology.

Shima Seiki SDS-ONE®: This is the desktop interface computer package which has Shima Seiki Software on that is used to build garments and design ‘packages’. When put into a USB interface in the machine, it is ‘read’ and the information tells the machine what to knit. This is an important part of the Shima operating software.

Swatch: this is a small piece of sample fabric to test out the knitted or printed structure on a small scale to make sure the construction and application technique works, before undertaking a full scale garment or fabric sample.

Takedown: The takedown qualities refer to the amount of pressure applied on the garment when it is being fed through the rollers to come out of the machine. If the take down quality is too small, the stitches will burst as there is too much tension being applied on the needles. If the takedown quality is too loose, the garment will not be held tightly enough so the stitches will become disfigured.

Toile: This is another word for ‘prototype’. This is commonly used in apparel dressmaking to assess the initial designs of a garment. It often uses non-expensive fabrics to trial out a shape or pattern, before progressing to the final product.

Quasi experiment: A set of experiments which include a few parameters to test a subject by. This is a creative process and is metaphorically linked to genetic-based algorithms.

Virtual interface: The use of the Shima Seiki SDS-ONE® CAD system to virtually create knitted garment simulations.

WholeGarment®: A patented machine technology which allows a garment to be constructed on one machine with minimal post-knitting construction. The development of this machine is often referred to as the pinnacle in machine knitting in the last century.

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