Practice-based textile design research as a method to explore knowledge transfer frameworks

Bernadette McCabe

A thesis submitted in partial fulfillment of the requirements of The Nottingham Trent University for the degree of Doctor of Philosophy

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Abstract

The aim and focus of the study shifted from exploring unknown decorative potential of materials and processes to focus on the context within which the samples were developed. Identified as a *knowledge transfer framework,* this concept was explored as a means to identify the key elements which provided the context for novel sample production and to highlight the potential of this work to contribute a primary strategy for future hybrid material developments. The background context includes examples of theory and practice to illustrate the dynamics of knowledge transfer and materials and processes with emphasis on textiles. For example there is a growing interest to combine traditional textile processes with new material developments, redefining the discipline of textile design into hybrid specialisations. This research is based on the argument that current practice highlights the need to identify and improve the *knowledge transfer frameworks* for these specialisations to evolve in the future. The practice-based textile design work produced in this research includes two case studies. Case study one explores the effects of sodium hydroxide a substance already recognized in textile design and in the textile finishing industry. Case study two explores the effects of chitosan on selected substrates and as a material in itself. The work with chitosan takes the research beyond current practice as a substance less familiar in textile design. Each body of work presents samples with descriptions of techniques, outcomes and evaluations. Following the development of samples, the practice was then evaluated in relation to knowledge transfer, identifying and evaluating the practice as a means to explore knowledge transfer frameworks.

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Introduction

The research originated out of an interest and a fascination in a way of designing with textile materials, inspiring new ways to consider the promise of process and new material manipulations in design. The original focus was to explore the hidden potential of textile processing to generate design effects on fabrics within the vision of hybrid material developments. The production of samples and process development gradually became by-products of a larger issue which emerged as the practice was carried out. It became clear that the knowledge transfer required between science and design was not easily achieved due to certain barriers. A primary barrier was understanding the new technical and scientific language which was used in literature and in face-to face discussions. Also the researcher lacked some skills and knowledge required for handling chemicals and equipment in the laboratory. Before the researcher could carry out experimentations, these barriers were reduced through demonstrations and discussions allowing the researcher to engage with the new elements and develop unique practices to produce samples which could then be assessed for decorative potential. It became clear that the focus of the research had shifted from exploring the decorative potential of samples to focus on the importance of the supporting context within which the samples were developed. The new aim of the practical research was then to identify the key elements which provided the context for novel sample developments, namely the *knowledge transfer framework* recognising the potential of this body of work to develop improved strategies for future applications.

The aims of the research are:

1. To critically evaluate the dynamics/ relationship of knowledge transfer and materials and processes, with particular emphasis on textiles.
2. To establish the range of outcomes on cotton, cellulose acetate and cellulose triacetate fabrics following the application of sodium hydroxide and then dyed.
3. To explore the design potential of chitosan producing a range of samples alongside technical descriptions of process.
4. To evaluate the practice in relation to knowledge transfer.

Chapter 1 provides a background to the thesis providing an overall perspective of the dynamics of knowledge transfer in the context of textile material developments. The chapter is not a conclusive study of knowledge transfer however theoretic models are discussed in combination with examples of practice which provide evidence of knowledge transfer taking place. The chapter is structured in response to three key questions which were chosen to clarify knowledge transfer in the context of materials and processes. The questions include; what is knowledge transfer? why is it important to reconsider practice from the perspective of knowledge transfer frameworks? and what are the barriers that prevent knowledge transfer? Evidence of knowledge transfer is identified in examples of practice both within and outside textile design as a result of a variety of explorations of materials and processing techniques. These explorations for new material developments challenge every aspect of our understanding of traditional textile design, feeding an on-going desire to explore existing techniques and those not yet established as having design potential. This thesis argues that strategies to improve knowledge transfer to enable such new material developments would benefit from understanding the underlying *knowledge transfer frameworks,* in other words, improve the contexts within which the science and design elements must communicate. The importance of reconsidering practice from the perspective of knowledge transfer frameworks is discussed with reference to the changing role of textile designers. Examples are provided which highlight the changing relationships between textile design and technology, moving towards the interest in hybrid practice and multidisciplinary teams in which knowledge transfer skills are developed through practice. Implications of knowledge transfer frameworks to other design disciplines are discussed followed by exploring the barriers that prevent knowledge transfer. The main categories are identified as facilities, literature, insufficient knowledge of outcomes and organisational barriers. The chapter provides evidence to justify the benefit of reconsidering practice as knowledge transfer frameworks to improve future strategies for knowledge transfer in design collaborations.

Methodologies for practice-based research (Chapters 2 to 6)

The facilities used for the small-scale, hand produced samples include the research laboratory in addition to use of the kiln and vacuum forming machine. Creative interaction with the materials, processes and discussions within the research team allows concepts for technique development to inform a progression of ideas. Spontaneous thoughts are often difficult to capture and act upon as many of the processes and chemical reactions require preparation and planning. These spontaneous concepts include ideas for technique development, from which novel samples may result in addition to ideas to explore placement on fabrics and combinations of effects. The difficulty is often capturing the concept of the physiochemical reactions as visual and textural fabric characteristics without the use of the actual samples. The work does not include fabric testing to determine performance characteristics as the key aim is to provide a link between the process parameters and aesthetic fabric characteristics. The work does not necessarily extend the science discussion but re-interprets the data to allow a wider audience to participate.

Chapter 2 outlines case study one, which employs practice-based research methods as a means to creatively explore the design potential of a novel processing technique on fabrics. Sodium hydroxide, a chemical familiar to the textile finishing industry, is initially applied to cotton; cellulose triacetate and cellulose acetate fabrics then the samples are dyed using disperse and direct dyes to illustrate resulting dye effects. The experiments cover eleven phases in which the processing parameters are modified as a means to produce diverse outcomes on the fabrics. Technical descriptions of process are included alongside images with written descriptions of resulting samples. This draws links between the process parameters and the outcomes. The range of aesthetic effects becomes more defined allowing the samples to be assessed against key characteristics. Cellulose acetate is eventually selected as the most responsive fabric type as it consistently produces diverse dye effects, transparent effects and change in fabric handle. These resulting aesthetic effects are less consistent with the cotton and cellulose triacetate and the research focuses on cellulose acetate alone. To complete the exploration of design potential selected images of cellulose acetate are then scanned into fashion illustrations where the fabrics are visualised within the context of garment design.

Chapter 3 to chapter 6 includes the results of case study two, in which small-scale hand produced samples are produced. In contrast to case study one, the material has no previous connections to textile design. Chapter 3 provides a background to the research, while chapters 4, 5 and 6 present the three categories of sample developments. Chapter 3 begins with a brief review of the existing applications of chitosan with reference to its unique inherent properties. In particular, biodegradability is a favourable characteristic and initially supported the decision to carry out the explorations; however the resulting samples were not developed to directly contribute to the sustainability debate. Scientific knowledge provides the foundation for the study, drawing on research developed by the design of materials research group. Key characteristics are identified and categorised as having design potential in particular, film forming properties and having an affinity to certain dye types. Materials are chosen from a wide range of categories to combine with chitosan to produce an initial expansive vocabulary of effects. These effects depend upon the processing parameters, the inherent characteristics of the substrates and the interactions with the chitosan solutions. Due to the variety of outcomes, substrates used and processing techniques, the outcomes were difficult to asses. The use of mind maps introduced a method that incorporated a visual technique to help evaluate the work allowing the variety of outcomes to be considered simultaneously resulting in decorative themes to be identified. This new perspective of the research resulted in a structure by which the outcomes could be reconsidered and categorised in a linear fashion which is more suited to the format of thesis. The three decorative themes include physical effects of chitosan, colour effects of chitosan and surface texture effects of chitosan. The initial Mind map is reworked to illustrate the resulting samples according to the new categories of decorative themes. The following three chapters represent each theme.

Chapter 4, Physical effects is the largest of the three categories including sub-headings according to physical properties. These include film forming effects, temperature effects, binding effects and sculptural effects. The chapter begins with the technical formula and processing skills which establish a foundation for all chitosan experiments. Written descriptions of process reflect a scientific method including images to translate the outcomes into visual data. Samples are initially difficult to assess according to aesthetic criteria as the understanding of decorative effects develops throughout the work. Gradually the work generates an overall perspective on the range of effects, and the most successful combinations are more easily identified. Each development contributes towards a greater understanding of the parameters of the decorative potential of chitosan including the least successful samples. Design visualisations conclude the chapter.

In chapter 5, the Colour effects of chitosan category applies similar methods as developed in chapter 4. Batik effects explore chitosan film as a resist, protecting underlying cotton fabrics from dye. Film on fabric concentrates on application methods which includes brushing, pouring and printing, with the aim of producing smooth transparent films. The final section explores the colour effects of chitosan film and chitosan solution with embedding resin. The chapter concludes with CAD developments and interior design visualisations.

Chapter 6, Surface texture effects of chitosan concludes case study 2. This is the smallest group and includes plates with surface texture effects of chitosan smooth surfaces. The work also explores the irregular film forming characteristics of chitosan solution in combination with granular substances and dye powder. These results contribute the least number of samples however they provide a boundary to the overall design potential of chitosan. The success of earlier samples is evident in comparison. The chapter closes with a summary on the design potential of chitosan.

Chapter 7 evaluates the practice produced in this research in relation to knowledge transfer. Key questions include, what can this practice contribute to the knowledge transfer debate; what is the knowledge transfer framework developed from the practice; what are the examples of knowledge transfer resulting from the research; what are the benefits of knowledge transfer specifically with reference to textile design; what are the barriers identified in this research that prevent knowledge transfer; what are the constraints of knowledge transfer in the context of this research; how might outcomes and conclusions be influenced by the limitations within the research?

Methodologies used to assess knowledge transfer

The success of knowledge transfer from science to design was also evaluated by presenting the research outcomes to external groups to determine their consideration of the work from specific contexts. Three groups were selected to feedback different perspectives to the research in particular comparing positive and negative aspects of the research outcomes between each group. The work was considered by a group of interior architect students, a group from the textile industry and a group with specialist interests in knowledge transfer. The practice-based methods employed to transfer knowledge to the external groups included a combination of presenting samples as images on PowerPoint and handing out actual samples. Feedback was generated following the presentations in the form of completed questionnaires, transcripts of the taped events and discussions.

The key elements of the underlying infrastructure which support the research include facilities, specialist background knowledge and processing skills providing a strategy to improve future knowledge transfer frameworks. The chapter argues that although the samples and technical descriptions of process are the initial focus of the practice-based research, they are the by-products of the knowledge transfer that takes place. This thesis engages with elements of science as a means to explore the design potential of materials and processes, with knowledge transfer between disciplines as a result of the enabling knowledge transfer framework.

Chapter 1: The dynamics of knowledge transfer in the context of textile material developments

The aim of Chapter 1 is to explore aim 1;

> To critically evaluate the dynamics/ relationship of knowledge transfer and materials and processes, with particular emphasis on textiles.

The chapter is not a conclusive study of knowledge transfer however examples of practice are discussed which provide evidence of knowledge transfer between and across disciplines with particular emphasis on textile design. The research is evaluated against theoretic models where similarities and differences in objectives are identified, thus underpinning the rationale for this research. Examples of practice are provided to highlight existing cases where knowledge transfer has taken place, arguing that understanding the underlining knowledge transfer frameworks could help inform strategies to support future material and process developments. The comparison of theoretic models and examples of practice help to establish the background context from which the research question developed. The chapter is structured in response to the following questions to help define the context;

1. What is knowledge transfer in the context of materials and processes?
2. Why is it important to reconsider practice from the perspective of knowledge transfer frameworks?
3. What are the barriers that prevent knowledge transfer?

1.1 What is knowledge transfer in the context of materials and processes?

1.1.1 Theoretic models of knowledge transfer

In order to provide a basic understanding of what is meant by knowledge transfer, theoretic models have been compared against which the research question can be considered. The first knowledge transfer model is proposed by the Department for Trade and Industry (DTI), which considers knowledge transfer as that which can interact with industry in the form of technology, patents and spin-out companies, seeing knowledge as a means of providing a competitive advantage. This ideal is supported by Knowledge Transfer Partnerships (KTP) which are part funded by the government, enabling organisations to work on specific projects with experts from a relevant university or research organisation. The overall purpose of these collaborations is to increase profitability as a result of targeted strategic innovations, although additional benefits are also recognised. In these contexts, profitability might however act as a barrier to the full potential of research as knowledge transfer, as the focus would be a marketable product with emphasis on specific performance and end-use. This perspective alone is too restricting for the research context as such defined parameters would limit the opportunity for creative interplay to actually inform the research question.

In contrast to the DTI perspective, a much broader understanding of the term knowledge transfer is identified in the model proposed by the Arts and Humanities Research Council (AHRC). Here, it is seen as more than just a linear process linking research to business solutions especially within the creative industries. As argued by Crossik (2004), the arts and humanities additionally recognise the hidden dynamic exchange between people which is difficult to place in the traditional concept of technology transfer. The creative interplay between researchers and users uncovers new opportunities and new challenges, demanding a broader conception than considering a particular invention which is then directly transferred to business. In a discussion with Yvonne Hawkins (Appendix 5), Director of Knowledge and Evaluation at the AHRC (Hawkins, 2004) knowledge transfer was seen in a wide sense and is still in its infancy as a defined subject. In a research context the knowledge learnt and the journey undertaken are recognised as key factors. In the discussion Hawkins admitted that it was not yet clearly understood what was required from the creative industries although the heart of the model concerned the connections that happen through people, not just the commercial success of new products. This model provides a much more flexible approach to the concept of knowledge transfer although details of knowledge transfer methods were not sufficiently established to provide strategies on which the research could build. The model developed in this research compares to the AHRC concepts, additionally providing details of the actual knowledge transfer framework developed within the practice. The definition of knowledge transfer developed in this research is;

> knowledge transferred from science to textile design using practice-based research methods.

Further details of this model are discussed in Chapter 7. The model developed by the Knowledge Creating Company (von Krogh et Al, 2000: 9), considers knowledge transfer under the theme, 'Knowledge Creation' and has identified 5 key points labelled 'Knowledge Enablers'. These organisational activities recommended to enable knowledge creation include:

1. Instil a knowledge vision
2. Manage conversations
3. Mobilize knowledge activists
4. Create the right context
5. Globalize local knowledge

It is argued that all five points of this model were present in the context of the practice developed for this research. However, specific characteristics which created the research context (point 4) were identified and collectively described as the *knowledge transfer framework.*

1.1.2 Examples of practice illustrating knowledge transfer

Aim 1 proposes to critically evaluate the dynamics of knowledge transfer and materials and processes, gathering evidence of what is driving the need for such exchanges. The aim was not to evaluate individual examples of practice in terms of knowledge transfer, rather to begin to identify what knowledge transfer has taken place. Although the work was not specifically developed for its contribution to the knowledge transfer debate, evidence of knowledge transfer is still identified. The central theme focuses on knowledge transfer within the context materials and processes from which two main categories have emerged; knowledge transfer as a result of explorations of existing techniques and explorations through non-established techniques.

1.1.2a Knowledge transfer through explorations of existing techniques

Knowledge transfer through practice is evident historically, for example the Japanese techniques of Shibori (Wada, 1983) where the dyer works with the characteristics of the cloth following a sequence of treatments to manipulate the cloth into 3-D forms. Contemporary practice builds on the shibori technique with combinations of natural and synthetic materials introducing thermoplastic fibres to produce textural and structural effects.

Figure 1.1: 'Shibori' July 1994, Jun'ichi Arai.
(Braddock and O'Mahony, 1998:85)

The Jun'ichi Arai fabric produced for Christine Keller (Figure 1.1) comprised a warp of a polyamide slit film coated with a fine layer of aluminium with a fine woollen weft yarn. The woven fabric was then finished using a shibori resist technique following the application of acid dyes. The resulting effects combined the 3-D puckered dyed black areas contrasting against the undyed surrounding fabric. The knowledge of the thermoplastic properties of the polyamide warp was explored in the context of a traditional process illustrating the transfer of knowledge between material science, processing techniques and design application.

Similar interactions between materials and processes illustrate knowledge transfer in collaborations such as the lottery-funded Hitec-Lotec programme (2001). Industrial placements for a selection of designer-makers from a variety of disciplines were supported to explore industrial machinery using practice-based methods whereby designer-makers had access to industrial machinery for a limited period of time. The work of Sophie Roet (Figures 1.2 and 1.3) combined traditional craft elements with industrial techniques to produce 3-D surface effects incorporated into simple fashion silhouettes.

Figure 1.2: Sophie Roet Hitec Lotec (2000: 29)

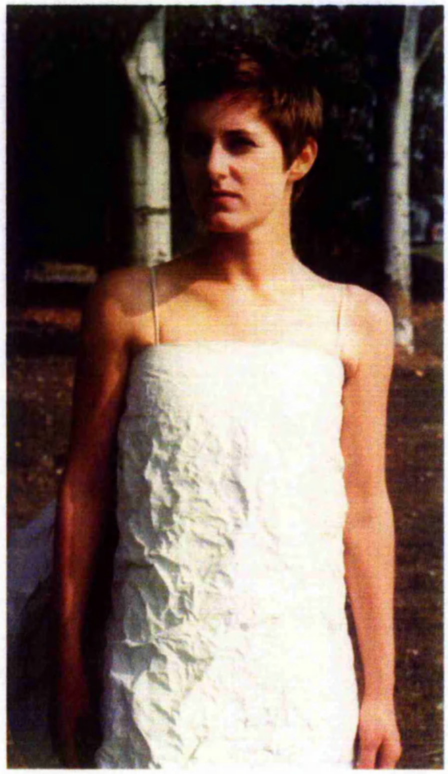


Figure 1.3: Sophie Roet, Fabric of Fashion (2000)

Her interest in developing textiles includes explorations of natural and synthetic fibres with layering and bonding of ready-made fabrics. Roet's *Hitec-Lotec* commission was carried out in collaboration with *CS Interglas,* whose technical textiles are normally used for architecture, aircraft and other industrial applications. The resulting fabric was created by sandwiching metallic sheeting between layers of 100% silk on either side. The materials were bonded using neoprene glues, natural resin and heat treatment. The resulting textile combined the delicate qualities of the silk with the malleable qualities of the hidden metallic sheet which allowed the resulting form to retain its shape independently. The specialist knowledge required for the materials and industrial process had to be transferred to the designer-maker in order to engage and explore creative outcomes.

The approach adopted by *Nuno Corporation*[1] combine fabric construction elements with innovative processing techniques fusing hand-craft and industrial methods (Braddock & O'Mahony, 1998), allowing practice to explore the potentiality of materials and process combinations. The philosophy of Nuno is to encourage diversity of material combinations through process-led exploration of both hand techniques and industrial processes where appropriate. Nuno's textiles illustrate the key role practice in the form of artistic experimentation plays, in transferring knowledge from specialist knowledge of textiles into a decorative context, often with no specific application at time of production.

> Experimenting with materials is at the core of the design process, mixing yarns and odd materials, inspired also by ancient craft traditions of Japan such as Shibori techniques....(Watkins, 2006:20)

Previous to the initial experiments the outcomes of combinations of materials and processes is not known therefore the practice is integral to the design process. The success of Nuno's strategy is evident by the resulting innovative material combinations which combine industrial and handmade with traditional and innovative finishing processes (McQuaid, 2006).

The work of textile designer Janet Stoyel (Weaver, 1999), contributes to several debates around textiles, technology, processes and the opportunities created through experimentation. Stoyel developed a unique patented process using Photon laser and Ultrasound technology resulting in *Laserlace*® and *Laseretch*® techniques. These technologies both relied on an understanding of process and materials resulting in colour and pattern effects on a variety of textiles and metal substrates (as seen in Figure 1.5). Initial prototypes were developed into various successful commercial products ranging from lace-like fabrics (Figure1.4) to metallic substrates with surface colouration effects (The Cloth Clinic, 2005). These explorations were not restricted by the pressures of an external manufacturer as Stoyel invested in her own equipment allowing an on-going research environment to fully engage with sample exploration.

[1] Nuno – Japanese fabric manufacturer

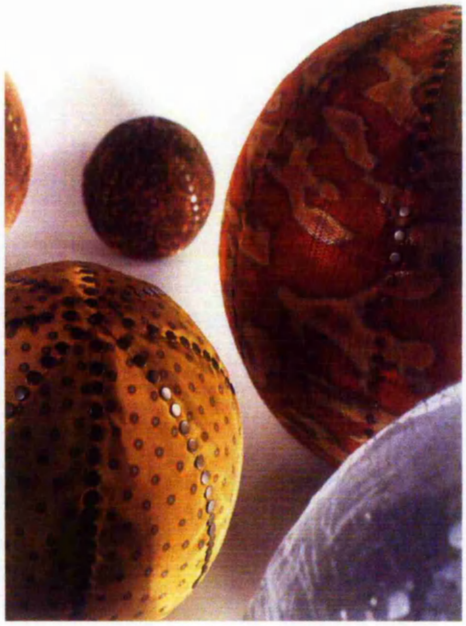


Figure 1.4: Janet Stoyel
L5 Snowflake lace©
(The Cloth clinic 2005)

Figure 1.5: Janet Stoyel
(Hitec-Lotec 2000)

The research developed by Janet Emmanuel (1998) explored a combination of basic substrates covering the basic groups of animal, vegetable and mineral fibres with techniques employing ultrasonic welding as seen in Figure 1.6.

Figure 1.6: Janet Emmanuel, Ultrasonic Welding Acoustic Shadows, (2000)

Emmanuel (2000) describes her fabric research through a technical understanding and scientific parameters thereby generating a new vocabulary for the development of textile forms. Her research suggests that the designer develops a language, which incorporates some basic aspects of material science, understanding the implications these have on the processes employed. Emmanuel focused her early research work on the development of 3-D forms illustrating the variety of outcomes resulting from explorations of industrial technologies again in a research context.

Engaging with the properties of neoprene rubber foam, Lauren Moriarty illustrates the use of practice to discover new applications for combinations of materials and technology. Through her series of geometric structures (Figures 1.7 and 1.8), Moriarty incorporates a traditional repeat pattern technique used in textile design which contributes both structure and surface decoration to the resulting form.

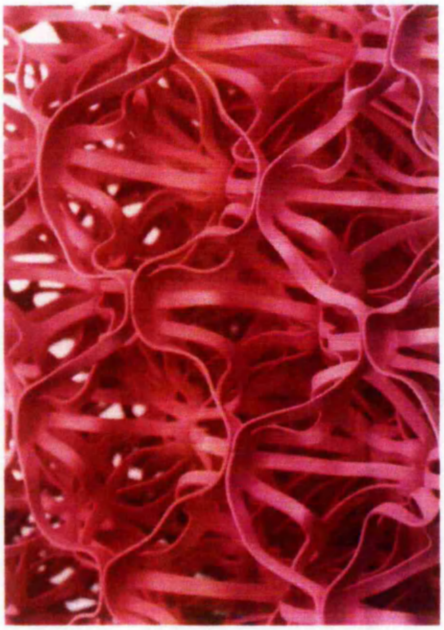


Figure 1.7: Lauren Moriarty.
Geometric Pink Structure (detail).
(Jerwood Applied Arts Prize, 2002)

Figure 1.8: Lauren Moriarty.
Noodle block rubber cushion
(The Sunday Times, 2004:85)

Her practice embraced the properties of neoprene rubber foam, exploring their inherent structural and flexible characteristics in design contexts. This is an example of knowledge transfer of materials into new design contexts.

Moving away from textile design, knowledge transfer is key to the material development agency *Panelite*, a company formed at the crossover between architecture and material production. The team consists of a core of trained architects with experience in fabrication methods and a shared ambition to invent new materials for the built environment. Their design philosophy similarly recognises the potential of materials and processes to innovate. New materials are developed by drawing on existing processes from other industries which are evolved in-house using a process of iteration and evaluation on computer software. Here engagement with materials and processes can be much more accurately controlled as the scientific data is re-interpreted visually as a catalogue of material effects.

Table 1.1: Development model of Panelites' honeycomb panel series. (Anon 2002)

Development stage	Description
1. Substances (speculative)	Begin with a material that has inherent potential for unpredictable variation or visual lapse: honeycomb core. Two honeycomb panels produced with rigorously identical components and methods will nonetheless exhibit perceptible differences in their core pattern. The degree of potential variation can be further exacerbated according to the specific selection of components.
2. Process (manipulative)	The variables are manipulated in the process by which the core is fabricated into a honeycomb sandwich, generating a series of prototypes for evaluation.
3. Prototypes (catalogued)	The resulting catalogue of material effects is evaluated aesthetically on the level of the call (geometry of the cell, nature of the thickening, quality of the cell membrane) as well as on the overall panel (singular and multiple lapsus, deviation) and technically in terms of performance criteria (peel strength, stiffness, flatness, impact resistance, density, light transmission).
4. Products (iterated)	Some prototypes are immediately archived for future reference. Others lead to further iterations and lines of research. From this research new techniques are evolved, refined, and when possible patented.

This constant development of prototypes allows aesthetic, technical and production criteria to evolve and be evaluated. The development process of *Panelite's* honeycomb panel series is explained in Table 1.1. Key terms such as speculative materials and manipulative processes reflect their experimental philosophy towards design exploration. A major advantage using this technique is the ability to explore initial outcomes without the need for physical samples. Here the knowledge transfer context engages with material explorations in virtual space rather than a physical laboratory space. Similarly the virtual landscape also provides textile designer Jane Harris, with a new opportunity to expand on her background experience and knowledge of textile materials, processes and design. Her virtual fabric developments synthesise a vocabulary of textile materials with computer generated images (CGI) producing the illusion of realistic fluid textile substrates. In order to combine these diverse backgrounds, Harris learnt the computer technology resulting in images of textiles generated in computer 'language' as a set of linked co-ordintates on CG software rather than fabric construction data detailing fibre and fabric specifications. The opportunity for this specific case of knowledge transfer was dependent on gaining access to specialist equipment at restricted times when expertise was not always available. Self-education through practice was key to the knowledge transfer process resulting in the use of a technical language to bring to life moving textile pieces. (Fabriconversations, 2005 and Fabrication, 2005).

Initiatives in new material developments promote the interest in accessing and exploring materials and processes. Organisations such as *materiO*, a Paris-based independent information centre on materials, provide access to specific, reproducible and obtainable materials. The company forges links between creative people transferring knowledge between diverse backgrounds including architecture, industrial design, scenography, fashion design, publishing and fine arts together with manufacturers, engineers or researchers. *Material ConneXion®* and the Dutch consulting agency *Materia* are also consultancies involved in the dissemination of new and innovative materials, working at the crossroads between the user and manufacturers experimenting with materials and technologies.

At *material_vision*, (2003) the creative opportunities resulting from explorations of materials and processes were discussed at a forum with designers from a variety of disciplines. Materials were recognised as bringing more than just performance to the value of products. The enabling factor to optimise the characteristics of the materials was having an understanding of the underlying material technology. Understanding allows confident use. If you understand, you can better combine and apply to new areas, predicting the behaviour of the assemblies and environmental conditions the material will be used in. Allowing the characteristics of a new material to interact on design is recognised in Architecture, whereby Polymer Composite Materials (PCM) are explored for new aesthetic and spatial effects. Johan Bettum (2002) is the leader of the Norwegian research programme in Oslo, where Polymer Composite Materials (PCM) are researched for their capacity to produce non-linear, novel aesthetic effects as part of the process-based approach to surfaces, with a focus on materials and material technologies. Within this model the material systems are coordinated according to their performance criteria and aesthetic contribution to a design concept. Transferring knowledge across disciplines allows external expertise to inform knowledge transfer within textile design.

1.1.2b Knowledge transfer through explorations of non-established techniques

The basis for the research proposal developed from an early fascination for fabric manipulation, which introduced the concept of additional methods to design fabric.

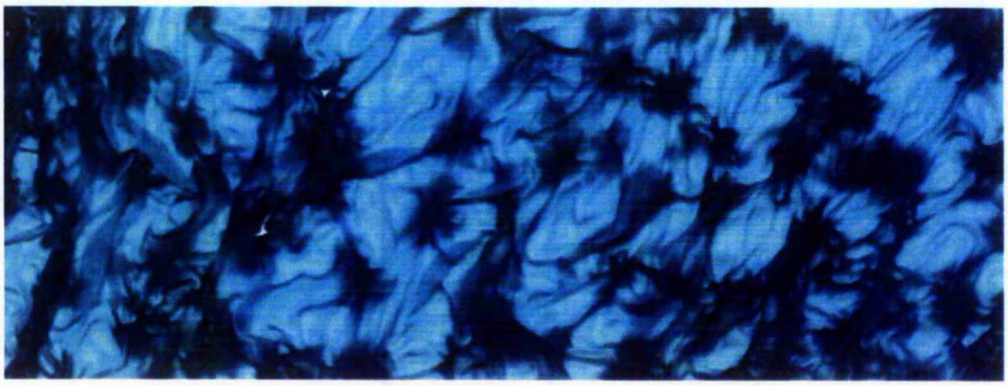


Figure 1.9: McCabe, (1997). Heat manipulated and dyed polyester

Traditional textile design disciplines include knit, weave, embroidery, print and dyeing, however the process of designing textiles using heat manipulation had not previously been considered by the researcher as a method to design fabric. The practical investigations of a simple process of heat manipulation of polyester altered the surface structure of the fabric, thus influencing its appearance and handle. Figure 1.9 illustrates the random characteristics that the process contributed to the design of the fabric; the uneven surface texture with dark-centred blue clusters was a direct result of locally heating thermoplastic fibres. These new design dimensions contributed a palette of texture effects not possible through construction techniques alone.

Fabric of Fashion (2001) identified two key practitioners who combined unusual and unconventional fabric processing techniques with garment design, contributing to the re-evaluation of textile design processes. In the first example garments were buried to allow natural degradation processes result in decomposed structures which were used in the graduate collection of Hussein Chalayan (Figure 1. 10). Fabric manipulations of burned elastoplast fabrics and scorched felted wool inspired Shelley Fox in her simultaneous developments linking fabric to pattern cutting (Figure 1.11).

Figure 1.10: Hussein Chalayan.
Fabric detail from buried dress, 1995.
(Fabric of Fashion, 2001)

Figure 1.11: Shelley Fox.
Burnt elastoplast curve dress, 1999.
(Fabric of Fashion, 2001)

The practice-based research work, *Skin Stories* by Zane Berzina (Figures 1.12a to 1.12d), reflects the intention to push the boundaries of textile design beyond established techniques producing new areas of hybrid expertise. Applying an interdisciplinary approach to art, design, technology, biology and material science interactive textile surfaces were produced. Prototypes such as 'Touch-Me Wallpaper' were described as,

> An interactive sensory-appeal textile membrane for wall coverings which respond to environmental or human heat by changing colour, releasing aromatic scents and regulating the ambient temperature within a room in order to enhance people's wellbeing. (Skin Stories, 2003)

Figure 1.12a

Figure 1.12b

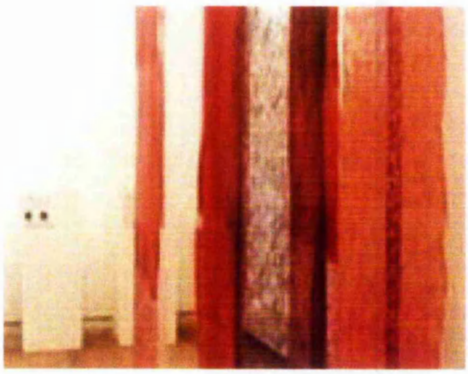


Figure 1.12c

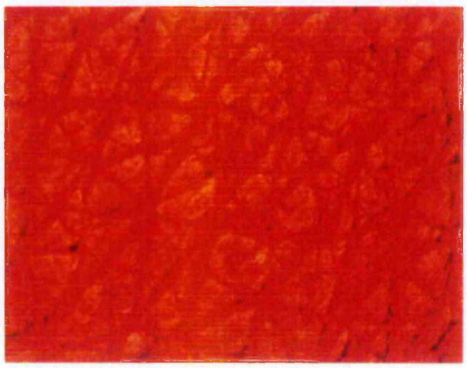


Figure 1.12d

Knowledge transfer between multi-disciplinary teams has resulted in successful collaborations between artists, designers, scientists, fibre and fabric engineers, combining the latest materials into both decorative and functional applications. The exhibition and catalogue 'Future Textiles: Fast Wear for Sport and Fashion'

(O'Mahony and Braddock Clarke, 2005) presented many examples of such collaborations where techno textiles are recognised for both decorative and performance characteristics however this leads us to the next question. What can we gain by considering these examples of practice from the perspective of knowledge transfer frameworks?

1.2 Why is it important to reconsider practice from the perspective of knowledge transfer frameworks?

The evidence provided in section 1.1 suggests that knowledge transfer already takes place within contemporary practice without reference to knowledge transfer itself. Generating strategies to improve knowledge transfer would depend upon an understanding of the contexts which enable such transfer. In an attempt to identify the underlying framework the practice carried out in this research was reviewed as an infrastructure which enabled the links and barriers at the science and design interface elements to be identified, thus forming the key components of a preliminary knowledge transfer model. It is suggested that the model could then be transferred to other practices such as those outlined in 1.1 as a means to evaluate existing methods.

1.2.1 Changing role of textile designers

New methods that involve chemical and mechanical explorations of materials require skills and knowledge of textiles in addition to specific knowledge of the science or technology being explored. Such integrations require knowledge of textile design and textile technology allowing an exchange of data to inform the direction of practical research. Examples from textiles research and textile practitioners provide evidence which highlight the changing relationships between textile design and technology, with a growing interest to explore design through process-led investigations, often reaching beyond traditional textile design conventions. *Stories of technology,* was the theme of the conference, *A twist in the yarn* (Manchester Metropolitan University, 2001). Papers from Jane Harris, Sarah Taylor, Janet Emmanuel and Julie Sodden presented their practice-based research completed in the field. Although a variety of topics were addressed, the design / technology interface was consistently challenged through materials and technique combinations.

A desire to improve the synergy between design and engineering in textiles prompted the *International Textile Design and Engineering Conference*, INTEDEC 2003, whereby technologists and designers were brought together under the title *Fibrous Assemblies at the Design and Engineering Interface.* The term fibrous assemblies moved away from the traditional textile definition to include all fibre-based flexible and non-flexible structures, from fibres to fabrics, garments, composites and other made-up articles. These shifting boundaries remove the categories which defined traditional practice, promoting multi-disciplinary developments in which unconventional research and developments can be supported. Thinking outside conventional approaches to fabric development is a logical step to progress the textile discipline. This is reaffirmed by the links being encouraged by the *TechniTex Faraday Partnership.* Researchers from industry, academic institutions and other organisations from diverse specialisms are encouraged to explore the boundaries of what is called *technical textiles*, combining performance and aesthetic characteristics leading to a broader understanding of multifunctional textiles. The theme of encouraging networks within the textile industry and universities was the focus of 'Academia to Industry (2005)'. Knowledge Transfer Networks are proposed to replace the existing Faraday Partnerships in addition to an online Advanced Materials Forum and Smart Materials Network (TechniTex, 2006) with the aim of encouraging knowledge exchange between existing networks and to encourage new collaborations to evolve.

Contemporary examples illustrate the interest in hybrid practice and multidisciplinary teams as evidence of knowledge transfer in the production of innovative sample developments. However the descriptions of underlying contexts which enable transfer of knowledge between disciplines are less evident, restricting the benefit of such practices as a means to improve knowledge transfer between disciplines, in particular contexts which engage the science and textile design interface.

Traditional design / technology boundaries are challenged as a result of practice-based research methods in which the designer has direct interaction with the materials and technology. This growing interest of designer-makers engaging in exploring technology implies a shift in the traditional acceptance of the role of manufacturing techniques from volume production to an additional role for exploration. Supporting designers to experiment around the technology and techniques would encourage an improved dialogue between design and technology. As illustrated in Colchester (1991: 40),

> Nuno's fabrics provide one of the most significant pointers towards the future: gradual fusion of history, craft, diverse cultural influences and technologies that indicate that design has become the true successor of the traditional crafts.

Results of the Hitec-Lotec project (2001) emphasise the potential outcomes in exploring materials through industrial processes allowing innovation to inspire an interactive working process.

The development of fabric forms through investigative research has a promising future for new product areas. For example, new expressions of fabrics offer the potential to inspire designers constructing hybrid architecture alongside new concepts of how we interpret and use our environments. For example the Textural Space exhibition (Textural Space, 2001) provided representations of constructed and processed material environments, which encourage imaginative and emotional responses.

1.2.2 Textile design as hybrid specialisations

The availability of knowledge, technology and an expanding choice of materials are transforming the discipline of textile design into a diverse mixture of hybrid specialisations, combining unusual materials, processes and techniques. This cross-fertilisation of ideas between diverse fields within the textile industry is echoed in Future Materials (World Textile Publications, 2002) fusing knowledge between areas such as technical textiles, nonwovens, paper, resin, films, composites, coatings and laminates. This approach is reflected in the wider context of materials and design beyond the textiles industry as identified in 1.1 where links between creative people of varied backgrounds, manufacturers, engineers and researchers are being forged. New philosophies towards material development support the need for knowledge transfer frameworks to improve the synergies between researchers across diverse fields.

Contemporary textile design practice emphasises the interest by designers in exploring technology, science and engineering as creative methods for textile development. Wayman (2001) recognised two types of designer. Creative designers who may be stimulated more by the visual aspect and technical designers who are driven more by understanding the combination of materials and processes. These are increasingly becoming a combined role, thus suggesting the formation of a hybrid technical designer. Textile design must also bring function and aesthetics together, considering styling and decoration with functionalistic approach.

Textile designers are usually classified according to their specialisms of which there are several categories. Their expert knowledge allows the production of innovative solutions to design problems, as a result of understanding combinations of the specific materials and processes involved to produce a certain outcome. The growing interest in developing processes and techniques, not previously considered from a design perspective, suggests the need for more textile specialisms according to the technology employed. Sadhale (1997) described the textile designer as playing the role of a manager, fitting creative elements into the technical aspects of fabric design. As textile design involves more stages of development it is increasingly necessary that the designer employs a holistic approach and understands the links between the production and the design process.

Textile design maybe considered as a service that is carried out to fulfil a design brief, determined by the requirements of the end-product. As such it may be considered as an intermediate product which is used and made into the final product by other industries (Newton, 1997). The implications of new processes would influence the subsequent design stage of the textile product. Combined with the increasingly complex nature of fabric processing, the definitions of textile design practice are expanding across multiple disciplines incorporating a complex interaction of processes and combination of specialists. Evidence of designers mixing textile techniques and manipulating cloth to create new ideas highlights the on-going need for an improved dialogue between creativity and technology, putting emphasis on understanding the technical issues influencing the design outcome. The integration of techniques such as texturing, plastifying, moulding, bonding, and ageing continues to challenge the boundaries of the textile design discipline.

1.2.3 Implications of knowledge transfer frameworks to other design disciplines

It is clear that the research also contributes to the wider contemporary debate in the development of new materials and processes beyond textile design. The research did not initially focus on the end-application of new samples as products, but to illustrate the design potentiality of specified materials through empirical methods where the end result could directly inform the design concept. As recognised by Manzini (1989), *...the point of depart for design was once the material itself, today it is the mutable quality of materials.* The implications of this perspective on the textile industry are that established techniques and processes have the potential to be reconsidered as flexible systems to produce hybrid combinations of materials. This requires creative explorations of existing processes and those beyond current textile design practice. In support of this De La Rosa (2004) said,

> It is time to free textiles from the constraints of the industrial revolution and embrace the vast possibilities of the technological revolution.

1.3 What are the barriers that prevent knowledge transfer?

From the experience of the researcher, the textile finishing industry is used as a key example to illustrate how barriers prevent interaction between designers and technology.

1.3.1 Facilities

On a visit to the UK based design-led specialist textile printer Belford Prints, Patricia Belford (2003) highlighted a key concern that textile design disciplines are still too separate and students need to acquire a better balance of knowledge between design and technology. She commented that in industry facilities are lacking for the opportunities to carry out these explorations and time is limited to research ideas where any research for new effects was carried out by existing staff between on-going commercial outputs. Additionally any literature produced is often technical or contains scientific data which limits interpretation of information regarding decorative potential. The need to reduce the distance between the textile designer and the process to allow exploration of materials to influence the design concept was reinforced in a visit to a large UK-based fibre company. There was no design department, instead textile design work was outsourced to consultants while the marketing department dealt with aesthetic developments. It would be interesting to see how design exploration of processing techniques could be more successful in this system. Although Storey (1992:173) claims, "the best results do not come until an acceptance and an understanding of the new methods enables the designer to use them to his advantage" the opportunities to explore the methods and processes seem to be lacking.

1.3.2 Literature

Textile designers have mostly been aware of the limitations of finishing processes, paying attention to fibre content and fabric construction according to processing restrictions. Many of these processes may offer the potential to influence design development if the opportunity for investigation is taken as highlighted in 1.3.1. Literature provides useful information to assess the resulting performance characteristics of fabrics, but there seems to be a lack of information which links technical information to design potential. The following literature search explored a range of features associated with textile finishing techniques, firstly putting them in the context of the overall manufacture of textiles. Barnett, (1997) gives a basic outline of the textile production process, illustrating the position of textile finishing in relation to the whole operation.

1. fibre production
2. yarn production
3. fabric production
4. dyeing and finishing
5. making up garments or other textile products

All fabrics are finished in some way. In its simplest form this includes washing and ironing with other processes being more complex. The finishing process converts grey[2] goods into finished cloth ready for use. It is not necessary to produce an exhaustive list of the many finishing processes available but to note the variety and complexity of the processes included within the textile finishing industry. Definitions and classifications of textile finishing techniques are wide and varied.

Most of the literature available is of a technical bias including descriptions of the manufacturing processes (Fiscus, 1989), the expected outcome of the techniques and sometimes more detailed explanations of the underlying chemistry and chemicals involved (Flick, 1990). Technical descriptions may be difficult to visualise in terms of the resulting pattern on the cloth and the influence on final product. Perhaps the data could be translated using terms more appropriate to a wider audience rather than only to specialists in the field.

A technical definition of finishing is given by McIntyre and Daniels (1995) "finishing: descriptive of processes, physical or chemical, applied to a substrate to produce a desired effect". Braddock and O'Mahony (1998: 97) put finishing techniques into the context of fabric design stating that finishing is the final process in production and the last stage at which unusual and innovative fabrics can be created. The Encyclopaedia of Textiles (1980: 394) simplifies the term whilst acknowledging the complexities involved "finishing is a comprehensive term covering those processes which follow the actual construction of a fabric and are designed to give it special characteristics in accordance with the end-use to which it will be put". Hatch (1993) expands on the classifications of finishing processes including the type of modification process employed, whether the results are visually apparent, the longevity of the effect and the number of added benefits to the substrate.

1. Chemical, mechanical and / or thermal
2. Visible or non-visible
3. Durable, semi-durable, renewable or temporary
4. Single or multifunctional

[2] *grey cloth:* cloth before it has been bleached, dyed or finished. Also known as greige cloth, (Anstey and Weston, 1997).

Contemporary literature provides useful information to assess the resulting performance characteristics of fabrics, but there is a lack of information which links technical information to design potential. This could be addressed with images of samples and descriptions of aesthetic effects which could then be manipulated to achieve design effects. For example materials known for performance characteristics can not be assessed for decorative potential as the scientific data does not communicate decorative characteristics. This is exemplified in the case of specialist finishes such as coatings applied to woven fabrics used on Architectural constructions including the Georgia Dome in Atlanta, USA, the Millennium Dome in London, UK, Sony Centre in Berlin, Germany. Although strict performance criteria are fulfilled there is little indication of process exploration to discover new creative outcomes. Many specialist finishes were originally developed for medical and military applications with the emphasis on protective properties. However if there is opportunity, could these technologies be explored outside the context of technical performance to explore design outcomes? It is recognised that in order to develop more innovative high quality products, companies involved in the coating and technical textiles industries need to invest in more research and development in laboratory environments. Hibbert (2001) devotes a major section in her book specifically to new properties and finishes, some of which are listed in Table 1.2. Many of these finishes are now actively incorporated into the design concept of garments or products for their performance properties but how many have been explored from a creative perspective? How can this knowledge be applied to inspire new concepts and decorative applications?

Table 1.2: Examples of properties achieved with selected finishing treatments

Properties	**Example of finish applied**
Ultraviolet protection	Ceramic molecules in surface finish
Antibacterial protection	Chitosan coating
Fire resistance	Chlorine and phosphorous coating
Abrasion resistance	Quartz coating
Weatherproof treatment	Resin or silicone coatings
Thermal insulating materials	Paraffin-wax based phase-changing material (PCM)
Chemical protection	Carbon finish
Reflective textiles	Microscopic glass beads with reflective backing
Phosphorescence	Dyes impregnated with phosphorescence
Antistatic properties	Polytetrafluorethylene (PTFE) membrane

1.3.3 Insufficient knowledge of outcomes on fabric characteristics

In order to incorporate new processing techniques into the design process of fabric, the range of properties and characteristics must be understood to anticipate their contribution to the final performance of the product. Barnett (1997: 20) wrote "successful designing can only take place when a sound understanding of all the processes involved in its production is applied". Aldrich (1996) supports this view and recognises the importance in understanding fabric characteristics and their implications with specific reference to garment design. In this context the emergence of new processing techniques have unknown effects on pattern cutting and garment construction. Any new processes developed would also have implications on the proceeding treatments, together with presenting opportunities in subsequent stages of application and design. Technical data and literature needs to communicate how these processes translate into certain fabric characteristics, such as drape, handle, shear, weight, thickness and stretch, similar to those used by Aldrich to classify fabrics.

1.3.4 Organisational barriers

Rethinking textile processing techniques has implications on organisational structures, traditions, processes and productivity. For example finishing techniques are typically regarded as the end of the fabric production process; however design interaction is increasingly modifying the nature of these operations and industry traditions. For example Figure 1.13 Miyake's "Pleats Please" collection (Holborn, 1995) illustrates that the traditional model can be adjusted, completing garment construction before finishing, thus allowing the final silhouette to be directly influenced by the pleating operation. The partially crushed and dyed garment illustrates how Issey Miyake directly linked the finishing technique and the design concept of the completed garment. The position of the binds on the garment directly relates to the resulting creased form dictating the final shape. Could this technique be applied to other finishing processes – applying the finish to the constructed form?

Figure 1.13: Issey Miyake. Partially crushed and dyed.
Autumn/Winter 1993/1994 (Holborn, 1995)

1.4 Chapter conclusion

In response to aim 1, a critical evaluation of the dynamics of knowledge transfer and materials and processes was achieved by answering three key questions.

The first question asks what is knowledge transfer in the context of materials and processes? Knowledge transfer in the context of materials and processes was most comparable to the model supported by the AHRC. Creative interplay between researchers and teams of diverse specialists formed the heart of the model in which interactions with materials and processes allowed the discovery of new opportunities and new challenges. Still in its infancy as a defined subject, no clear strategies were available on which the research could build although the knowledge learnt and the journey undertaken were equally valid outcomes as the material samples. Examples of textile practice helped to provide provided evidence of knowledge transfer taking place although as a by-product of an on-going desire to explore the outcomes of materials and processing techniques. Examples of practice illustrated investigations of materials and process which allowed the unidentified knowledge transfer process to proceed through discovery and experimentation.

Question two, Why is it important to reconsider practice from the perspective of knowledge transfer frameworks, provided the opportunity to discuss the hidden value of practice-based research work as *knowledge transfer frameworks,* mainly translating existing contexts and practice as strategies to support the changing dynamics of materials and design. Not only does this have implications for the role of textile designers but also the wider development of materials and processes as flexible systems. Examples have been given within and beyond textiles to support the argument that textile developments are being encouraged to evolve beyond traditional materials, techniques and expectations. This vision has great potential if supported by infrastructures including teams of individuals from varied disciplines, organisations and research institutions with facilities to respond to such interests. Sparke (1986) describes the development of a new language for design aesthetics defined by a combination of technology, price, function and social symbolism. The generation of increasingly more structured fabrics delivers more complex messages about what and how we perceive textiles escalating the need for creative exploration of technology and materials to develop new design aesthetics.

Creative exploration is not always associated with textile manufacturing operations where efficiency and production control have often taken priority to produce large volumes of fabric with little product variety. Manufacturers are being forced to be flexible and react to the market to provide differentiation. In view of this, it is recognised that integration is a key concept in the future success of manufacturing operations, enabling the process of an increasingly diverse range of products. As flexible manufacturing and product diversification becomes a reality it would be equally competitive to respond to demand for innovative products having actively explored the creative outcomes of the processes. Colchester (1991) suggests this approach for fabric printing. Rather than adopting patterns to fit production techniques, the technology can be used as creative resources for the production of technical effects in addition to the literal translation of designs.

The examples of practice illustrate knowledge transfer as a by-product of practice taking place across a widespread interest in multidisciplinary teams to develop hybrid materials. The chapter identifies lack of data on the knowledge transfer frameworks in which the knowledge transfer events took place. It is suggested that additional knowledge could be gained by considering the frameworks within which the practice was carried out. Certain questions could not be answered such as what worked, what didn't work, how the teams communicated, what could be improved, thus restricting the benefits of existing data to inform strategies for future research collaborations.

The final question was proposed to identify the barriers that prevent knowledge transfer. These barriers were identified as;

- Lack of facilities and opportunities to carry out explorations between designer and processes.
- Time restrictions on industrial production reducing the opportunity to explore new ideas.
- The literature was often of a technical nature communicating technical and performance characteristics but with no links to design potential.
- Insufficient knowledge of outcomes of new processes on fabric characteristics implying a high risk factor of unknown results on proceeding and subsequent stages of the design and manufacturing processes.
- Organisational barriers such as rethinking traditions, processes and resulting implications of lower outputs and productivity.

Building on these conclusions the thesis introduces two case studies of practical research of materials and processes from which knowledge transfer frameworks evolved. Not only were unique decorative characteristics of materials identified, but the context of the knowledge transfer process was identified. Case studies 1 and 2 (Chapters 2 to 6) present examples of small-scale practice-based research, which highlight novel, decorative outcomes, underpinned by the knowledge transfer framework which enabled the successful science and design collaboration.

PART TWO

Chapter 2: Case study 1: Sodium hydroxide

The following chapter includes experiments which illustrate the resulting characteristics of fabrics following chemical treatment in sodium hydroxide then dyed.

2.1 Introduction

Aims of chapter two:

1. To explore the application of sodium hydroxide on selected substrates
2. To develop new skills and knowledge of the materials combining technical understanding with aesthetic development.
3. To generate suggestions for further investigations

Initial trials of a variety of materials and processes were considered for creative exploration using laboratory based small scale, practice-based research methods. These techniques included applying heat to fabrics, perming fabric and fibres and applying silicones to fabrics. These techniques were explored simultaneously to initial investigations with sodium hydroxide on cellulose acetate with the aim of identifying a combination with unexplored creative potential. Sodium hydroxide was specifically chosen as it was recognized that diverse dye effects (Roberts and Clipson 1994) could potentially be generated as a result of a chemical process called deacetylation. Deacetylation is the process in which cellulose acetate and cellulose triacetate fibres are modified resulting in chemical properties similar to cellulose. Following deacetylation the cellulose acetate and triacetate fibres had affinity for direct dyes. This was supported in initial investigations as cellulose acetate fibres which normally have affinity for disperse dyes, were successfully chemically modified to have affinity for direct dyes. This suggests the possibility of generating diverse dye effects as different colour disperse and direct dyes could be included in the dyebath. Historically the process of making cellulose acetate receptive to direct dyes was explored in the textile industry however working on a commercial scale, reproducibility was difficult to achieve without precise controls.

The underlying theme was to explore the potential creative outcomes of selected materials and processes developing new skills and knowledge to deliver more consistent results. The outcomes of experiments were analysed combining technical feasibility and aesthetic contribution directly informing prospective research. Towards the end of the research the depth of skills and knowledge allowed the researcher to relate processing techniques to the range of potential effects. The connection between technical knowledge and aesthetic values allowed the processing parameters to be questioned and combined as a tool to develop novel combinations of effects. Images of samples were applied to suggestive rather than definitive end uses. The initial experiments were necessary to become familiar with the materials and processes and understand the parameters for investigation.

2.2 Materials

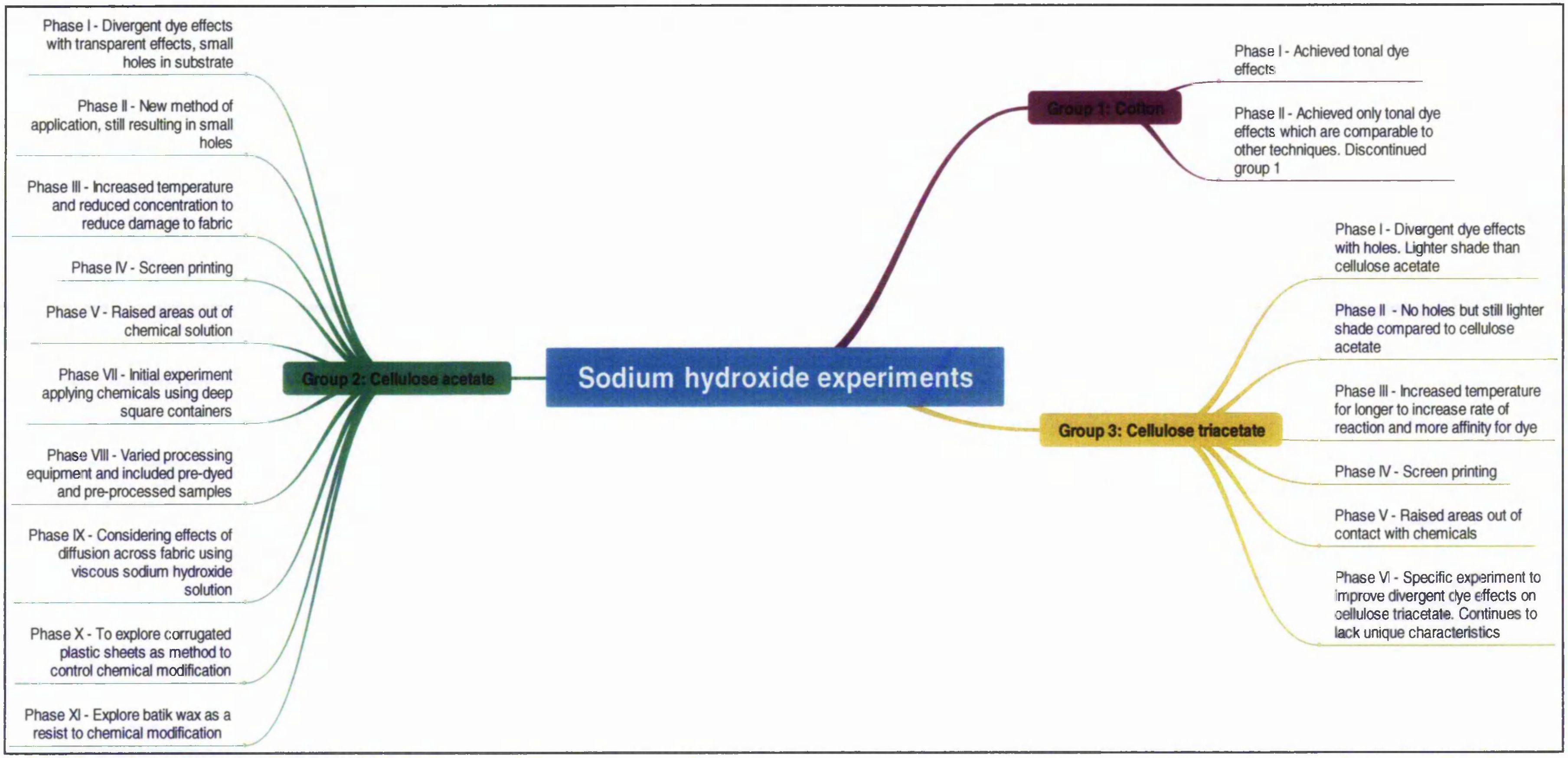
2.2.1 Sodium hydroxide

Sodium hydroxide is a strong alkali which is also known by its chemical formulae, NaOH, or an alternative term often used in textile industry, which is caustic soda. Examples of existing processes in the textiles finishing industry using sodium hydroxide include mercerization on cotton in which sodium hydroxide is applied to cotton fibres causing swelling. The swollen fibres become more receptive to dye and results in a deeper shade being achieved. The fibre also becomes more lustrous giving the impression of a smoother, shinier surface. Sodium hydroxide applied to cotton fibres can also produce seersucker and shrink effects. The effect of the fibre swelling in diameter results in a reduction in the length, closing the gaps between the fibres and shrinking the fabric. The placement of these effects can be controlled using application techniques and the characteristics of the fabric can be manipulated to the desired effects.

2.2.2 Substrates used

Cotton, cellulose acetate and cellulose triacetate fabrics were chosen as a result of their specific properties and particular reactions with sodium hydroxide. The initial body of research explored the effects of sodium hydroxide on these substrates in order to generate comparisons of possible outcomes. As the research progressed the samples dictated future research directions according to potential for further exploration under the aesthetic and technical criterion developed. The substrates were systematically eliminated as the experiments developed, concentrating on cellulose acetate as the most responsive to the experiments. The research directions are illustrated in Mind map 1.

Mind map 1: Sodium hydroxide experiments.



2.3 Experimentation phase I

2.3.1 Aim: To explore the effects of viscous sodium hydroxide solution on selected fabrics. Initially it was thought that differential dyeing effects could be achieved on the front and reverse faces of selected fabrics as a result of applying a viscous solution of sodium hydroxide. If the solution did not soak through to the other side the chemical reaction would only take place on one side therefore resulting in differential dying effects.

2.3.2 Method

Figure 2.1 below illustrates the basic processing stages which were carried out on all samples. As the research develops this model was extended to include additional processing stages constantly reviewing previous outcomes in a reciprocal manner. Group 1 contained cotton fabrics (samples1 and 2), group 2 cellulose acetate fabrics (samples 3 to 4a) and group 3 cellulose triacetate fabrics (samples 5 and 5a).

Figure 2.1: Basic processing stages carried out.

Preparation of fabric samples → Application of NaOH to specific areas → Processing conditions → Wash until neutral pH → Neutralise in 0.5 % acetic acid → Dye

Sample 1 was initially laid flat on a glass plate and samples 2 to 5 were taped around the edges. This was to put the fibres under tension during chemical reaction as is carried out in the mercerization process. A viscous solution of 6% CMC[1] with 11% sodium hydroxide was applied with a pipette. The samples in group 1 were left to dry at room temperature and samples in group 2 and 3 were put in the oven at 42° C until dry. Once dry, rinsed and neutralised the samples were examined for results before dyeing.

2.3.3 Method for dyeing

Samples from all three groups were put in a dyebath containing disperse and direct dyes. As outlined in 2.1 the inclusion of both disperse and direct dyes in theory should highlight the affinity of different fibre types for different dyes. Contrasting colour dyes were chosen to illustrate the extent of each dye take up.

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[1] (Sodium) Carboxymethyl Cellulose used to thicken the solution.

2.3.4 Results after dyeing

The results are initially discussed in groups then compared for evaluation. Group 1 contains cotton samples, group 2, cellulose acetate and group 3, cellulose triacetate.

Group 1: Cotton

As seen in Table 2.1 both cotton samples took to only the direct blue dye reflecting the fibres affinity for this dye type. More dye was absorbed by the area treated with sodium hydroxide than the surrounding fabric with equal effect on the face and reverse of the samples. Sample 1 was left on the surface of the glass plate during

Table 2.1: Initial effects of viscous sodium hydroxide solution on cotton fabrics.

<table>
<tr><th></th><th>Results after dyeing</th><th>Fabric samples</th></tr>
<tr><td rowspan="2">Group 1 – Cotton fabric</td><td rowspan="2">Only direct dye taken up by cotton fibres.

Deeper shade of direct dye where sodium hydroxide applied on both faces of fabric.

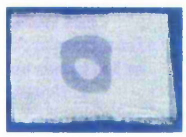
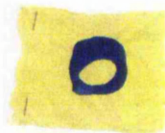
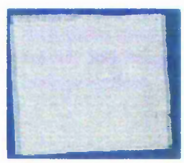
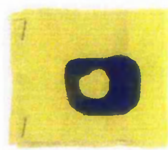
No transparent areas or noticeable change in fabric handle.

Sample 1 lighter shade than sample 2.

Fibres were physically modified not chemically modified.</td><td>
Sample 1
Calico</td></tr>
<tr><td>
Sample 2
Calico</td></tr>
</table>

processing, while sample 2 was taped in place. There were no resulting transparent areas and no obvious change in fabric handle or drape.

Table 2.2: Initial effects of viscous sodium hydroxide solution on cellulose acetate and cellulose triacetate fabrics.

	Results before dyeing	**Results following dyeing**		**Fabric samples**	
				Treated undyed samples	**Treated dyed samples**
Group 2 -Cellulose acetate	Noticeable transparent areas where treated with solution. No holes appeared in treated area.	Divergent dye effects on both sides of the fabric resulting in disperse and direct dye take up.	Deepest dye results from group. Small holes in treated area.	 Sample 3 1x1 jersey knit	 Sample 3a
			Lighter shade of direct and disperse dye take up compared to sample 3.	 Sample 4 3x1 twill	 Sample 4a
Group 3 - Cellulose triacetate	Slight fibre modification where treated.		Yarns in treated area move more readily following both processes.	 Sample 5 Plain weave	 Sample 5a

Group 2: Cellulose Acetate

Table 2.2 compares images of samples of cellulose acetate and cellulose triacetate following initial processing in sodium hydroxide before and after dyeing. The undyed cellulose acetate samples had noticeable transparent areas where treated by the sodium hydroxide, as highlighted by the background coloured card showing through the fabric. When dyed, both 3a and 4a absorbed the direct and disperse dyes on both faces of the fabric. The knitted cellulose acetate (sample 3a) resulted in the deepest dye shades in the group however small holes also developed in the treated areas. The transparent effects were not as clear in the dyed samples perhaps due to the choice of dyes used.

Group 3: Cellulose Triacetate

In Table 2.2, cellulose triacetate (sample 5) less fibre modification was evident where treated in the sodium hydroxide solution than group 2. When dyed, the cellulose triacetate took both disperse and direct dyes however the take up of direct dye was not consistent in the treated area. Although the fibres were chemically modified the uneven direct dye take up illustrates that the process needs to be modified if a more uniform result is required.

2.3.5 Conclusion

The initial aim was to produce fabrics with two sided dye effects. Viscous sodium hydroxide was applied to one side of the samples to vary the affinity of the fabric for the dye. This aim was unsuccessful as the solution soaked through to both sides on samples in all groups with the same dyeing effects resulting on both faces. Although this was unsuccessful additional effects included tonal dye effects on the cotton fabrics, transparent effects and changing fabric handle on cellulose acetate and triacetate samples. The cellulose acetate samples (group 2) responded most successfully to the experiment producing a combination of divergent coloration possibilities with transparent effects. The cellulose triacetate responded less successfully as the chemical modification of the fibres was not uniform throughout the treated area. Overall the three fabric types have been assessed in relation to their response to the application of viscous sodium hydroxide solution in particular noting divergent dye effects, the additional effects of transparency and fabric handle. These characteristics have the potential to produce a combination of contrasting effects allowing new aesthetics to be explored.

As a result of this experiment arising questions include; Can the sodium hydroxide be screen printed to control the areas of direct dye? Is the outcome influenced by the method of application of the solution to the substrate? Is it possible to create single sided effects if a more viscous solution is applied? Can the process be modified to reduce damage to the substrates? These questions illustrate how the research inspires new directions through practical engagement with process.

2.4 Experimentation phase II

2.4.1 Aim: To compare the characteristics of dyed samples following whole or part exposure to sodium hydroxide solution

The results of phase I included tonal dye effects on cotton with divergent effects, transparent effects and changing fabric handle on both cellulose acetate and cellulose triacetate samples. Phase II continued the exploration of these effects with the aim of varying the contact of the fabric with the chemical solution to explore possible outcomes. This was achieved as a result of considering the method of application of chemical solution in addition to applying a range of resist techniques to the substrates. The application of sodium hydroxide included two methods; samples were either partially dipped in solution or were fully submerged. The resist techniques involved tying shaped objects in the substrates or folding the fabric to prevent contact with the chemical solution.

2.4.2 Method

Figure 2.2: Modified processing stages.

Preparation of fabric samples	→	Application of NaOH to specific areas	→	Wash until neutral pH	→	Untied fabric samples	→	Neutralise in 0.5 % acetic acid	→	Dye

Figure 2.2 illustrates the processing stages carried out. Before processing, the fabric samples were individually knotted or tied to achieve resist effects producing unequal contact with the chemical solution. The samples were then either fully submerged in a solution of 30% sodium hydroxide or dipped in the solution and left for 10 minutes. The samples were then washed until pH neutral and the ties were removed. They were then neutralized in 0.5% acetic acid then

dyed at the boil for 30 minutes. The fabric types included cotton, cellulose acetate and cellulose triacetate. The cotton group was extended to include cotton muslin which is a thinner fabric than calico, generating a comparison to the results.

2.4.3 Results

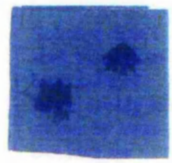
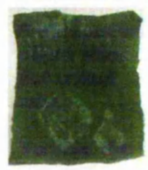
Group 1: Cotton

As seen in Table 2.3, the cotton samples in group 1 reacted to the process with tonal dye effects and some 3-D surface texture effects. There were no transparent effects or noticeable changes in fabric handle or drape. Samples 6 and 7 were both tied with large round plastic shapes to create areas of resist and part dipped in solution for ten minutes. Once dry and neutralized the resist ties were removed and the samples were dyed with a direct blue dye. Darker shades of dye resulted where more direct dye was absorbed in the treated areas, noticeably more on the face in contact with sodium hydroxide, thus the fabrics had different patterns on each side. Sample 8 was tied with small round balls closely together, then fully submerged in solution following the same process as samples 6 and 7. The dyebath was prepared with a mixture of yellow and red direct dyes resulting in a variable orange shade. The fabric also had 3-D surface texture effects reflecting the position and shape of the objects used. Surface texture effects were also noticeable in sample 10 where a glass cube was tied into the substrate. Subtle surface texture effects were evident in samples 11 and 12 but not as enhanced as sample 8.

Group 2: Cellulose acetate

All the cellulose acetate samples (samples 13 and 14) produced divergent dye effects together with varying degrees of transparency (Table 2.4). These three samples were tied with round plastic balls and partially dipped into viscous solution of NaOH. Sample 13 resulted in small holes, however 13a was intact. The knitted samples (13 and 13a) also dyed to a deeper shade than the cellulose acetate woven sample (14). The transparency effects were less well defined on the knitted samples than the woven sample. Perhaps this was due to the thicker fabric pile and hence more time required for chemical reaction. Whilst sample 14 resulted in medium dye take up compared to samples 13 and 13a, the transparent effects in the treated area added an illuminating quality to the substrate. Holes in sample 14 appeared at the edges of the treated areas.

Table 2.3: Characteristics of dyed cotton samples following whole or part exposure to sodium hydroxide solution.

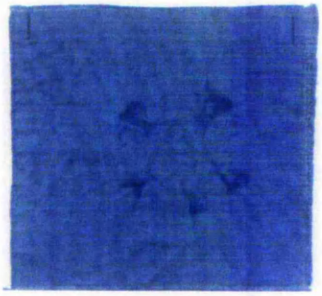
	Sample number	Resist used	Application technique for NaOH	Dyeing	Results	Fabric samples
Group 1 - cotton	Sample 6 Calico	Tied with large round objects in the fabric.	Dipped into 30% NaOH solution. Left for 10 minutes at room temperature. Left until dry.	Direct blue dye.	Deeper shade of direct dye on side in contact with solution. No noticeable changes in surface texture. Solution didn't soak through to both sides of fabric evenly as shown by tonal dye take up.	 Sample 6
	Sample 7 Calico					 Sample 7
	Sample 8 Calico	Tied with small round objects in the fabric.	Fully submerged in 30% NaOH solution. Left for 10 minutes at room temperature. Left until dry.	15ml direct yellow 10ml direct red 20ml sodium chloride	Variable orange shade. Surface texture effects.	 Sample 8
	Sample 9 Calico	Pleated and stapled.		15ml direct solar blue 10ml direct solar yellow 20 ml sodium chloride Made up to 300ml with distilled water	Variable green shades. No surface texture effects.	 Sample 9
	Sample 10 Muslin	Tied with cube shapes and pleated.			Surface texture effects where tied around cube. Variable dye take up.	 Sample 10
	Sample 11 Calico	Pleated diagonally across fabric.			Variable dye take up echoing diagonal pleats. Slight surface texture where pleated.	 Sample 11
	Sample 12 Calico	Random scrunched and tied.			Variable dye take up echoing resist used. Slight effect of surface texture.	 Sample 12

Group 3: Cellulose triacetate

Table 2.4 contains cellulose triacetate samples which were prepared by tying round objects into the substrates. Sample 15 was partially dipped in the sodium hydroxide whilst samples 16 and 17 were completely submerged. Sample 15 was dyed in direct blue with disperse yellow and samples 16 and 17 were dyed in direct violet with disperse yellow to compare dye effects. As in 2.4, the cellulose acetate (15), produced lighter shades of disperse and direct dye take up when compared to cellulose acetate. Sample 16 and 17 resulted in an overall combination of the violet (direct) and yellow disperse) dyes across the whole of the fabric. The take up of disperse and direct dye was not as well defined as the cellulose acetate samples following the same stages of processing. Additionally no transparent effects or physical fibre modification was evident (in 15 to 17) when held up to the light.

2.4.4 Conclusion

The aim of phase II was to compare the characteristics of dyed samples following whole or part contact with sodium hydroxide solution. Reinforcing the results from phase I, cotton (group 1) produced tonal dye effects and both cellulose acetate and cellulose triacetate produced divergent dye effects. In addition to tonal dye effects the cotton samples also included surface texture effects depending on the resist technique applied, however there was no evidence of transparent effects on this substrate. Cellulose triacetate (group 3) produced divergent dye effects yet again transparent effects were not evident. The cellulose acetate samples (group 2) resulted in combinations of well defined divergent dye effects with the fabric becoming thinner in the most exposed areas allowing silhouettes to be seen through the fabric when held up to the light. Over exposure to the chemicals caused damage to the cellulose acetate resulting in small holes as seen in samples 13 and 14. In summary, phase II highlighted that cellulose acetate produced the widest range of effects however a small amount of fabric damage was incurred. The cellulose triacetate displayed divergent dye possibilities without the thinning effects. Cotton produced only tonal dye effects with evidence of surface texture effects. These were not unusual outcomes for cotton substrates relating to seersucker effects mentioned in 2.2.1. Cotton was discarded from further research as diverse dye effects were not produced. The research focused on cellulose acetate and cellulose triacetate from this point.



Sample 6

Sample 7

Sample 8

Sample 9

Sample 10

Sample 11

Sample 12

Table 2.4: Dyed cellulose acetate samples following part exposure to sodium hydroxide solution.

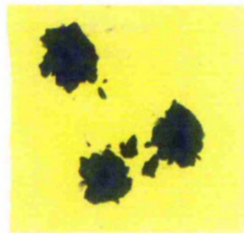
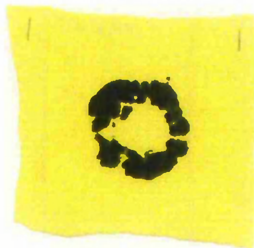
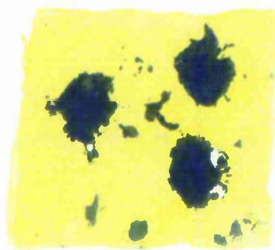
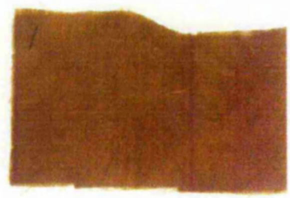
	Sample numbers	Resist used	Results		Fabric samples
Group 2 Cellulose acetate	Sample 13 Cellulose acetate jersey rib	Round plastic balls tied into samples. Dipped into viscous sodium hydroxide solution as used in 2.4.2. Allowed to dry at room temperature overnight.	Samples dyed successfully with the disperse dye. Variable deep shades of direct dye take up. Transparent effects where treated.	Small holes in treated area.	 Sample 13
	Sample 13a Cellulose acetate jersey rib	Disperse yellow Direct blue		No holes.	 Sample 13a
	Sample 14 Cellulose acetate 3x1 twill		Medium direct and disperse dye take up. Holes in sample. Noticeable transparent effects in fabric.		 Sample 14

Table 2.5: Dyed cellulose acetate samples following whole or part exposure to sodium hydroxide solution.

	Sample numbers	**Conditions when applying sodium hydroxide**		**Dyeing**	**Results**	**Fabric samples**
Group 3 - Cellulose triacetate	Sample 15 Cellulose triacetate plain weave	Round plastic balls tied into all samples some reverse tied. Allowed to dry at room temperature overnight.	Dipped only the tied areas into viscous sodium hydroxide solution as used in 2.4.2.	Disperse yellow Direct Blue	Lighter shades of disperse and direct dyes compared to cellulose acetate.	 Sample 15
	Sample 16 Cellulose triacetate plain weave		Fully submerged in solution.	Direct Violet Disperse Yellow	Boundaries between disperse and direct dyes not well defined. More of an overall colour effect.	 Sample 16
	Sample 17 Cellulose triacetate plain weave					 Sample 17

2.5 Experimentation phase III

Cellulose acetate and cellulose triacetate were selected for further research based on the consistent outcomes of novel visual effects which were diverse dye effects, transparency and more fluid feel to the fabric of the drape. However each substrate also produced characteristics which were unsatisfactory and might be improved as a result of modifying the processing parameters.

2.5.1 Aims: To modify processing parameters to reduce damage on cellulose acetate and to increase the rate of chemical reaction on cellulose triacetate thus improving affinity for disperse dye. The experiment was modified from earlier methods by reducing the concentration of chemical solution from 30% to 1% in addition to increasing the temperature during processing.

2.5.2 Method

Cellulose acetate and cellulose triacetate substrates were tied to create resist effects in order to vary the contact between the substrates and the chemical solution. The samples were completely submerged in a solution of 1% sodium hydroxide and heated up to 50°C for 10 minutes. The samples were taken out of the solution, the ties were removed then the samples were rinsed in water and neutralized in acetic acid. The samples were put in a dyebath containing10ml direct violet dye stock, 10ml disperse yellow dye stock with 10ml sodium chloride. The dyebath was made up to 300ml with distilled water and dyed for one hour at 100°C. Contrasting coloured disperse and direct dyes were chosen in order to emphasise divergent dye effects reflecting the areas where chemical modification had changed the affinity of the fibres from disperse dyes to direct dyes.

2.5.3 Results

Group 2: Cellulose acetate

The cellulose acetate, samples 18-20 (group 2, Table 2.6) appeared to be similar colours resulting in violet and yellow colour combinations in varying patterns. The woven samples (18 and 20) contained some sharp lines at the boundaries between direct and disperse dyes when compared to the knitted sample (19), whose colour effects were gradual tonal changes. The knitted sample (19) produced a similar colour palette as 18 and 20 except the disperse yellow was not as vivid. This suggests fabric structure also influenced the chemical modification process in particular the contrast between defined pattern effects on the woven fabric compared to the gradual pattern effects on the knit. Overall the colour effects were generally dull as the most prominent dye was the direct dye, in this case chosen to be violet. The coloured patterns reflected the position of the fabric when in contact with the chemical solution which then influenced the affinity to each dye type. For example sample 18 features a square shape in the centre as the fabric was wrapped around a cube during chemical processing. Samples 19 and

20 were both randomly tied resulting in all over colour effects. The samples were all fully submerged in sodium hydroxide therefore the transparency effects were consistent across the fabric surface with less obvious contrast.

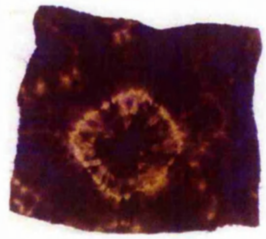
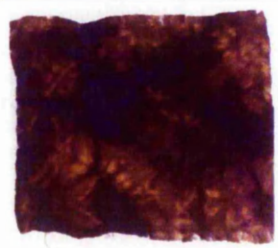
Group 3: Cellulose triacetate

The cellulose triacetate sample (21) did not produce as noticeable defined areas of chemical modification when compared to the cellulose acetate samples (18-20). The resulting mustard colour suggested more disperse dye (yellow) take up than direct dye (violet) with no lines defining the dye types. The sample contained darker and lighter shades where some chemical modification took place however there were still no transparent effects. The processing conditions improved the divergent dye effects on the cellulose triacetate compared to earlier experiments.

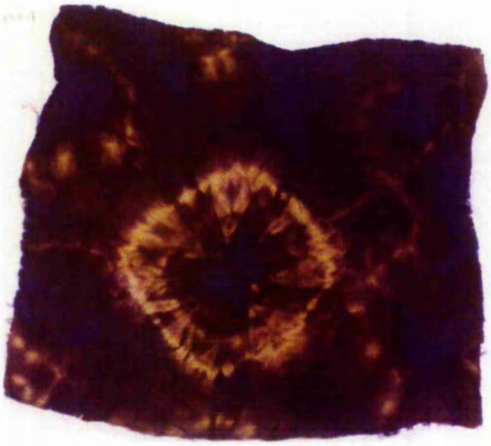
2.5.4 Conclusion

The aims of phase III were twofold. The first aim was to modify processing parameters in order to reduce damage on cellulose acetate. Secondly to increase the rate of chemical reaction on cellulose triacetate thus improving affinity for disperse dye. The chemical process was modified by heating up a 1% solution of sodium hydroxide (previously 30% in phase II) and leaving the substrates fully submerged for an hour rather than 10 minutes. The experiment successfully produced cellulose acetate samples with divergent dye effects and transparency results without causing damage to the fabric. The cellulose triacetate samples were also improved as a result of increasing the rate of chemical reaction improving affinity with direct dye. However there is a noticeable difference in dye take up between the two fabric types. Cellulose triacetate proved to be more difficult to chemically modify using the methods to-date. Options to resolve this might further increase the rate of chemical reaction by increasing the concentration of sodium hydroxide, the time and the temperature of the experiment. In contrast, the cellulose acetate samples produced consistent results and supported the decision to continue the research in this area.

Table 2.6: Cellulose acetate and cellulose triacetate samples fully submerged in 1% sodium hydroxide solution for an hour.

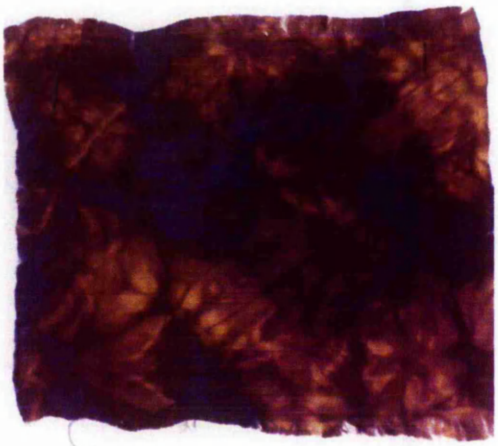
	Sample numbers	Results		Fabric samples
		All samples	Individual samples	
Group 2 - Cellulose acetate	Sample 18 Cellulose acetate 3x1 twill Tied sample around glass cube.	Resulting colours are violet, yellow with a mixture of tones of this colour combination. Similar to tie-dye effects.	Sharp lines, square shape. Transparent effects across most of fabric.	 Sample 18
	Sample 19 Cellulose acetate Knitted jersey rib Tied at random.		Boundaries between direct and disperse dyes are blurred - gradual tonal change.	 Sample 19
	Sample 20 Cellulose acetate 3x1 twill Tied at random.		Random effects where tied. Lines are sharp compared to sample 19 but less sharp than sample 18.	 Sample 20
Group 3 - Cellulose triacetate	Sample 21 Cellulose triacetate plain weave Tied at random.	Less direct dye than disperse dye – more yellow than violet colour. No clear definition between direct or disperse dyes – results in a mustard colour with darker and lighter shades. No transparent effects.		 Sample 21

Further work with the cellulose acetate will explore application techniques and resulting divergent effects with transparency characteristics.



Sample 18

Sample 19



Sample 20

Sample 21

2.6 Experimentation phase IV

Having generated a basic understanding of the expected outcomes of the materials within the processing parameters, the research explored screen printing as an alternative application method. Cellulose triacetate was not included in this experiment as previous results showed that it might be more difficult to chemically modify if being processed at room temperature.

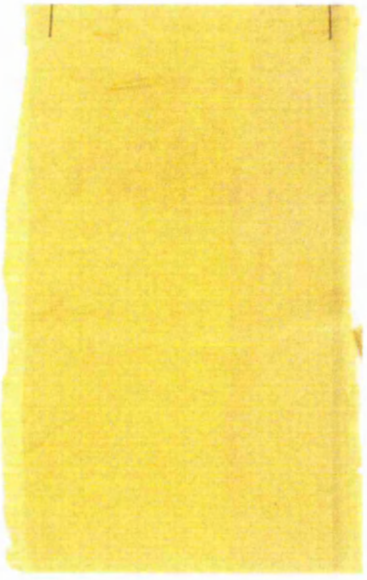
2.6.1 Aim: To screen print sodium hydroxide noting resulting effects on cellulose acetate fabrics.

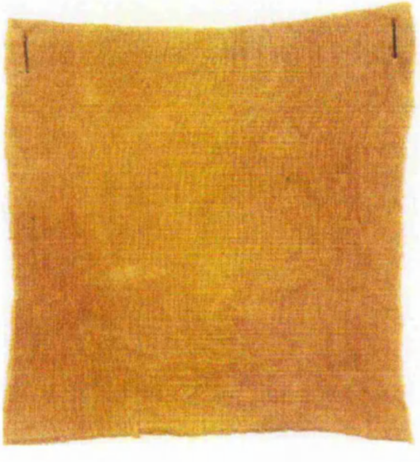
2.6.2 Method

Using a test screen, a viscous solution of sodium hydroxide combined with Manutex-F print paste was printed onto cellulose acetate 3x1 twill (sample 22) and cellulose acetate jersey rib (sample 23). The print solution was left on the substrates for ten minutes at room temperature in addition to five minutes in the drying cupboard to raise the temperature and increase the rate of chemical reaction. The samples were then washed to remove excess solution, neutralised and dyed in a dye bath containing direct (violet) and disperse (yellow) dyes.

2.6.3 Results

It was anticipated that the print screen would not withstand the sodium hydroxide solution as screens are normally cleaned using sodium hydroxide. Both the samples took the yellow disperse dye readily although the uptake of the violet direct dye was much reduced when compared to earlier experiments. Both samples showed little detail from the print however the woven sample (sample 22) had a faint image in the middle top section (not clear in the picture). The minor chemical reaction was only evident on the side the print paste was applied and did not soak through to the other side of either fabric.





Sample 22

Sample 23

2.6.4 Conclusion

The initial aim to screen print sodium hydroxide onto cellulose acetate fabrics proved technically successful however the resulting visual effects on the fabrics were less vibrant when compared to earlier experiments. The violet direct dye take up was less extensive and there were no visible transparent effects or changes in fabric handle. A possible explanation could be that the contact with chemical solution was reduced and the processing conditions resulted in a lower rate of chemical reaction. Improvements to the chemical modification of the fibres could be suggested by increasing the temperature, time, concentration and penetration of the solution into substrate. Also using a print paste that would hold moisture and could be heated up in an oven to give a reaction might improve the outcomes. The lack of detail on the knitted sample could also have been due to the nature of the fabric structure and the increase in thickness requiring more solution to penetrate the fibres allowing a more intense chemical reaction to take place. Despite the fact that the results were faint, future work could build on this as a potential process to specify areas for chemical modification. Research would have to be carried out to explore suitable print images, scale and repeat, perhaps building on the single-sided result as a feature.

2.7 Experimentation phase V

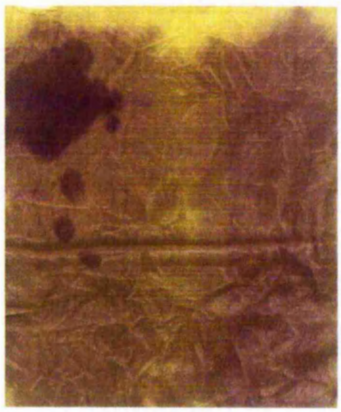
The research outcomes up to and including phase III, highlighted the range of visual effects in relation to processing parameters such as temperature and concentration of solution during the chemical modification stage. The formula developed in phase III was modified by increasing the concentration of the sodium hydroxide according to substrate in particular using a stronger solution for the cellulose triacetate in addition to increasing the time in solution. The next phase explored a method to control the extent of chemical modification by raising areas of fabric out of solution during processing.

2.7.1 Aim: To explore the effect of raising areas of substrate during chemical modification.

2.7.2 Method

The containers were specifically chosen to allow some areas of the fabric to be treated in solution whilst other areas were not initially in direct contact. Plastic trays with individual deep square compartments provided a repeating structure, separating chambers with angled sides (see Figure 2.3). Dry, undyed substrates were placed between two plastic trays and held in this position for the duration of the chemical process. Holes in the compartments in the top tray allowed 12ml of solution to be poured into each compartment without contacting the raised areas of fabric.

Table 2.7: Areas of substrate raised during chemical modification.

	Sample numbers	Results	Fabric samples
Cellulose acetate	Sample 24 Cellulose acetate 3x1 twill	Transparent effects focused in centre of vessels. Lines of direct dye continue away from each centre – up the sides of the vessels. Surface area was all chemically modified to various degreed.	 Sample 24
Cellulose triacetate	Sample 25 Cellulose triacetate plain weave	No pattern from contrasting areas of direct and disperse dyes. Chemical solution spread over the fabric surface with no reference to the shape of the vessels used. No transparent effects.	 Sample 25

The cellulose acetate was treated with 2% solution whilst the cellulose triacetate was treated in 10% solution. Both samples were left for an hour to process at room temperature. The samples were then rinsed and dyed for an hour in a dyebath containing direct dye (violet) and disperse dye (yellow) for easy comparison with earlier research outcomes.

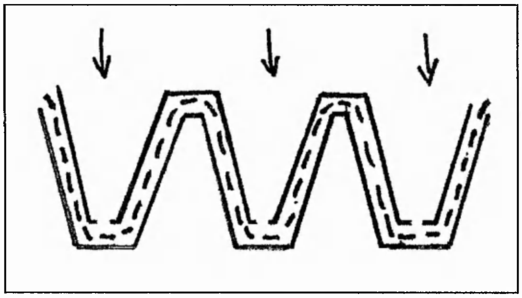


Figure 2.3: Square vessels used.

2.7.3 Results

It was anticipated that only the substrate in contact with the solution would be chemically modified producing divergent dye effects and transparency as seen in earlier experiments.

Sample 24

As seen in sample 24 (cellulose acetate), the majority of the fabric surface area has been chemically modified to different degrees. There are repeating elements where the fabric was most in contact with the solution as shown by violet centres. These areas were constantly in contact with the solution resulting in greater conversion of the cellulose acetate to cellulose thus absorbing more direct dye. These areas are also characteristically transparent when held up to the light contributing a luminous quality to the colour. Although the pattern is not an exact repeat there is an element of continuity as the chemical manipulation has sustained effects outward from the main centres. The resulting rounded shapes expanded sufficiently to meet other dilated centres thus covering the majority of the surface area.

Sample 25

Sample 25 (cellulose triacetate) was treated similarly to sample 24 except a 10% solution was used in order to provoke a more intense chemical reaction. There was no distinct resulting pattern between areas of direct and disperse dyes as the sodium hydroxide solution spread over the fabric surface with no reference to those areas mostly in contact with the chemical. As a result the dye effects lacked any particular detail or promise of control. Characteristically there were no transparent effects when held up to the light.

2.7.4 Conclusion

This process was more suitable for the cellulose acetate (sample 24) than the cellulose triacetate (sample 25). It produced visually exciting results combining tonal variations within a network of dilating lines emerging from specific centres. No damage was caused to the cellulose acetate as seen in earlier samples. The initial aim of exploring the effects of raising selected areas of the substrate out of the solution during processing proved to be a successful method to control the extent of chemical modification. This method produced non-identical repeats of divergent dye and transparent effects on cellulose acetate. Cellulose triacetate continued to be less responsive than the cellulose acetate to this process suggesting the parameters need to be further explored to intensify the chemical reaction for this substrate.

In order to better understand the results it was decided that investigations should consider the parameters which influence the contact between the sodium hydroxide and the substrates used. These might include size and shape of containers to help limit exposure to chemical modification, the strength of solution, length of time, temperature, and subsequent choice of dyes considering colour mixing potential in combination with transparent effects.

2.8 Experimentation phase VI

The research to-date produced divergent dye effects with cellulose acetate in contrast to the less responsive outcomes with cellulose triacetate. Therefore the next stage in the research focused specifically on cellulose triacetate to explore the possibility of improving divergent dye results.

2.8.1 Aim: To improve divergent effects on cellulose triacetate.

2.8.2 Method

Phase VI was carried out in two stages allowing the results from stage one (sample 26) to inform stage two (samples 27 and 28).

Stage one, sample 26.

Increasing amounts of 10% sodium hydroxide solution was measured into each well of the shallow plastic tray beginning with 5ml increasing up to and including 9ml, as seen in Figure 2.4. A dry fabric sample was placed over the tray ensuring the solution was in contact with the substrate. A flat plastic tray with a weight in the centre was placed on top and it was left to process at room temperature for just over 65 hours. The sample was then rinsed, neutralised and dyed in disperse blue and direct red for one hour.

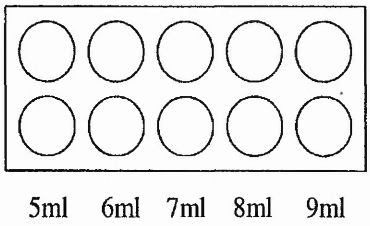


Figure 2.4: Round wells in tray.

Stage two, samples 27 and 28

The same process was carried out for sample 27 as sample 26 with the following modifications. 7ml of 10% sodium hydroxide solution was measured into each well of the shallow plastic tray and the sample was left to process at room temperature for 17.5 hours. Sample 28 was wet before being processed for 17 hours in a deep plastic square tray with 7ml of 10% sodium hydroxide solution. No weight was placed over sample 28. Samples 27 and 28 were rinsed, neutralised and dyed in disperse blue and direct yellow for one hour.

2.8.3 Results

Stage one, sample 26

The fabric was severely damaged in the areas submerged in 7ml solution up to and including 9ml of solution. The fabric also contracted around the damaged areas as shown by the uneven edge of the sample. The direct dye take up and fibre modification was more local than in previous experiments rather than spreading out across the surface of the cellulose triacetate.

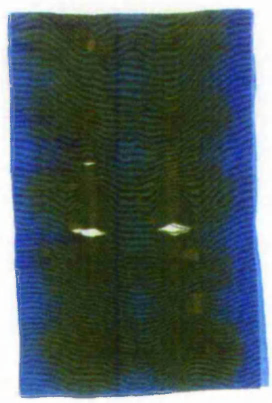
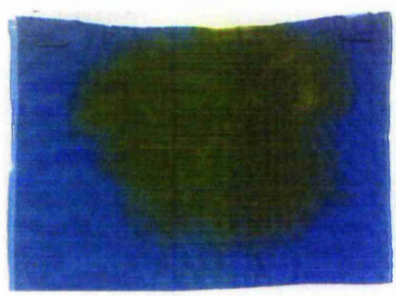
Stage two, samples 27 and 28

Sample 27 was also treated in the shallow tray (Figure 2.2) with circular shaped wells. The gradual divergent effects between disperse and direct dyes resulting in blue, green and yellow colours once again had no definite lines. The transparent effects on the fabric were in the centre of the round wells where the substrate was constantly in contact with the solution throughout the process. These effects were more prominent than previous samples (such as sample 25). There was a reduced amount of fabric damage between the round hollows specifically in the centre where the fabric was positioned below the weighted area. Sample 28 produced transparent effects in the very centre of piece with tonal green effects resulting from the blue and yellow disperse and direct dye mix. The square shape of the vessel was not evident in the resulting dye pattern bearing similar characteristics as sample 25.

2.8.4 Conclusion

Several parameters were varied in order to explore if cellulose triacetate could produce more successful results. The length of processing time was extended in stage one to 65 hours. The combination of complete submersion and extended processing time damaged the fibres although direct dye take up improved. Stage two resulted in more satisfactory outcomes after reducing the processing time to 17 hours consistently measuring 7ml of solution in each well. Sample 28 resulted in a combination of transparency and tonal dye effects with no evidence of damage. In conclusion a combination of divergent dye and transparency effects were produced on cellulose triacetate. These effects took longer to process than the cellulose acetate samples and did not result in the same distinct pattern effects even when the same processing equipment was used. The chemical process was revised to enable better chemical modification on the cellulose triacetate however the results continued to lack any unique characteristics when compared to the cellulose acetate.

Table 2.8: Divergent dye effects on cellulose triacetate following treatment in 10% sodium hydroxide solution for 65 hours.

		Sample numbers	Results	Fabric samples
Cellulose triacetate plain weave	Stage 1	Sample 26	Fabric was severely damaged from 7ml to 9ml of solution where it was submerged in solution. Fabric contracted where damaged.	 Sample 26
	Stage 2	Sample 27	Gradual divergent effects between disperse and direct dyes - tonal blue, green and yellow colours - no definite lines. Transparent effects on the fabric where constantly in contact with the solution throughout the process (in the centre of round hollows). Minor fabric damage between round hollows where positioned below weighted area.	 Sample 27
		Sample 28	Transparent effects in the very centre of piece. Tonal green effects resulting from blue and yellow colour mix. No pattern resulting from different shape processing vessel. No fabric damage.	 Sample 28

Initially research included three fabric types to explore the varying combinations of sodium hydroxide and dye effects on each. The cotton samples were eliminated after phase I as the resulting outcomes were not as varied as the cellulose acetate and cellulose triacetate. Cellulose acetate was found to be the most responsive to initial experiments however more focused explorations with cellulose triacetate provided improved outcomes although less dynamic than the cellulose acetate. Having established various processing parameters which consistently gave divergent dye effects and transparency, phase V began to consider the significance of processing equipment size, shape and position in relation to decorative effects. Phase VII now focused on cellulose acetate considering combinations of techniques and resulting divergent dye effects.

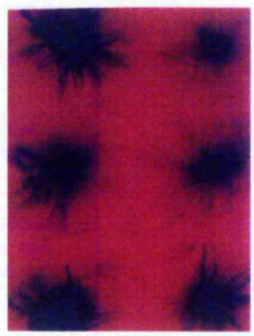
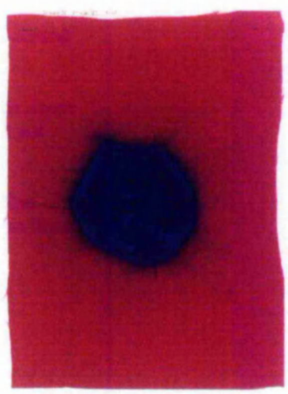
2.9 Experimentation phase VII

2.9.1 Aim: To explore the effects of chemical modification on cellulose acetate using repeats of deep, square plastic trays to regulate the position of application. Cellulose acetate was selected as it produced the most effective outcomes in response to the processing parameters.

2.9.2 Method

All samples were untreated and dry before processing. Samples 29 and 30 were both processed in the deep plastic trays with square shaped wells (Figure 2.3) pouring 16ml of 2% sodium hydroxide into each hole. Sample 29 was left to process without a top tray of the same shape holding the substrate in place. Sample 30 was arranged in the deep tray and the solution was poured into each vessel. Then a glass rod was used to twist against the fabric in the centre of each vessel. This repositioned the fabric causing folds which lifted some fabric out of the solution for the remaining processing time. Sample 31 was placed in a wider deep, round container and 150ml of 2% sodium hydroxide was poured in. In contrast to 29 and 30, sample 31 lay flat against the sides of the container without any folds or creases. All the samples were processed for one hour at room temperature. After one hour the samples were rinsed in cold water then put in a dyebath containing direct blue 106 and disperse red 11 for one hour. The dyes were specifically chosen to explore the potential of blue and pink colour mixing outcomes.

Table 2.9: Diverse dye effects on cellulose acetate following treatment in 2% sodium hydroxide solution processed in various containers.

Sample numbers		**Results**	**Fabric samples**
Cellulose acetate plain weave	Sample 29	Same colours both faces of fabric. Transparent effects in central areas. Divergent dye effects reflected the shape of the deep square vessels. The area of only direct blue (lighter shade) was contained in the central square area with a darker blue surrounding it. Darker blue lines leading away from the central area.	 Sample 29
	Sample 30	Same colours both faces of fabric. Transparent effects in centre of processed areas. Divergent dye patterns did not reflect the shape of the square vessels. Chemical modification influenced by the position of the fabric and any folds whilst in solution. Not exact repeats.	 Sample 30
	Sample 31	Same colours both faces of fabric. Transparent effects in the central direct dye area. Divergent dye reflected the shape of the round container but not exactly. Slight shadow of darker blue around central shape but no lines.	 Sample 31

2.9.3 Results

The dye take up reflected three main categories. Fully submerged areas taking more direct dye (light blue); partial submerged areas taking a mixture of disperse and direct dye (dark blue colour); areas not chemically modified resulting in taking up only disperse dye (pink). In all samples the colours and patterns were the same on both faces of the fabrics. The transparent effects remained in the most chemically modified areas thus also had affinity for direct dye.

Sample 29

The divergent dye effects vaguely reflected the square shapes of the vessels with the same colours and patterns both faces of fabric. The area of only direct blue (lighter shade) was contained within the central square areas with darker blue between the pale blue and the pink (disperse dye). The darker blue dye take up progressed away from the centre as if being smudged towards the untreated disperse pink area. The short smudged lines featured around both shapes.

Sample 30

The divergent dye patterns did not reflect the shape of the base of the square vessel rather the position of the folds in the fabric whilst in the solution. The patterns were not exact repeats however the range of effects were consistent. The areas of partial direct and partial disperse dye take up (dark blue) consisted of thicker dark blue lines with less defined dark blue shadows between the paler blue and pink colours.

Sample 31

The direct dye reflected the round shaped vessel but not the exact shape. A narrow band of darker blue surrounded the central shape but there were no lines radiating away from the central point.

2.9.4 Conclusion

Phase VII illustrated that chemical modification was directly influenced by the position of the fabric whilst in solution and could be adopted as a method to control the chemical modification process. Where sample 29 was left in contact against the deep square vessels resulting in more defined shapes, sample 30 was manipulated so that the fabric folded and partially lifted out of solution. The resulting dye pattern of sample 30 reflected the position of the vessels but not their shapes. The dimensions and shape of the holding container was also important to the take up of chemical solution as shown by the absence of lines in sample 31 compared to samples 29 and 30. Sample 31 lay relatively flat against the base of the vessel. This resulted in a more controlled area of direct dye take up with no lines diffusing into the non treated fabric. Overall, the samples illustrated that the dimensions and shape of the vessels directly influenced the capacity for chemical modification. Further studies needed to be carried out to consider the specific relationship between the processing variables such as equipment size, shape and how the substrates are positioned within them.

2.10 Experimentation phase VIII

The processing equipment used to hold the chemical solution was varied to include a plastic tray with smaller round holes (as used in phase VI) and a flat, shallow plastic tray. The range of initial substrates was extended to include pre-dyed samples in addition to samples from earlier experiments.

2.10.1 Aim: To re-process pre-dyed samples in addition to samples processed in earlier experiments.

2.10.2 Method

Sample 32a and 32b (Table 2.10)

The pair 32a and 32b were still joined during chemical processing then divided before dyeing to compare results. 10 ml of 2% sodium hydroxide solution was measured into alternate pairs of round holes in the shallow plastic tray before the fabric was placed on top. No weight or top tray was placed over the fabric to hold in place. The samples were left to chemically modify for one hour at room temperature. The sample was then divided into two and only half was dyed for an hour in a dyebath containing disperse red 11, and direct blue 106 at the boil. As with samples 32a and 32b, the pairs in the range 33a to 35b (Table 2.11) were all joined during chemical processing then divided before dyeing to produce comparisons. A flat shallow tray containing 200ml of 2% sodium hydroxide solution was prepared and the substrates were added in the following manner;

Sample 33 – the dry fabric was laid horizontal flat in the solution.

Sample 34 – wet, scrunched then dried to produce a dry crinkle surface before being added to the sodium hydroxide. The sample was laid horizontal in the flat tray although not all the fabric was submerged.

Sample 35 – wet and scrunched to produce a wet crinkle surface then laid horizontal in the flat tray although not all the fabric was submerged.

Sample 36 (cut off sample 29) wet, scrunched then dried to produce a dry crinkle surface texture

Sample 37 (untreated substrate) wet, scrunched then dried to produce a dry crinkle surface texture.

The samples were left in the chemical solution for one hour at room temperature.

Sample 38 (Table 2.12)

Fabric taken from sample 29 - a viscous solution of 11% sodium hydroxide was applied with a pipette and left for 1.5 hours to process at room temperature.

All the samples were put in the dye bath with 32b.

Table 2.10: Diverse dye effects on cellulose acetate following treatment in 2% sodium hydroxide solution processed in round containers.

Sample numbers		**Results**	**Fabric samples**
Pre-dyed cellulose acetate	Sample 32a	Chemical modification removed colour in the areas where in direct contact with the sodium hydroxide. Diffusion is not evident. Same colours both faces of fabric.	 Sample 32a Sample 32b
	Sample 32b	Transparent effects within circular areas. Divergent dye effects reflect the shape of the shallow round holes with dark blue outlining adjacent holes. Darker blue colour surrounds light blue core.	

Table 2.11: Diverse dye effects on cellulose acetate following treatment in 2% sodium hydroxide solution processed in flat containers.

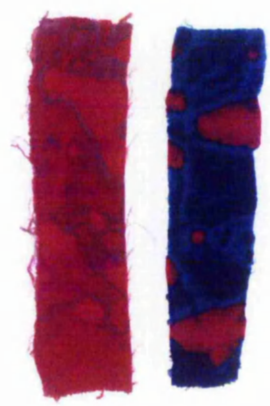
	Samples	Results	Fabric samples
Pre-dyed cellulose acetate	Sample 33a Not re-dyed	Chemical modification removed more colour at one end than the other. Suggests the fabric was not equally submerged in solution. Pre-dyed fabric did not return to white when treated.	 Sample 33a Sample 33b
	Sample 33b	Transparent effects not as clear. Divergent dye produce tonal graded effect. No specific lines or obvious boundaries between disperse or direct dyes. Chemical modification is more intense at one end than the other.	
	Samples 34a	Chemical modification is evident where dye has been removed resulting in lighter lines across the surface. These would be the lighter blue areas if re-dyed.	 Sample 34a Sample 34b
	Sample 34b	Not as easy to define transparent areas. Divergent dye effects reflect the uneven chemical modification due to uneven surface whilst processing. Disperse areas are consistently surrounded by dark blue lines before lighter blue areas.	
	Sample 35a	More dye is removed than 34a.	 Sample 35a Sample 35b
	Sample 35b	Similar results as 34 except the reduced areas of pink after subsequent dyeing suggested more chemical modification than sample 34. The centres of the disperse (pink) islands remain noticeably unmodified when compared to 34b.	

Table 2.12: Diverse dye effects on cellulose acetate following treatment in 2% sodium hydroxide solution processed in various containers.

	Sample numbers	Results	Fabric samples
From sample 29	Sample 36	The (square) light blue direct dye areas from sample 29 remain relatively unchanged. Random pink islands of disperse dye where the substrate is not submerged in solution outlined by a dark blue tones. Multi-tonal effects where the fabric is chemically modified to different degrees resulting in varying dye take up.	 Sample 36
Untreated	Sample 37	The random effects look similar to sample 34 except produced on a larger scale. As with other samples the resulting colours reflect chemical manipulation and affinity to direct or disperse dyes.	 Sample 37
From sample 29	Sample 38	11% viscous sodium hydroxide produced even tones of light blue direct dye outlined by sharp dark blue line. Chemical modification was restricted to the areas of substrate in direct contact with solution with no lines spreading away. Transparency was heightened when held up to the light as the fine dark blue contrasted with thinner fibres.	 Sample 38

2.10.3 Results

In all samples the same colour effects were produced on both faces of the fabrics.

Sample 32a and 32b

In sample 32a the areas in direct contact with the sodium hydroxide resulted in lighter disperse dye. The full extent of the chemical modification was not clear until the sample was re-dyed producing sample 32b. Migration of chemical solution across the surface was illustrated in 32b by the direct dye take up around the adjacent holes which was not initially in contact with solution. The transparent effects were contained within the circular areas. Darker blue colour surrounded the light blue core of the circles.

Sample 33a and 33b

In contrast to the other samples in phase VIII a gradual tonal effect was produced as the fabric was completely submerged in the sodium hydroxide. There were no sharp lines defining the divergent dye effects however the colour was deeper at one end of the fabric suggesting uneven chemical modification. The transparent effects were not as clear.

Samples 34a to 35b inclusive

Sample 34a was dry when put in solution whereas 35a was still wet. This resulted in more migration of chemical solution across the fabric surface in sample 35 resulting in more direct dye take up. Overall sample 34b took less direct dye than 35b. The transparent areas were less easily defined. The divergent dye effects reflected the uneven chemical modification due to uneven surface whilst processing. Notably the disperse areas were consistently surrounded by dark blue lines possibly suggesting the boundary of chemical modification.

Sample 36

The larger light blue areas from earlier processing remained relatively unchanged. The random pink islands of disperse dye represented areas where the substrate was not submerged in solution and were outlined by a dark blue colour. Across the fabric there were multi-tonal effects where the fabric was chemically modified to different degrees resulting in varying dye take up.

Sample 37

The random effects look similar to sample 34 remembering that sample 34 was pre-dyed before chemical modification. The same characteristics featured reflecting chemical manipulation and affinity to direct or disperse dyes.

Sample 38

Two application techniques were combined in sample 38. This included the effects created from square vessels in sample 29 together with more controlled effects resulting from the application of viscous sodium hydroxide. The chemical modification was controlled within the areas in direct contact with viscous solution and produced more even tones of light blue direct dye outlined by dark blue with no lines spreading away. The transparency was evident when held up to the light as the fine dark blue lines contrasted and outlined the thinner areas of fabric

2.10.4 Conclusion

Primarily the aim was to consider the position of the fabric in the solution and the shape of the vessel used. Pre-dyed samples were used in addition to sections from sample 29. Four main application methods were explored on pre-dyed and pre-treated substrates:

1. Partial application of chemical solution using flat tray with round holes
2. Lying the fabric flat in a shallow tray fully submerged in chemical solution
3. Lying creased fabric in a shallow tray creating an uneven surface
4. Application of viscous sodium hydroxide to specified areas of substrate.

The application of viscous sodium hydroxide contained the chemical manipulation within the area solution was applied to. Leading on from this, phase IX explored further application of viscous sodium hydroxide in particular as a method to control chemical modification within a specified area.

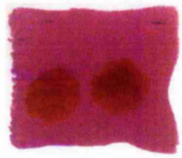
2.11 Experimentation phase IX

2.11.1 Aim: To explore the outcomes of treating samples in 11% viscous sodium hydroxide solution considering the effects of diffusion across the surface of the fabric.

2.11.2 Method

11% viscous sodium hydroxide solution was poured into the base of circular wells in the plastic tray. A pre-dyed sample and a pre-treated sample were placed over the tray in contact with the viscous solution. The samples were left for 1.5 hours at room temperature before being rinsed and dyed in direct red 95 for 30 minutes.

Table 2.13: Cellulose acetate treated in 11% viscous sodium hydroxide solution.

Sample numbers	Results	Fabric samples
Sample 39	Pre-dyed in disperse red. The viscous sodium hydroxide stayed within the area applied. Distinct transparent areas where chemically modified. Redyed in only direct red 95. No characteristic lines surrounding the cellulose and cellulose acetate sites.	 Sample 39
Sample 40	Pre-treated sample from earlier experiment. Transparent areas not as defined as sample 36. Viscous solution once again did not spread outside area applied.	 Sample 40

2.11.3 Results

In both samples 39 and 40 the chemical reaction was limited to the areas initially in contact with the viscous solution with no evidence of diffusion across the surface following dyeing. Both samples contained transparent areas in the chemically modified areas although it was more evident in sample 39.

2.11.4 Conclusion

The application of viscous sodium hydroxide solution was a successful method to control diverse dye effects following the steps outlined above. Although no additional effects were discovered the repeated outcomes proved the technique to be reliable. The interest in controlling application and chemical modification on the substrates was further reconsidered in *phase X* looking at processing equipment.

2.12 Experimentation phase X

2.12.1 Aim: To explore corrugated plastic sheets as method to control chemical manipulation.

2.12.2 Method

Samples 41 to 43

Corrugated plastic sheets were initially prepared by blocking either end of the hollows to prevent chemicals leaks. Using a pipette, 2mls of 10% sodium hydroxide solution was applied along every second hollow in the corrugated plastic sheets. The fabric samples were placed over the sheets and gently pushed into the long wells to ensure contact was made with the chemical solution. The samples were covered with a second corrugated plastic sheet and left to process for 10 minutes at room temperature. The samples were then gently washed, neutralized then dyed in individual dyebaths.

Sample 44

2mls of 2% sodium hydroxide solution was poured into alternative groves of the corrugated plastic and the fabric was gently pressed down to initially wet out with chemical solution. The sample was left for 5 minutes at room temperature then gently washed and dried. The sample was then retreated in 10% solution turning through 90° to the original direction of the groves. The sample was processed for 5 minutes at room temperature, washed, neutralized and dyed.

As the percentage of cellulose and acetate fibres in the individual samples could not be measured the dyebaths were prepared using estimates of disperse and direct dyes. However the purpose of the experiment was not to reproduce samples rather to explore ideas and resulting effects.

2.12.3 Results

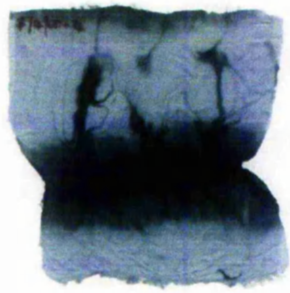
Similar characteristics between samples 41 to 43 included;

Contraction where treated in sodium hydroxide

Harsh fabric handle in treated areas resulting in papery texture

Various colour effects resulting from disperse and direct dye combinations

Table 2.14: Cellulose acetate treated in sodium hydroxide between corrugated plastic sheets.

Sample number	Results	Fabric samples
Sample 41	No damage to substrate. Slight harsh effect on fabric where most chemical modification took place. Lines between disperse and direct dyed less defined. Similar colours were chosen for direct and disperse dyes explore tonal effects rather than contrasting effects. Direct dye selected to be darker than disperse dye – contrasting colour effects.	 Sample 41
Sample 42	Slight damage to substrate reflecting areas of most intense chemical reaction. Fabric crunchy where treated in solution. Repeating process created puckering effects across surface. Position of chemical modification effected drape and movement of fabric. Dyed only in disperse dye to reflect a negative of the chemical process.	 Sample 42
Sample 43	Central areas of most intense chemical reaction turned the fabric hard and fragile, tearing easily. Fabric seems to have almost parchmentised with a more papery texture than fabric. Chose contrasting colours for dyebath; Disperse dye – terracotta Direct dye – aqua blue	 Sample 43
Sample 44	More direct dye take up in areas which were in direct contact with the chemicals. Diverse dye effects from yellow and blue combination. Softer handle to fabric than samples 41 to 43. Yellow areas resembled texture. Blue and yellow dyes were chosen to explore if the resulting colour mixing effect would produce green colour.	 Sample 44

Sample 44 was generated using a slightly modified process to samples 41-43 therefore the resulting characteristics were less comparable. In particular the fabric handle in sample 44 was softer than samples 41- 43 probably as a result of using a lower concentration solution and being in the solution for a shorter period of time.

The resulting colour combinations from the samples highlight:

- Use of similar colour disperse and direct dyes (sample 41)
- Adding only disperse dyes to the dyebath (sample 42)
- Using contrasting disperse and direct dyes (sample 43)
- Using complimentary disperse and direct dyes (sample 44)

2.12.4 Conclusion

The initial aim of phase X was to explore selected processing equipment as a means to control chemical manipulation. Samples 41 to 44 displayed a limited element of control although not as precise as using viscous solution as in phase IX. New characteristics produced in this section included the hardening of treated areas which resulted in shrinking effects on the surrounding fabric. This was particularly noticeable around the edges. Opportunities for further development include exploring the shape of the equipment possibly in combination with viscous solution allowing a wider range and control of effects. In addition, possible colour combinations could be better explored using combinations of direct and disperse dyes outlined above. In order to better predict colour and tonal outcomes further research would need to address the implications of the chemical modifications with regards to affinity for dye types. Phase XI continues the theme of methods to control chemical reaction applying combinations of previous techniques with batik wax resist.

2.13 Experimentation phase XI

2.13.1 Aim: To explore earlier processing methods in combination with batik wax as a resist to chemical modification from sodium hydroxide solution.

2.13.2 Method

Samples 45 to 52 were all produced as a result of individual processing techniques resulting from skills and knowledge developed in previous experiments. Table 2.15 outlines the processing methods used to produce each sample in addition to descriptions of results alongside images. The processing techniques explored a range of samples including untreated fabrics, pre-dyed samples; those with batik wax applied and pre-processed samples.

2.13.3 Results

The resulting creative effects in this final phase of experiments are varied and reflect the complex layers of processes that have developed throughout the research. The results are described in Tables 2.15 alongside images for reference.

2.13.4 Conclusion

The main aim of phase XI was to explore earlier processing methods in combination with batik wax as a method to resist chemical modification from sodium hydroxide solution. The samples in Table 2.15 illustrates the successful outcomes of this technique as a resist to chemical modification. The resist created from batik wax extended the range of potential creative effects. These effects included raised surface textures where thin lines of batik wax resisted concentrated chemical solution (sample 48). Also the element of control with the application of wax allowed more influence regarding surface modification resulting in more specific patterns generation (samples 46 and 51). Additional characteristics discovered in phase XI included the contrasting harsh and soft areas of fabric as a result of the intensity of the chemical modification which varied, depending on processing conditions such as concentration of solution and length of time exposed.

Table 2.15 (over two pages): Diverse dye effects of cellulose acetate combining batik wax resist with earlier modification processes.

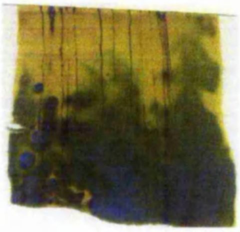
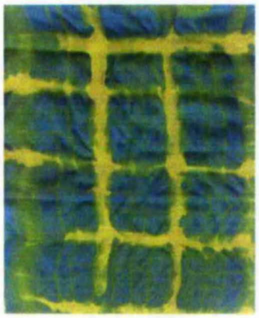
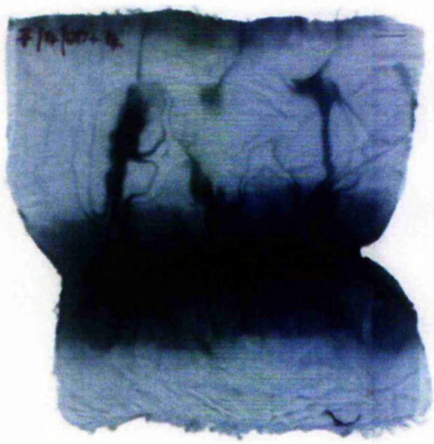
Sample numbers and method	Results	Fabric samples
Sample 45 Initially treated for 5 minutes in 10% sodium hydroxide poured in adjacent channels of corrugated plastic tray. Sample removed and dried. Batik wax applied. Fabric then laid flat in tray with 200ml of 2% sodium hydroxide solution for one hour. Sample was then dyed using direct yellow and disperse blue dye.	The corrugated plastic sheet did not produce defined areas of chemical modification due to using adjacent channels. The chemical solution migrated across the fabric surface resulting in dye effects across the surface. The batik protected the underlying fabric from chemical modification resulting in disperse dye take up in these areas.	 Sample 45
Sample 46 Batik wax was applied to untreated fabric. The fabric was laid flat in 2% solution for an hour then rinsed and neutralized. Batik wax was left on at beginning of dyeing but melted off in hot dyebath. Dyed sample in direct blue 90 and disperse yellow 9 for one hour.	Good definition of pattern compared to sample 47. Batik wax did not completely prevent chemical modification to underlying fabric resulting in combined disperse and direct dye combinations. Overall fabric colour reflected the uneven chemical modification from complete submersion in solution.	 Sample 46
Sample 47 Batik wax was applied to untreated fabric as in 46. 5ml of 2% sodium hydroxide was poured in every 2nd channel of corrugated plastic sheet. Fabric was processed for 30 minutes then turned through 90° for another 30 minutes. Didn't put extra solution in when changed position. Dyed in direct blue 90 disperse yellow 9 for one hour.	It was anticipated that chemical modification would result in stripe effects. Less chemical manipulation than sample 46 as shown by the high degree of disperse dye take up. Resulting drape of the fabric is fluid with a reduced transparency effect.	 Sample 47
Sample 48 Applied batik in thin stripes down length of fabric. Poured 10% sodium hydroxide solution into alternate channels of corrugated plastic and processed fabric for 10 minutes at room temperature. Rinsed, neutralized and dyed using only disperse blue 71 for one hour.	The dark direct dye highlighted the transparency effects within the chemically modified areas. Sample highlights the difficulty in controlling direct dye take up when chemical solution has unknowingly migrated across the surface. Resulted in dark shadows. Evidence of raised surface texture effects where lines of batik wax protected underlying fabric from intense chemical modification. Created ridge effects.	 Sample 48

Table 2.15 (continued)

Sample numbers and method	Results	Fabric samples
Sample 49 Untreated fabric was placed in corrugated plastic sheet with 10mls of 2% sodium hydroxide solution in every 2nd channel. The fabric was processed for 30 minutes then turned through 90° and processed for another 30 minutes. Dyed in direct yellow and disperse blue for one hour.	Light drape and soft handle with no brittle areas or damage to the fabric. The placement of chemical modification produced puckering effects similar to shrinking effects.	 Sample 49
Sample 50 Pre-dyed fabric in disperse red 11 10% caustic poured in alternative channels of corrugated plastic. Fabric was processed for 5 minutes. Turned fabric 90° and repeated process. After 5 minutes removed fabric and dried. Applied batik wax in vertical and horizontal lines. Put fabric back in solution for further 5 minutes. Removed, gently washed and neutralized. Put in dyebath with direct yellow 50 for an hour at the boil.	Fabric contracted creating puckering effects similar to 49 with contrasting harsh and soft areas in horizontal and vertical stripes where most intense chemical modification took place. No fabric damage. Transparent effects in chemically modified areas.	 Sample 50
Sample 51 Pre-dyed in disperse red 11 for an hour. Applied batik wax design across the surface. Poured 2% sodium hydroxide in flat, shallow tray and laid fabric over making sure fully submerged. Processed for one hour at room temperature. Took out, rinsed and dried. Sandwiched selected areas of fabric between 3 individual square vessels (see Figure 2.1) and poured 10ml of 10% sodium hydroxide into each. Left in solution for 3 minutes. Removed fabric, washed, rinsed and neutralised. Dyed using direct yellow 50 for an hour at the boil	Overall light feel to fabric resulting from lying flat in tray and complete submersion in chemical solution. Contrasting transparent effects resulted from additional processing in square vessels using a higher concentration of chemical solution. No damage was incurred. Edge of fabric remained pink where not fully treated in flat tray. Both sides of fabric were not the same as batik wax did not equally penetrate both sides of fabric.	 Sample 51
Sample 52 A batik grid was applied to bottom third of untreated fabric. 10% sodium hydroxide solution was poured in alternate channels of the corrugated sheet and the fabric was laid in for 3 minutes. The fabric was then turned through 90° and the process was repeated only on the area with batik wax applied. The fabric was processed for a further 3 minutes then rinsed and neutralized. Dyed in a dyebath containing disperse red 32 and direct yellow 50.	The processed areas of batik combined with double exposure to sodium hydroxide were highly distressed and fragile. The final sample contained fabric qualities with areas of parchment-like characteristics. These areas were brittle and damaged but were held together with fibres protected by batik wax resisting chemical action. The resulting colour reflected the disperse and direct dye combination.	 Sample 52

2.14 Design Visualisations

The following section highlights visualisations which were developed to illustrate potential design application. The fabric samples were chosen as they offered unique characteristics as surface patterns, textures and colours. The implications of these effects are visualised in selected design contexts linking the new aesthetics to specific applications. The design visualisations were developed by scanning existing images and inserting the fabric samples to the required sections.



Sample 41

Sample 41 was applied to Figure 2.5 putting the dark, surface texture at either end of the piece. In particular the chemically modified fabric would provide edge detail possibly influencing the drape of the garment.

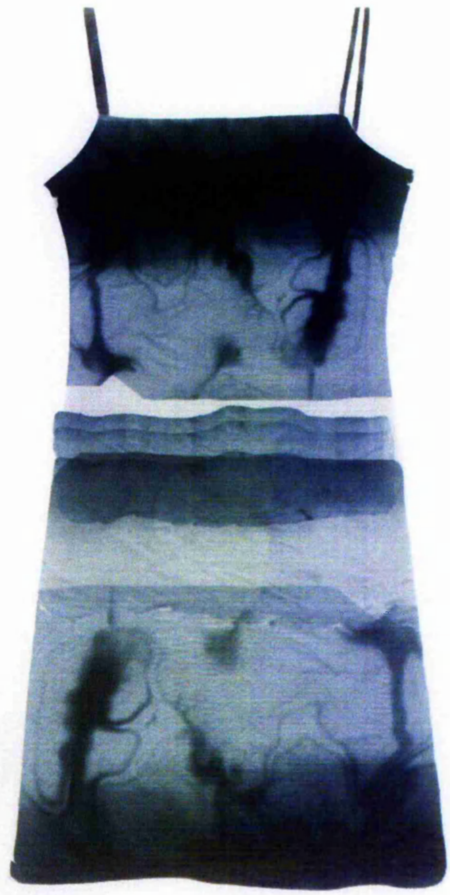


Figure 2.5: Dress overlay.
(Background image Couverture, 1999:9)

Sample 24

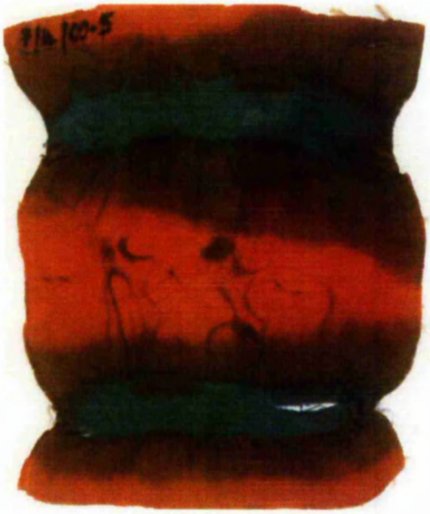
Figure 2.6: Purple and yellow shirt overlay. (Background image Burberry Prorsum, 2005:81)

Samples 24 was considered one of the most successful samples. The direct dye (violet) reflected the movement of the chemicals across the fabric resulting in a non-repeating surface pattern contrasting the violet tones against the yellow background. Figure 2.6 does not illustrate the transparent areas of the fabric. The pattern contributes to the eclectic mix of the pin-stripe suit and knitted stripy scarf.

Sample 42

Surface texture effects influenced the position of sample 42 on Figure 2.7. The ruched vertical column would also influence the drape, shape and fit.

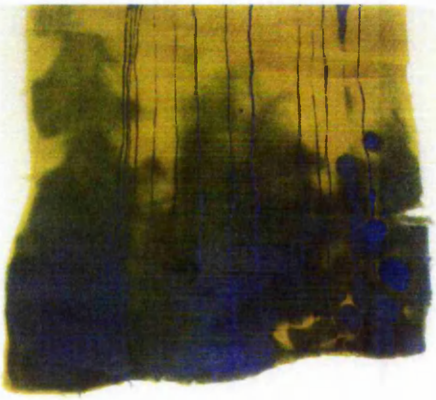
Figure 2.7: Ruche shirt overlay.
(Background image Messori, 2005:184)



Sample 43

Although the colours applied to sample 43 were originally selected to generate contrast, Figure 2.8 provides a context that seems compatible with the diverse colour combinations. This example draws on the potential of more subtle diverse dye effects in a gradual fusion across the fabric.

Figure 2.8: Diverse dye colour effects. (Background image Franck Boclet pour Francesco Smalto, 2005:255)

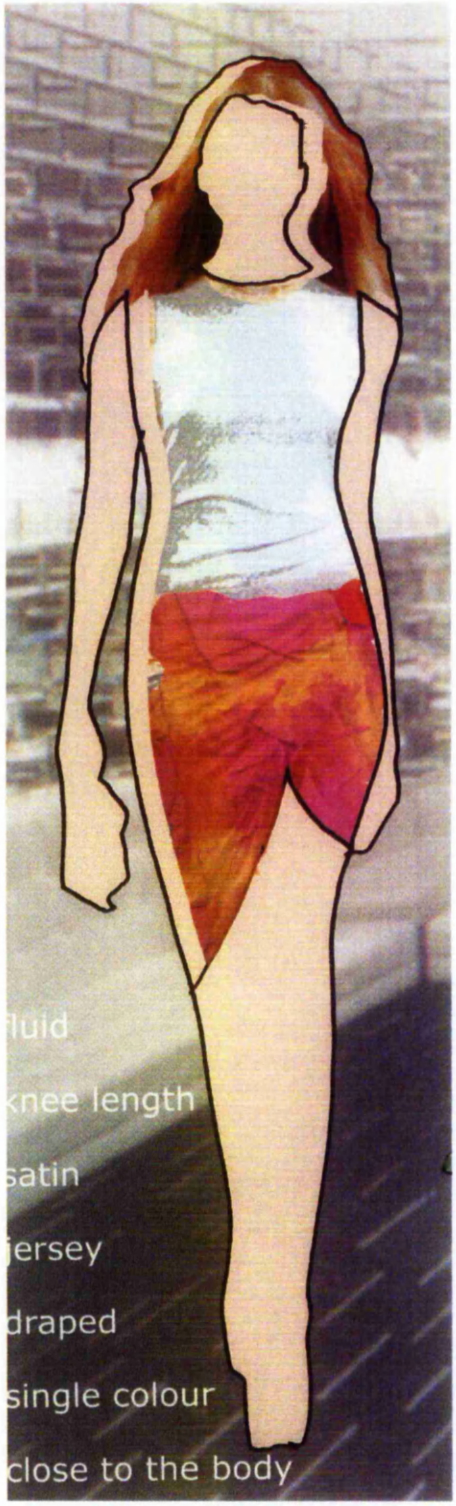


Sample 45

Sample 45 was chosen due to the varying dye characteristics resulting from a combination of batik resist with divergent dye effects. The random dye effects resulted from combinations of blue disperse and yellow direct dyes resulting in gradual colour mixing effects.

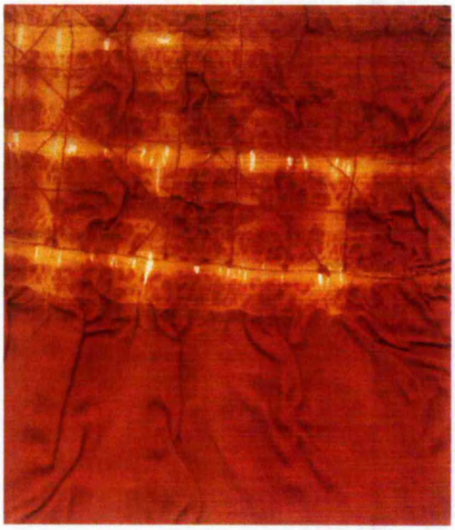
Figure 2.9: Diverse dye and batik dress. (Background image Textile View, 2005. 69:150)

Sample 50

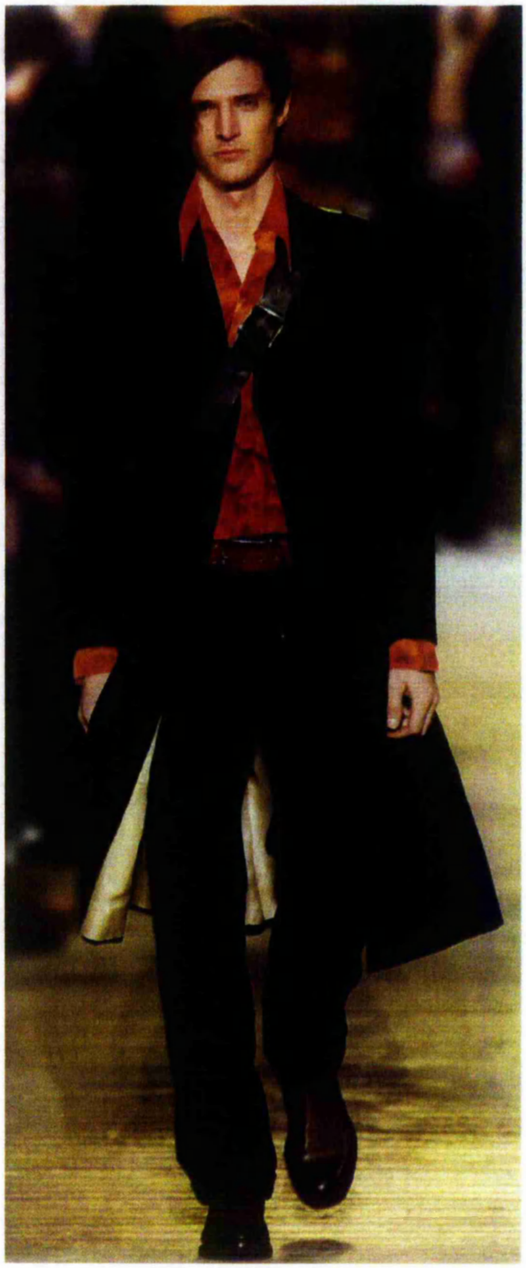


The combined surface texture and colour combinations were selected for figure 2.10 adding movement and vibrant colours to a simple silhouette.

Figure 2.10: Surface textured skirt. (Background image Textile View, 2005. 69:150)



Sample 52



Extensive chemical processing resulted in a grid-like pattern joined with unprocessed fabric which was protected by batik wax during chemical processing. The resulting colours and textures were complimentary additions to Figure 2.11 contrasting against the dark, structured outfit.

Figure 2.11: Textured shirt.
(Background image Paul Smith, 2005:311)

2.15 Chapter conclusion

Resulting from the practice-based research it is possible to compile a list of the creative effects resulting from the experiments carried out. This allows the research to be communicated in terms of potentiality, illustrating the range of possible creative effects, how these were created and what parameters could be modified to produce unique results.

The first aim in chapter two was successfully carried out following the application of sodium hydroxide explored on cotton, cellulose triacetate and cellulose acetate. Cellulose acetate was selected as the main focus for prospective research as the most responsive substrate reflected by the number of phases carried out in Mind map 1. The second aim was addressed by the development of new skills and knowledge including a technical understanding of the processing parameters, supported by written descriptions of technique alongside images of resulting samples. The range of resulting creative effects developed an aesthetic vocabulary which included knowledge of how each was created. Examples of creative effects include:

- *Diverse dyeing effects* which were the same on both sides of the fabric. The patterns and effects generated covered arrange of patterns, colours and tones adding spontaneity and unique characteristics with each piece. These would not be exactly repeatable adding value as one-off designs.
- *Transparency.* In combination with opaque areas of fabric transparent sections were illuminated enhancing the colours and patterns effects across the surface.
- *Contrasting fabric handle* effects with harsh and fluid sections added to the diverse texture and feel of the fabric.
- *3-D effects* caused by fabric shrinking added structure contrasting smooth and uneven surfaces.

The final aim to generate suggestions for further investigations was addressed as examples for design development at the end of the chapter. The new aesthetic effects were visualised as placements on garments however scale would have to be re-considered taking into account processing equipment and facilities. The design visualisations were developed by directly layering images of the samples into silhouettes considering the implications of the samples within the context of garment design.

Chapter 3: Case study 2: Chitosan

3.1 Introduction

The aims of the following chapters exploring chitosan are:

1. To generate samples of chitosan to explore its decorative design potential
2. To develop new skills and knowledge of the materials combining technical understanding with aesthetic development.
3. To generate suggestions for further investigations

Chapter 2 outlined Case Study 1, which explored the application of sodium hydroxide to selected substrates producing outcomes which illustrated creative potential. The methodology was driven by the necessity to engineer a specific chemical reaction between the chemical solution and the chemical properties of the substrate. This limited the range of potential explorations to specific substrates. Rather than limiting the outcomes, these parameters allowed focused investigations to result in an extensive body of knowledge combining the technical and aesthetic potentiality of the materials and processes. In contrast, Case Study 2 explored the decorative design potential of a material not previously explored for its aesthetic properties. A similar process of investigations in the laboratory produced a more extensive range of potential directions to pursue when compared to Case Study 1. The main difference was that the focus of the work was not a specific chemical reaction, rather a substance that is considered as a material itself. Exploring the design potential of a material that had no former application in design necessitated a wider range of experiments to establish a starting point from which more focused investigations could be made.

Chapter three begins with an introduction to chitosan as a material currently used in the textile industry for its performance characteristics. The practical experiments are then represented using mind-map techniques which allowed the samples to be categorised according to resulting characteristics. Decorative themes were established to make links between the resulting characteristics and a vocabulary appropriate in design. The chapter progresses through each decorative theme illustrating samples alongside methods and conclusions. The chapter concludes with a summary and recommendations for further study.

3.2 What is chitosan?

Chitin, which is mainly used as its derivative chitosan, is a substance which is widely distributed throughout nature and found in crab shells, prawn shells and lobster (Roberts, 1992). It is a major structural component responsible for shape and rigidity. As a by-product of the shell-fishing industry, research was initially carried out to investigate potential uses of waste products removed during processing, which can cause pollution problems. Companies worldwide are involved in research in this field, resulting in a wide range of potential applications across commercial, consumer and pharmaceutical products capitalising on the following distinct properties.

1. Anti-microbial
2. Highly positively charged
3. Biodegradable

3.3 Existing uses of chitosan

Chitosan is already used in the textile industry building on its hygienic properties rather than creative characteristics. Examples include chitosan fibres, its use for bacteriostatic finishing of woven fabrics, coating fibres or webs for odour minimising, use as a sizing agent for warp yarns and improving the dyeability of natural and man-made fibres (Bohringer and Rupp, 2002). Scientific literature provides information to assess the resulting performance characteristics of chitosan in its various forms such as the proceedings of the 3rd International Conference of the European Chitin Society (Peter, 1999), but there is no evidence of research which links technical information to decorative properties. Some examples of existing applications are listed in Table 3.1 illustrating that chitosan is widely used but not usually associated with the creative aspects of textile design. A key objective in this research is to produce samples which communicate design potential alongside technical descriptions of process and materials.

3.4 Experimentation

The development of samples with chitosan benefited from having access to an existing resource of expertise within the design of materials research group, which was based at Nottingham Trent University until 2001. Supervisory guidance in combination with regular contact with researchers in the laboratory enabled the researcher to develop a basic understanding of chitosan and develop a range of basic processing techniques. These new skills and knowledge provided a foundation to allow the researcher to explore chitosan, generating multiple samples in various combinations with other substrates and substances.

Table 3.1: Examples of existing applications of chitosan.

Properties	Applications
• Anti- microbial	Surgical gowns, plasters, bandages, bedding, socks
• Biodegradable	Sutures
• Film-forming	Printing paste, coating yarns
• Positive charge	Diet control pills, environmental uses (absorbs oil spills, and water pollution)

The practical research built on existing characteristics of chitosan already familiar to colleagues from the design of materials research group. As a result of discussions, two key characteristics were identified as having design potential;

1. Chitosan has film and fibre forming characteristics and has good adhesive properties, sticking readily to surfaces.
2. Chitosan has an affinity to certain dyes containing heavy metals (chromium and copper) and a high affinity for anionic dyes (acid dyes) under acid conditions.

These characteristics of chitosan formed the starting point for experimentation. Exploration began with empirical methods to determine what the range of effects could be and what design opportunities were available from the properties listed above.

The materials chosen to combine with chitosan were not restricted to any particular fibre type or construction technique, as it was thought this would restrict the potential outcome at this point. Substrates varied between textile and non-textile, flexible and inflexible in order to generate a broad understanding of the physical and chemical characteristics of chitosan in various combinations. Materials used in the experiments included examples from the categories shown in Table 3.2.

3.5 Design potential

Before deciding if chitosan had design potential, the research first explored a range of possibilities, including experiments with chitosan independently and in combinations with other substrates as seen in Table 3.2.

Table 3.2: Categories of substrates included in the experiments.

Flexible	**Non-flexible**
Non woven	Acrylic block
Woven	Clear casting resin
Warp and weft knit	Glass
Non fibrous films	

In addition to considering the effects with other substrates, the potential uses of chitosan depend upon its inherent characteristics in response to changing environmental conditions both during and after processing. As illustrated in the following series of Mind maps, the research progressed through multiple explorations to generate a broad understanding of chitosan under a range of processing conditions to produce diverse outcomes. However, the work was not a comprehensive study and did not include data on performance characteristics. Any judgement on suitability or performance criterion would depend upon the end- use requirement which varies widely across the design disciplines. It was not the aim of the research to find a specific end use for chitosan in textile design but more to ask the question if design possibilities exist, what they are and record the research progress, communicating the outcomes using suitable methods.

The design potential of chitosan within a textile design context was initially proposed by considering particular characteristics of chitosan in combination with existing textile processes. For example, building on both its film forming properties and its affinity to certain dyes, it was suggested that the application of chitosan film might work like the resist wax used in batik. Theoretically the printed area of chitosan would protect the underlying fabric from dye by absorbing dye in those areas leaving undyed fabric when the chitosan was removed. If successful, the implications of this would be that dyeing could be carried out at higher temperatures than traditional batik techniques which employ wax which melts at low temperatures. What effects could be created? Would seepage through the fabric generate similar or different effects as traditional cracked effects in batik? Also similarities could be drawn to laminating effects used in textiles which are widespread. The use of chitosan as a renewable biodegradable material might provide a more sustainable alternative than materials sourced from petrochemicals.

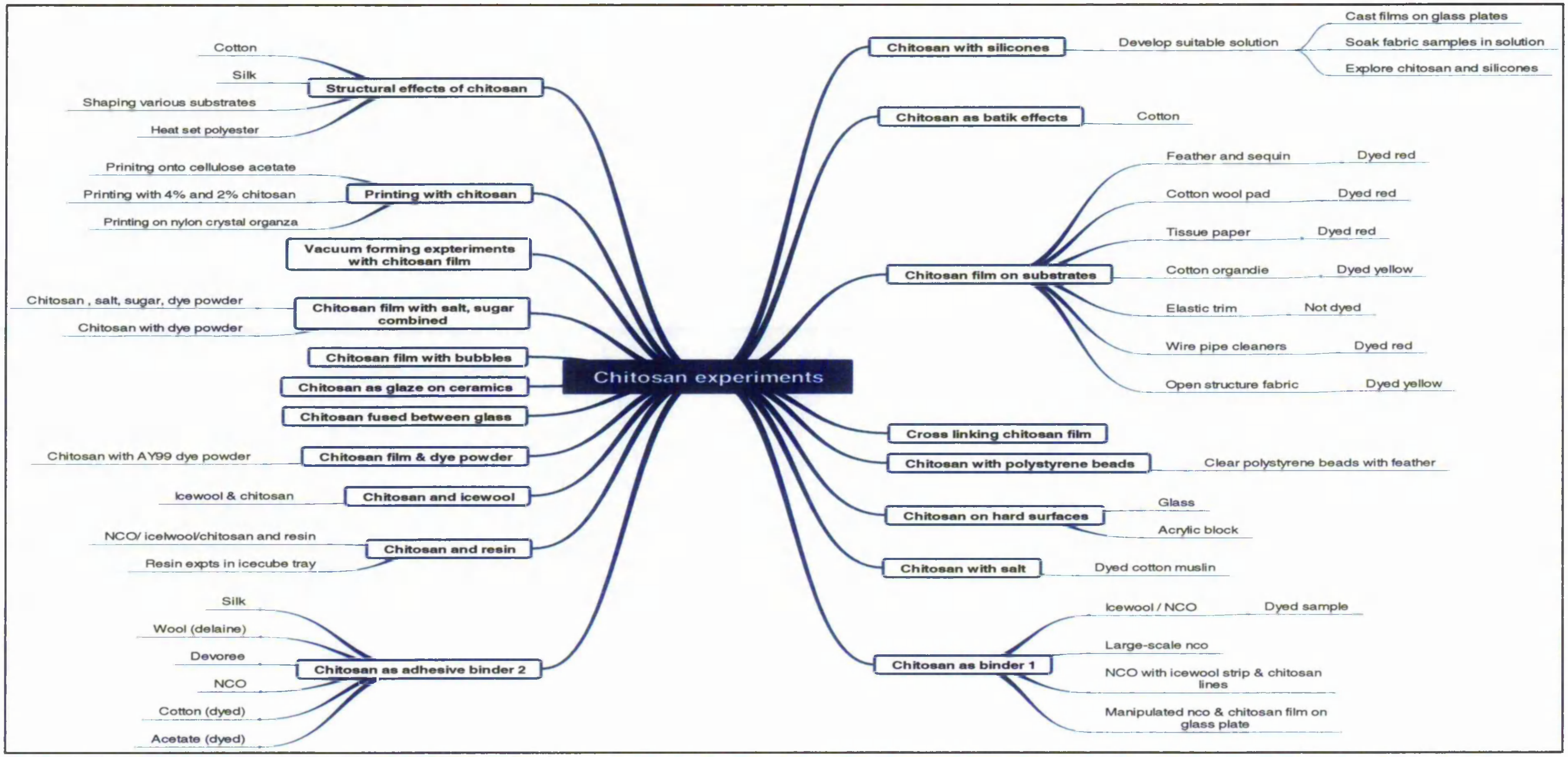
3.6 Mind mapping techniques

As a result of the many variables included in the research, the outcomes of the experiments were initially difficult to group according to defined characteristics. In order to assist the process of analysis, mind mapping software was used to model the progress of the chitosan experiments. As seen in Mind map 2, the experiments were identified according to either the substrates used in the experiment or the process being explored. This technique produced an overall visual account of the whole of the process, allowing the outcomes to be compared simultaneously. This new perspective of the research highlighted any recurring themes across the many variables resulting in a structure by which the characteristics of chitosan could be reconsidered and categorised, according to their contribution to decorative design. It was soon discovered that the outcomes of the experiments could be classified as three themes:

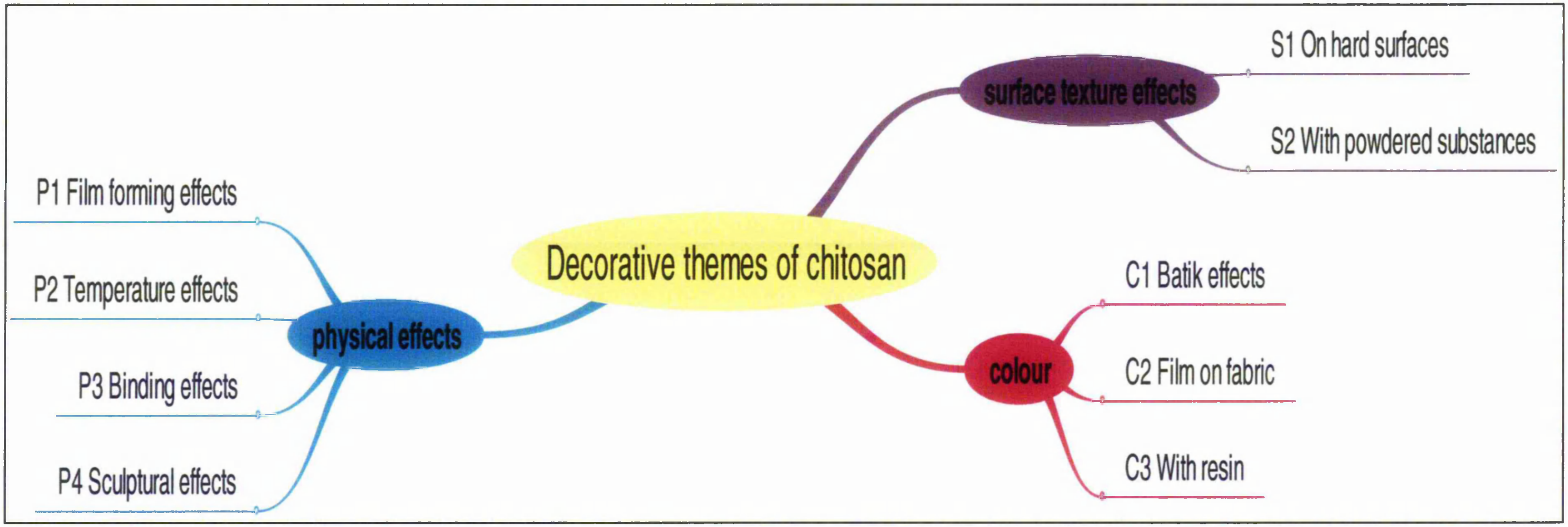
1. Physical effects
2. Colour effects
3. Surface texture

The above themes were applied to the branches in Mind map 2 and the model was reworked into Mind map 3. Sub categories emerged which linked diverse experiments according to these themes allowing a structure to form within the work. For the purpose of writing the thesis, the visual aid of Mind map 3 made it easier to format a written structure to reflect the nature of the practical work. Rather than forcing a linear path to link the diverse variables of processes used and outcomes the mind mapping technique allowed the practical element of the research to be systematically represented within the context of a thesis. The following body of work was compiled in response to using the mind map techniques to structure the work. Each decorative theme of chitosan was dealt with individually and the work was grouped according to relevant sub headings within each.

Mind map 2: Chitosan experiments.



Mind map 3: Decorative themes of chitosan



Chapter 4: Physical effects of chitosan

The first group of experiments to be examined are those in the Physical effects category. This group contained the largest number of experiments covering a wide range of processes and combinations of materials as outlined in Table 4.1 and Mind map 4.

Table 4.1: Sub-groups in physical effects experiments.

	Sub heading	Experiments
P1	Chitosan film forming effects	P1.1 Chitosan and silicone solutions P1.2 Chitosan and silicone solutions on substrates P1.3 Further exploration of chitosan and silicones P1.4 Chitosan film on substrates P1.5 Cross-linking chitosan P1.6 Cross-linking chitosan on feather
P2	Temperature effects	P2.1 Heating chitosan solution P2.2 Heating chitosan solution with polymers P2.3 Heating in kiln between glass P2.4 Heating in kiln with ceramic glaze P2.5 Vacuum forming
P3	Binding effects	P3.1 Icewool and nylon crystal organza P3.2 Icewool on various fabric types
P4	Sculptural effects	P4.1 Locally applied to substrates P4.2 Fully submerged fabrics P4.3 Developments of Icewool and chitosan combinations P4.4 Development of single large-scale Icewool and chitosan piece

P1 Chitosan film forming effects

The sub-sections under this heading include;

P1.1 Chitosan and silicones solutions

P1.2 Chitosan and silicone solutions on substrates

P1.3 Further exploration of chitosan and silicone

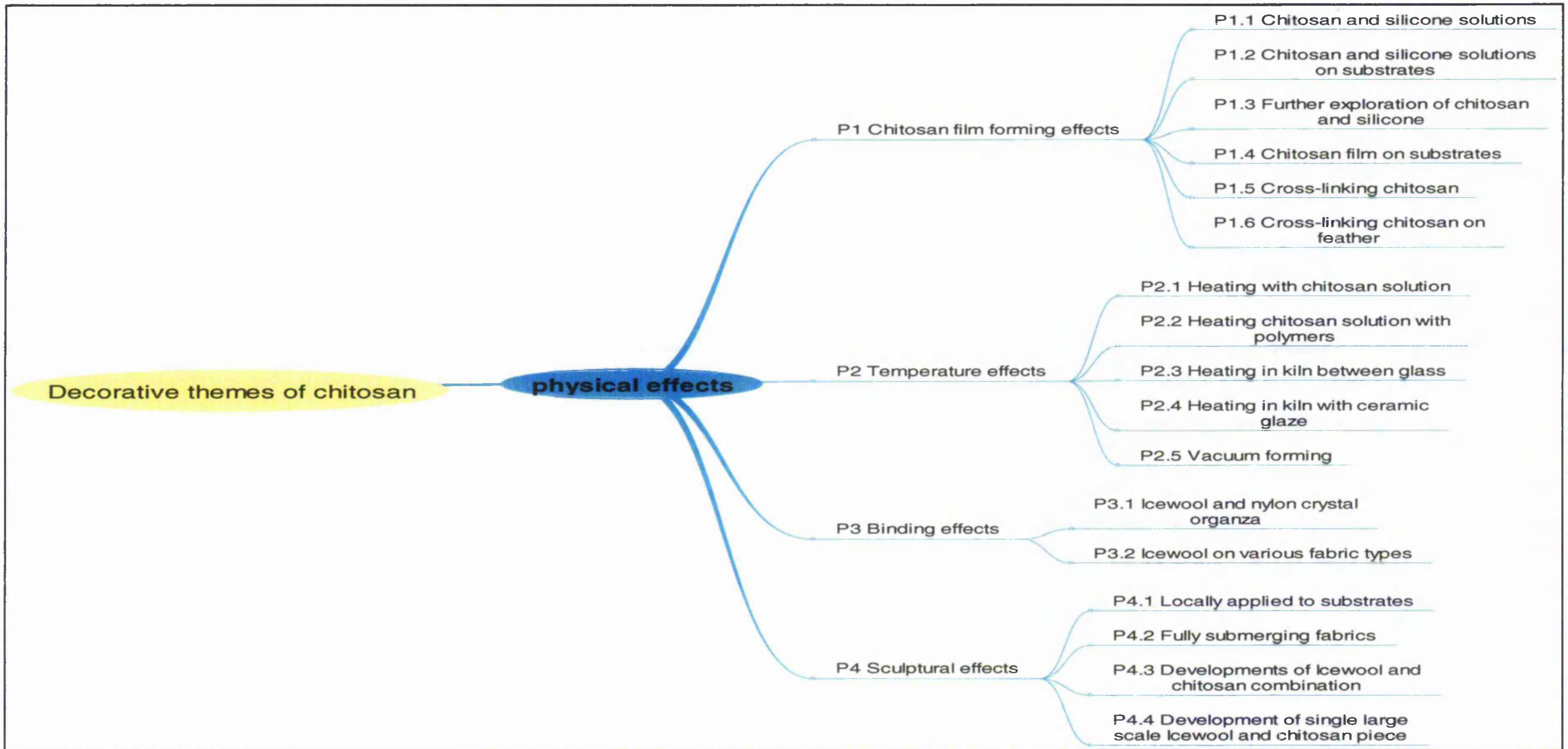
P1.4 Chitosan film on substrates

P1.5 Cross-linking chitosan

P1.6 Cross-linking chitosan on feather

P1.7 Film forming effects summary

Mind map 4: Physical effects of chitosan



P1.1 Chitosan and silicone solutions

P1.1.1 Aim: To explore the outcomes of casting films containing chitosan and a silicone polymer.

The first group of experiments explored formulas to produce chitosan films progressing to explore the potential of chitosan films with silicone polymers. Casting films with chitosan and Nulastic ™ (silicone) solutions was initially used to explore the possibility of contrasting elastic and rigid characteristics of the polymers producing innovative film effects. The experiments explored methods to produce films then applied the most suitable formula to various textile substrates.

P1.1.2 a Method: Mixing solutions.

6g of chitosan was made into slurry in 300ml of distilled water. 3.5ml of glacial acetic acid was added while stirring until dissolved. The solution was then filtered through PET mesh to remove insoluble particles. 30ml of Nulastic 24E™ (30%) was mixed with 30ml dilute acetic acid (12ml in 1 litre) to make the Nulastic™ solution. The following quantities were then mixed up, casting films from each solution.

Table 4.2: Composition of solution used.

Sample	Chitosan solution (ml)	Nulastic solution (ml)	Dilute acetic acid (ml)
1	20	20	0
2	20	15	5
3	20	10	10
4	20	5	15
5	20	0	20

P1.1.2 b Method for casting films, samples 1 to 5 (Table 4.2)

Five glass plates were soaked and scrubbed in warm soapy water finishing with acetone to remove grease. Each plate was numbered according to solution used. Solution was poured down the centre of each glass plate then a glass rod was used to roll the solution into an evenly distributed level film. The edges of the wet solution were roughly marked with a glass pen to help locate later when dry.

The glass plates were put on a level surface and left to dry at room temperature. The film was then cured in the vacuum oven at 100°C for 15 minutes.

P1.1.3 Results

There was a gradual reduction in film thickness from samples one to five, relative to the reducing amount of Nulastic™ in the solution. The films became less sticky with decreasing Nulastic™.

P1.1.4 Conclusion

Resulting samples proved that it was possible to combine chitosan and silicones solution to produce films. The film resulting from solution number 4 was chosen as the most successful outcome. Evaluation was based on several observations comparing the results from sample 1 to 5 including whether the surface remained sticky after curing in the oven; how readily the film could be removed from the surface of the plate without damage; and how evenly the resulting film dried across the surface of the glass plate as a continuous film. It was concluded that the quantities of solutions of silicone and chitosan in sample 4 produced the most successful film. The next stage of experiments would explore a range of quantities above and below this sample in order to generate a more defined outcome.

P1.1.5 Method to develop films between samples 3 to 5

The solutions were prepared using the same method as in P1.1.2 using the four selected quantities highlighted in Table 4.3. This range was chosen in order to produce a progression of outcomes and a more precise understanding of the quantities needed to produce the desired result. The films were cast and allowed to dry at room temperature before being cured in the vacuum oven at 100°C for 15 minutes.

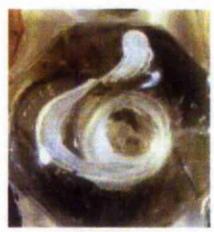
P1.1.6 Results

Samples 4ii and 4iv had the most continuous surface area and lowest level of stickiness. All the samples in experiment P1.1.5 dried in irregular shapes despite careful application and controlled distribution using a glass rod. The inconsistent shapes of 4ii and 4iv in Table 4.4 exemplify this. The remaining films from P1.1.5 were discounted for further experiments as only one recipe was required. The combination of the silicones and chitosan produced films which took on characteristics of both types of polymers producing a less fragile film than chitosan alone.

Table 4.3: Composition of solutions used in the range between samples 3 and 5.

Sample	**Chitosan (ml)**	**Nulastic 24E ™ (ml)**	**Dilute Acetic acid (ml)**
3	20	10	10
3i	20	9	11
3ii	20	8	12
3iii	20	7	13
3iv	20	6	14
4	20	5	15
4i	20	4	16
4ii	20	3	17
4iii	20	2	18
4iv	20	1	19
5	20	0	20

Table 4.4: Examples of chitosan and silicone films.

Film from sample 4 ii	**Film from sample 4iv**	**Samples in resin**
		 Sample 1
		 Sample 2

P1.1.7 Conclusion

4iv was selected as the solution to apply to fabric samples. It was more transparent compared to sample 4ii resulting from less Nulastic™ solution. The initial aim of casting films with chitosan and Nulastic™ (silicone) solutions was to explore if silicone would combine with the film forming characteristics of chitosan. As a result of experiments and evaluation the most successful recipe for films was chosen for further experiments when applied to fabric substrates. Although the resulting films were less brittle than chitosan the combination was less transparent.

P1.2 Chitosan and silicones solutions on substrates

P1.2.1 Aim: To explore outcomes of chitosan / silicone solution on a variety of fabrics, in particular looking for film forming effects on the fabric.

P1.2.2a Method: Applying film solution to fabric samples

The fabric samples were chosen to include a range of fibre types and fabric constructions but not to be exhaustive. The Nulastic™ and chitosan solution was prepared using the recipe developed in experiment P1.1.5 sample 4iv. The fabric samples were dipped in solution and any excess solution was squeezed off. The samples were laid on clean glass plates and a glass rod was rolled over the surface to promote an even cover of solution. Extra solution was poured over selected samples to see if this would produce areas of film formation. The fabric samples were left at room temperature until dry then put in the oven at 105°C for 20 minutes to cure. Once cured the samples were washed in a solution with small amounts of ammonium to neutralise the acetic acid. The samples were left for 15 minutes then rinsed in water to remove any remaining ammonium.

P1.2.2b Method: Dyeing films

The samples were dyed in a 1:1 premetalised dye solution using Acid Blue 158. The blue colour was chosen to contrast with the undyed substrates to highlight the extent of fabric coating. This dye type was chosen as it can be applied to chitosan under neutral conditions as the dye attracts to the chitosan not the fibre. Fibres such as wool also have an affinity for premetalised dyes which meant that the dye would readily take to the fibre in addition to the chitosan coating.

P1.2.2c Method: Preparation of dye stock

0.1g Acid Blue 158 dye powder

100ml distilled water

Total fabric weight = 0.02g

First the water was boiled then a small amount of water was added to the dye powder, mixing the solution to help dissolve the dye particles. Boiling water was added until all the dye was dissolved then topped up to 100ml with distilled water. The dye bath was prepared using 10mls of dye stock with 200mls water and heated up to about 80°C stirring continuously. Fabric samples were added and left to dye for 15 minutes, until dyed sufficiently.

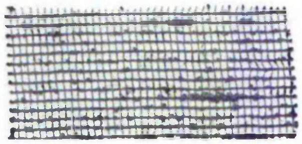
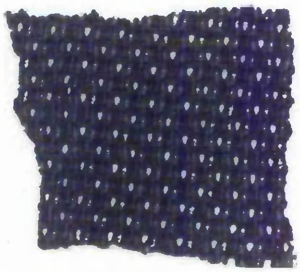
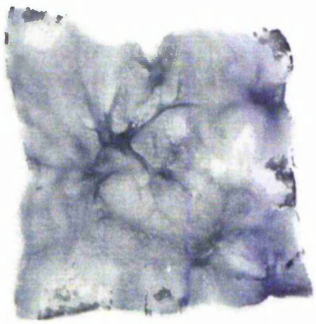
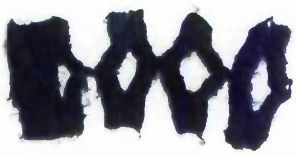
P1.2.3 Results (See Table 4.5)

The film solution took to all the previously undyed fabric samples as highlighted by the premetalised dye take up which only has affinity for certain fibre types. Dye take up was not level on samples 3 and 4 where the film solution had dried unevenly on the substrate, also around the edges of sample 1. The wool fibres in sample 5 also had an affinity to the dye type which accounts for the darker shade in comparison to the other samples. Previous heat manipulation on sample 3 had created an uneven surface preventing the sample from lying flat on the glass plate while the film was applied and had time to dry. This raised surface influenced the formation of the dried film and the resulting uneven dye take-up. Additionally an earlier heat process carried out on sample 4 influenced the uneven combined film and dye result. Stiffening effects were evident on samples 3 and 5 with no noticeable effect on samples 1, 2 and 4.

P1.2.4 Conclusion

The chitosan / Nulastic ™ solution took to all the fabrics as evident by the premetalised dye take up. No shiny film effects formed over the surface of the fabrics or between gaps in the fibres. Samples 3 and 4 illustrated the possibility of uneven fabric surface influencing the film take up on fabric if the surface is uneven. To encourage film effects on fabrics, more viscous solutions would be explored in further experiments to encourage thicker film formation.

Table 4.5: Results of applying mixed solutions of chitosan and silicone polymer to various textile substrates.

Samples	Fabric description	Results
	1. Open structure warp knit Polyester.	No stiffening effect. No visible film formed. Dye take up darker around edges of piece.
	2. Stretch knit Polyester / elastane.	No noticeable reduction in stretch. Even dye take up. No visible film formed.
	3. Polyester voile with previous heat manipulation.	Fabric didn't lie flat on glass surface during film application. Uneven take up of film solution. Uneven dye take up. Slight harsh effect on handle.
	4. Polyester / viscose devorée fabric with heat treatment.	No noticeable change in fabric handle. Dye take up uneven. No visible film formed.
	5. Wool Felt pre-treated in perm solution.	More dye take up than other substrates. Harsh effect on fabric handle. No visible film formed.

P1.3 Further exploration of chitosan and silicone

P1.3.1 Aim: To explore additional methods to produce chitosan and silicone films.

P1.3.2 Method

Glass plates were cleaned as described above and numbered. Solutions were applied to the glass plates in the methods outlined in Table 4.6.

Table 4.6: Applying silicone and chitosan separately onto glass plates.

	Combination of solutions	**Drying method**	**Results**
Film 1	Chitosan only Poured on and rolled with glass rod to evenly distribute.	Air dry at room temperature on level surface	Film formed. Film was then neutralised in 0.5% sodium carbonate solution. When neutralised edge of film came unstuck and dried in folds around the edge.
Film 2	Silicone poured on and chitosan randomly placed on top		Chitosan did not stick to the glass as previously but peeled off the surface. The silicones did not cure.
Film3	Silicone only		Silicones did not cure.
Film 4	Chitosan poured on then silicones poured on top and allowed to naturally diffuse.	Put in oven 55 °C turning temperature up after 2 hours	Chitosan dried but silicones did not cure. Turned up temperature to bake silicones. Took out after 1 hour.
Film 5	Chitosan poured on then silicone poured on top	Air dry at room temperature on level surface	Chitosan and silicones did not form a film

P1.3.3 Results (outlined in Table 4.6.)

P1.3.4 Conclusion

The methods outlined in Table 4.6 to produce silicone and chitosan films were not as successful as earlier methods. Chitosan solution alone was included as a standard (Solution 1), and produced the most successful continuous film. The combined mixtures did not form uniform films irrespective of the drying methods; whether left to dry at room temperature for long periods of time, or cured in the oven. Compared to the results in experiments P1.1 and P1.2 it was more effective to mix the solutions before curing to encourage the two polymers to bind.

The group of experiments from P1.1 to P1.3 resulted in a successful method to produce chitosan and silicone films overcoming the difficulty of surface tensions. Unfortunately when applied to substrates (P1.2) the resulting samples did not produce any shiny film effects which was a key aim of the experiments.

The original concept to combine the silicone and chitosan films was to contrast elastic and rigid characteristics of the polymers with the aim of producing innovative film effects. When applied to substrates no film effects were visible. Based on the lack of results it was decided to focus future experiments on the effects of chitosan films alone.

P1.4 Chitosan film on substrates

P1.4.1 Aim: To consider the resulting effects of chitosan film on various substrates specifically investigating film forming characteristics.

P1.4.2 Method

The samples in Tables 4.7a and 4.7b were placed on clean glass plates. 2% viscous chitosan solution was brushed over selected areas using a stiff brush. The samples were then dried in the oven and neutralised as described in P1.2. Selected samples were then dyed in either direct red and direct yellow dyes with the aim of highlighting any resulting film effects on the substrates.

P1.4.3 Results

The resulting characteristics from this diverse group of substrates included:

- Shiny effects
- Attraction to dyes
- Stiffening properties
- Binding two different substrates together

- Consistent areas of film formation on some samples

These outcomes illustrate constructive characteristics however it was difficult to produce consistent and uniform films. The contrasting film formation around the edges of the feather compare to the most uniform, consistent film produced on the open net.

Table 4.7a: Chitosan film on various flexible substrates.

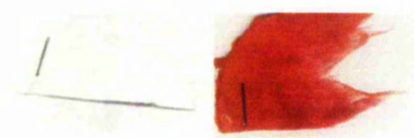
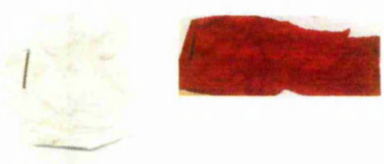
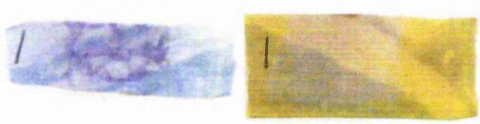
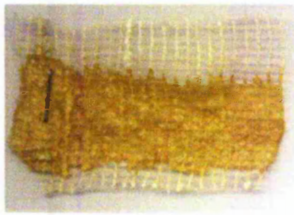
Description of substrate	Images	Outcomes
Loose feather fibres held together by central twine	 Sample 1	Film formed around loose fibres. Not uniform or continuous film. Shiny effects in places. Feather became matted as a result of wet treatments and possible lack of structure in the substrate.
Cosmetic cotton wool pad	 Sample 2	No shiny film. Stiffened substrate compared to original sample.
Torn layers of tissue paper	 Sample 3	No shiny film. Stiffened. Crunchy. Bound paper together.
Woven cotton organdie fabric with hand made paper on top	 Sample 4	Limited areas of shiny film. Paper came off during processing.

Table 4.7b: Experiment P1.4 Chitosan film on substrates.

Description of substrate	Images	Outcomes
Hand made paper with feather fibres	 Sample 1	No film formed. Feather stuck to the paper initially but wasn't further processed.
Narrow elastic trim	 Sample 2	Film formed on stretch of elastic. The brittle film was not resistant when elastic was pulled apart.
Regular open net	 Sample 3	Most consistent film formation from samples. Visible film between spaces of yarns. Contrast in handle between film and the fabric.
Wire pipe cleaners woven together in irregular open construction	 Sample 4	Chitosan film clung to structure of wire but no areas of consistent film coverage.

P1.4.4 Conclusion

The aim was to investigate film forming characteristics of chitosan solution on flexible substrates. A range of constructive characteristics produced novel effects however the properties of the underlying substrate must also be taken into account. In particular fabric construction and suitability to wet processing treatments. Although the chitosan stiffened the substrates the resulting samples did not loose flexibility or become too rigid. A question leading from these outcomes was if the film could be cross-linked to produce films that would be stable, potentially producing 3- dimensional (3-D) shapes without the need for a supporting structure.

P1.5 Cross-linking chitosan

P1.5.1 Aim: To develop a process to cross-link chitosan films. Theoretically the aim of this experiment was to begin to explore chitosan as an independent material capable of 3-D shapes without the need for a supporting base substrate. Cross-linking chitosan using bisulphite addition complex would potentially make the film insoluble in water and resistant to subsequent wet processing techniques.

P1.5.2 Method

A sample film was prepared on a glass slide and dried in the oven for 30 minutes at 50° C. It was then soaked in a solution of 1% bisulphite addition complex for 2 hours, removed from the solution, gently rinsed and again dried in the oven taking care when handling to prevent damage. In order to test that the film had cross-linked a small piece was put in 1% acetic acid. The sample was then put in a dyebath containing 2mls of sodium chloride, 2mls of direct solar red dye and water. After 20 minutes the sample was gently rinsed and put on a glass plate in the oven at 50°C until dry. In order to test if cross-linking was successful, a small piece was put in 1% acetic acid.

P1.5.3 Results

When dried in the oven the film seemed stronger than before treatment in bisulphite addition complex. The film dried in the position laid on the glass plate and stuck together where overlapping occurred. The film was fragile when wet and needed careful handling, tearing easily. The film did not dissolve in the acetic acid therefore cross-linking had occurred. The film was then used in subsequent experiments as can be seen in Figure 4.1.

Figure 4.1: Cross-linked chitosan film in resin.

P1.5.4 Conclusion

Cross-linking occurred as the chitosan film did not dissolve in acetic acid. This outcome inspired new questions in particular could chitosan film produce insoluble 3-D shapes? What would the effect be in combination with other substrates?

P1.6 Cross-linking chitosan on feather

P1.6.1 Aim: To explore cross-linking chitosan on feather form. Feather was chosen specifically as a result of earlier experiments in which the loose fibres were embedded in the chitosan film creating a novel film forming effects.

P1.6.2a Method: Applying the chitosan solution

A small amount of 2% chitosan solution was brushed over the surface of a cleaned glass plate and the feather was arranged in the required position. The feather fibres were easy to manipulate as the chitosan solution acted as glue, sticking the fibres to the glass surface where positioned. Additional solution was poured over the edges of the feather in its final position to encourage film development. The sample was put in the oven at 100° C until dry.

P1.6.2b Cross-linking

When dry, the sample was soaked in a solution of 1% bisulphite addition complex for 2 hours; removed from solution, gently rinsed and dried in the oven taking care when handling as the film tears easily when wet.

P1.6.3 Results

Selected feather fibres in the centre and around the edges were successfully covered with chitosan film. However while rinsing after treatment in bisulphite addition complex, the entire feather became wet and the central twisted yarns holding the fibres together began to unwind. This began to pull against the film but no damage was caused. Also as seen in Table 4.7a the edges of the feather became very matted due to the non-structured nature of the fibres.

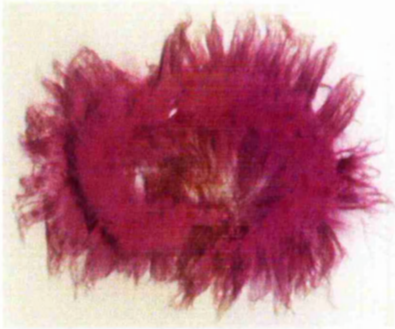


Figure 4.2: Feather and chitosan form.

P1.6.4 Conclusion

Considering the wet processing methods needed to produce chitosan films a more structured substrate would have been easier to process than feather. The resulting feather and chitosan film combination had an increased structural rigidity contributing new characteristics to the fibrous material.

P1.7 Film-forming effects summary

Chitosan films and the chitosan and silicones combinations were difficult to produce uniformly. The chitosan and silicones combination did not produce the required contrasting stretch and structure characteristics as originally intended as either film or fabric samples. The original concept of chitosan film on fabrics was to produce laminate effects combining the fabric structure and chitosan film as layers of material encapsulated between coloured, shiny film. Samples in P1.4 provided a range of effects in particular sample 3 (Table 4.7) which combined a shiny, coloured film covering the open structured fabric. In addition to film forming, samples illustrated that chitosan also held substrates together, binding materials into composite forms. In sample 1 (Table 4.7a), sequins were bound to the feather and sample 2 (Table 4.7a) torn layers of tissue paper were bound together. Chitosan films were more consistent when developed in combination with substrates providing a structure for the solution to adhere to.

P2 Temperature effects

The sub-sections under this heading include;

P2.1 Heating chitosan solution

P2.2 Heating chitosan solution with polymers

P2.3 Heating in kiln between glass

P2.4 Heating in kiln with ceramic glaze

P2.5 Vacuum forming

P2.6 Temperature effects summary

Earlier experiments cured chitosan solutions in temperatures up to 105°C. The following section explored effects of increasing the temperature considering effects on chitosan alone, in combination with polymers, in hot temperatures between glass plates and mixed with ceramic glaze. The section concludes with a vacuum formed sample in which thermoplastic characteristics were exposed.

P2.1 Heating chitosan solution

P2.1.1 Aim: To explore the effects of temperature on chitosan solution.

P2.1.2 Method (outlined in Table 4.8.)

P2.1.3 Results

Table 4.8 illustrates the results produced from heating chitosan solution at 190°C in the oven. The various outcomes depended on thickness of solution and length of time in the oven. The resulting characteristics included;

- Amber colours
- Brittle films
- 3-D skeletal forms holding the shape of the aluminium foil in which they were processed
- Surface texture effects

P2.1.4 Conclusion

Heating thin films of chitosan solution in the oven produced rich colour and texture effects, replicating the shape of the foil moulds and the amount of solution applied. The processing time ranged between 10 and 15 minutes in a constant temperature. Although the resulting forms were brittle structures, the colour, texture and 3-D structural possibilities contributed to the vocabulary of design potentiality. Samples 1 and 3 were included in resin forms in later work.

Table 4.8: Stages of development of chitosan solution on aluminium foil.

Method	Results
Sample 1 Poured chitosan along channel of aluminium foil and put in oven at 190° C for 10 minutes. Put back in oven for an extra 2.5 minutes. Total 12.5 minutes. When cool carefully remove from foil.	 Sample 1
Sample 2 Brushed solution on aluminium to give a thinner layer of solution than sample 1. Put in oven for 10 minutes at 190° C.	 Sample 2
Sample 3 Repeat of sample 2 on larger-scale pouring the solution along the channel. Manipulated the foil channel to give thin and thick areas. 15 minutes in oven at 190°C.	 Sample 3

P2.2 Heating chitosan solution with polymers

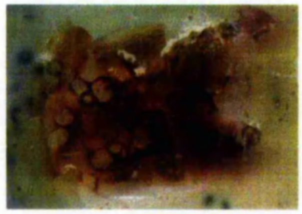
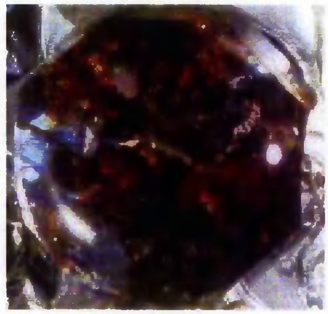
P2.2.1 Aim: To explore the results of heating chitosan solution in combination with low melting polymers, polystyrene beads.

P2.2.2 Method (Outlined in Table 4.9)

P2.2.3 Results

The softening point of polystyrene is 95° C however the temperatures varied from 100 190° C. The experiments produced a range of physical, colour and textural effects depending on length of time, temperature and sample preparation. The clear beads melted the most readily although the chitosan did not entirely mix with any of the polystyrene beads.

Table 4.9: Stages of development of chitosan with melting polymers.

Method	Outcomes	Images
Sample 1 Brushed chitosan on aluminium foil with blue, pink and clear polystyrene beads. Put in oven 100 ° C then increased to 190° C. Total time 15 minutes.	Sample burnt. Try lower temperature for longer.	 Sample 1
Sample 2 Brushed chitosan on aluminium foil with blue, pink and clear polystyrene beads. Set temperature to 150° C and left sample for over 2 hours. Allowed samples to cool then carefully removed foil from the baked chitosan form.	Clear polystyrene beads melted most successfully. Chitosan turned amber colour. Very brittle. Easily torn and rigid where polystyrene has part melted. Try samples with chitosan and beads in separate colours to decide which combination works best	 Sample 2
Sample 3 Brushed chitosan solution onto aluminium foil scattering pink and blue beads. Mixed into chitosan solution using brush. Put in oven at 110 °C and left until chitosan turned a light amber colour.	The chitosan hardened but the polystyrene beads did not melt. The film easily came away from the foil leaving the surface pattern and texture from the foil. Thick and thin areas of solution resulted in light and dark shades of amber. Perhaps a higher temperature would melt the polystyrene beads.	 Sample 3
Sample 4 Prepared a structure with wire and metallic shreds. Brushed thin coat of chitosan solution on glass plate to hold sample in place. Left sample to dry overnight forming a chitosan film. Removed from glass plate using a scalpel blade and turned over. Poured on more chitosan solution to thicken layer. Put in oven at 180 °C for 3 minutes. Scattered clear polystyrene beads over surface and reheated at 180°C for 20 minutes.	The supporting glass plate cracked. Took sample out of oven, beads not completely melted. Chitosan turned a deep amber colour. Resulting form is brittle but held together with internal structure of metallic shreds and wire.	 Sample 4

The coloured beads contributed to the opaque colour palette in addition to the amber colour of the chitosan. Thermal degradation caused the range of amber colours. The baked chitosan was again very brittle to handle although the addition of the melted polystyrene beads and the inclusion of wire and metallic shreds (sample 4) added rigidity and structure to the pieces.

Table 4.10: Details of chitosan with clear polystyrene beads.

Detail	**Large sample**	**CAD development**
 Sample 1	 Sample 2	 Sample 3

P2.2.4 Conclusion

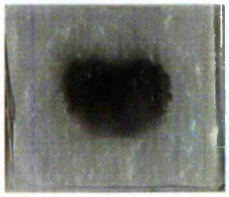
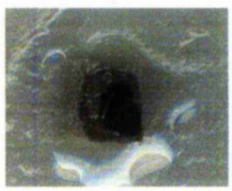
Processing chitosan solution at high temperatures produced a range of effects similar to those in P2.1. A further enquiry could be carried out to better predict the depth of shade of the heated chitosan with reference to the thickness of solution, temperature and time in the oven. Combinations of chitosan solutions with additional materials produced complementary effects including opaque characteristics and surface texture effects. The additional materials not only provided aesthetic qualities but also contributed structural rigidity to the samples.

The main characteristics included amber colours with highlights of coloured polystyrene beads and surface texture effects. The exception was sample 4, (Table 4.9) which also featured an internal wire frame supporting a composition of metallic shreds with clear polystyrene beads. This allowed the characteristics of the film to be viewed as a 3-D form. This piece was highlighted as having potential for further development in the feedback from Interior Architect students (Chapter 7). Table 4.10 illustrates details of chitosan with clear polystyrene beads with a subsequent CAD development building on sample 3.

P2.3 Heating in a kiln between glass plates

P2.3.1 Aim: To continue the exploration of chitosan at high temperatures.

Table 4.11: Chitosan samples heated in kiln between glass plates.

Sample description	Image
1. Fabric sample with chitosan on both sides	 Sample 1
2. Nylon crystal organza with 2 layers of chitosan	 Sample 2
3. Freeze dried chitosan	 Sample 3
4. Acetate from previous experiments	 Sample 4
5. Mixture of fabrics	 Sample 5

P2.3.2 Method

A range of chitosan samples were placed between glass plates and fired in a kiln.

P2.3.3 Results

See Table 4.11

All of the samples carbonized between the glass plates resulting in no defining characteristic signifying the use of chitosan. The glass tiles came out of the kiln with a mixture of black and white ash between the glass plates.

P2.3.4 Conclusion

The temperature of the kiln was too hot and the chitosan samples left no defining characteristics.

Continuing the exploration of chitosan and the effects of temperature, chitosan was put in a kiln with a ceramic glaze. The use of shells in glazing and whiting was highlighted as common practice in ceramics. It was suggested that as chitosan originated from crab shells, it might be comparable to other types of shell already used in this context.

P2.4 Heating in kiln with ceramic glaze

P2.4.1 Aim: To explore the results of chitosan heated in a kiln with ceramic glaze.

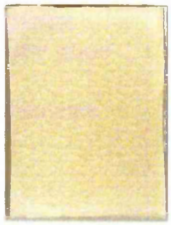
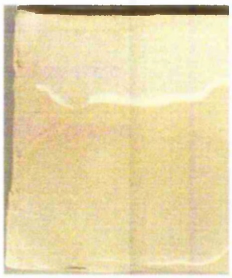
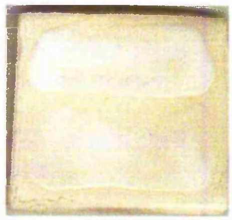
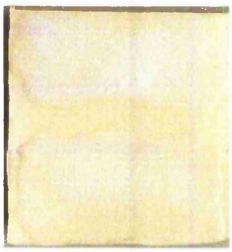
P2.4.2 Method

For each sample a total of 10g milled shell was mixed with transparent earthenware glaze and mixed with water (the water acts as a carrier for the particles which then absorbs into the porous surface leaving the particles on the surface). The solution was sieved the using a "120" sieve before the mixtures were brushed on the tiles. The ceramic tiles were fired at 1100° C for up to 12 hours in the kiln allowing two days to cool.

P2.4.3 Results

By method of comparison with other shell types (as seen in Table 3.11) the characteristics of chitin and chitosan were more easily identified and understood. Key features of the samples were identified by the patterns of the fractures and lines from different shell types. Colouration was noticeable from two shell types (prawn and mussel) however not present in the chitin or chitosan samples. There were no obvious differences between the chitosan and chitin samples.

Table 4.12: Ceramic glaze with various types of ground shell.

Mixture used	**Sample**	**Mixture used**	**Sample**
1. Chitin (crab) 9g Earthenware glaze 1g chitin	 Sample 1	4. Transparent earthenware glaze 10g Earthenware glaze	 Sample 4
2. Prawn 9g Earthenware glaze 1g Milled prawn shell	 Sample 2	5. Mixture 7g Earthenware glaze 1g Calcined mussel shell 1g milled prawn shell 1g chitin	 Sample 5
3. Mussel 9g Earthenware glaze 1g Calcined mussel shell	 Sample 3	6. Chitosan (crab) Chitosan solution mixed with earthenware glaze	 Sample 6

P2.4.4 Conclusion

Materials have different uses in different disciplines. It is useful to sometimes consider alternative perspectives to gain a better understanding of a new material. These outcomes would probably be interpreted differently by an expert in this discipline. These samples might contribute to the overall understanding of the new material although such high temperatures (as seen in Table 4.11) would completely destroy any fibrous content.

Following the characteristic film-forming effects and investigations with heat, comparisons were made to the Vacuum-forming process often applied in product design to develop prototypes. Thermoplastic sheets are laid over 3-d shapes and using heat in a vacuum, the thermoplastic material moulds itself around the underlying 3-d shape. P2.5 explored if this process would be compatible with chitosan film to produce chitosan forms.

P2.5 Vacuum forming

P2.5.1 Aim: To explore the possibilities of vacuum forming chitosan film.

P2.5.2 Method: Preparation of chitosan film for vacuum forming experiment.

Materials used;

PVC substrate

4% chitosan solution

Acid Blue 158 dye powder

Chitosan film pieces

Polystyrene beads

A piece of PVC was cut out and laid on a flat even surface placing glass plates at either edge to hold in place. PVC was chosen rather than glass plates to enable the film removal process. A small amount of chitosan solution was poured on and rolled with glass rod to distribute evenly. Additional materials were embedded in the chitosan solution; these included a variety of film samples from previous experiments with polystyrene beads. Acid blue dye powder was mixed with chitosan solution separately then poured onto selected areas. The solution began to separate on the PVC substrate due to surface tensions so additional solution was poured on to ensure coverage. A brush was stippled around edge of solution to explore colour effect. The solution was covered with a supported glass plate and allowed to dry at room temperature for two days.

P2.5.3 Results of the film preparation

It was uncertain that film would adhere to the PVC substrate while drying with only a small area remaining attached. The film wasn't continuous having separated in places resulting in holes. The added blue chitosan film pieces re-dissolved into the chitosan solution resulting in raised surface texture effects. The polystyrene beads previously processed with chitosan became more firmly attached in the solution than the beads alone which loosened off easily. The film face next to the PVC surface was noticeably the smoothest.

P2.5.4 Method used to vacuum form chitosan film

Following preliminary tests to produce a suitable 3-D shape, 9 glass cubes were arranged on the bed of the vacuum forming machine. The chitosan film was layered between two layers of PVC and heated. Initially a vacuum did not form with an unsuitable result. The experiment was repeated using one PVC layer placing the chitosan film directly onto the glass cube form. The effect of the heated PVC film and vacuum sufficiently manipulated the chitosan film resulting in a 3-D shape.

P2.5.5 Results

The chitosan film form readily peeled away from the PVC substrate with the additional materials embedded. The clear polystyrene beads did not melt in the heat and were not well attached to the film. The beads easily came off the surface leaving outlines of their shape on the surface. Beads which had been previously processed were better attached. Initially the sample smelt of acetic acid but this wore off over time. The film was less brittle than earlier samples and less susceptible to tearing. The resulting shape suggested that the film had thermoformed as a result of the vacuum forming process. Thermoplastic properties are not usually associated with chitosan resulting in a novel outcome. The film had not been neutralised therefore the chitosan was not cross-linked and might not be stable around water or liquids. This was the largest single piece of film generated in the research combining variations of colour, surface texture and shape.

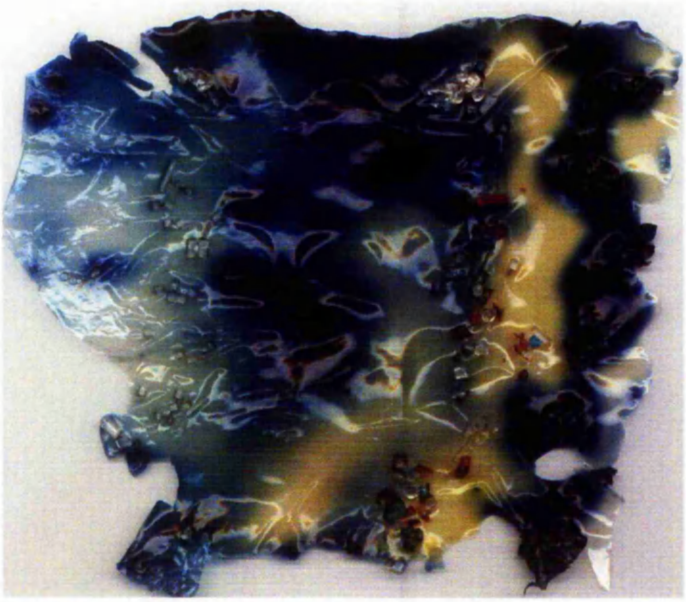


Figure 4.3: Vacuum formed chitosan film.

P2.5.6 Conclusion

Although the production of consistent uniform film is difficult, this sample included several stages of development as smaller pieces of film produced in earlier experiments were added to the chitosan solution, building up the larger sample in layers. Texture effects were visible where processed film had not entirely dissolved in addition to part-melted polystyrene beads. Following film development, the vacuum forming experiment showed it was possible to vacuum form chitosan film into a 3-D shape.

P2.6 Temperature effects summary

In summary, chitosan solution responded to the effects of temperature producing a variety of effects. The extreme temperatures used in the kiln, were too hot resulting in no defining characteristics whilst controlled temperatures in the oven produced unique aesthetic qualities. These included varying shades of amber with surface-texture effects of skeletal forms. When produced alone the films were brittle however in combination with melted polystyrene beads the samples were easier to handle. The composite melted beads with chitosan film added translucent colour allowing light to diffuse through and illuminate the samples. The vacuum forming process illustrated that chitosan film had 3-D potential illustrating unusual thermoplastic properties.

P3 Binding effects on fabrics

Samples produced in section P1.4, provided evidence of chitosan film binding substrates together. Sequins were bonded to feather and pieces of torn tissue paper were successfully glued back together. The following group of samples further explored the effects of chitosan film as binding effects on fabric substrates.

The sub-sections under this heading include;

P3.1 Icewool and nylon crystal organza

P3.2 Icwewool on various fabric types

P3.3 Binding effects summary

P3.1 Icewool and nylon crystal organza

P3.1.1 Aim: To explore the binding effects of chitosan solution on Icewool and Nylon Crystal Organza (NCO). The initial theory was to bond a knitted fabric sample to underlying woven fabric, using the stability of the woven construction as a foundation, whilst the stretch elements of the knitted fabric could be explored in combination with chitosan film. The fabrics were specifically chosen to contrast their diverse characteristics, as shown in Table 4.13.

Table 4.13: Comparing characteristics of Icewool and Nylon crystal organza.

Icewool	**Nylon crystal organza**
Warp knitted	Woven
Staple fibres	Monofilament yarn
Raised brushed surface	Flat smooth surface
Matt surface	Diffused light effects

P3.1.2 Method

The following stages were developed as the method to generate the samples shown in Tables 4.14 and 4.15. The process included;

1. Icewool strip preparation
2. Nylon crystal organza placed on glass plate

3. Icewool strip(s) positioned on nylon crystal organza
4. Application of chitosan solution using stiff brush
5. Dried in oven
6. Neutralised
7. Dyed if required
8. Rinsed and dried in oven

The Icewool strip was chosen in order to contrast the flat, smooth surface of the NCO with a textured sculptural 3-D shape. The strips comprised of narrow bands of Icewool with horizontal slits cut equally down the length (see Figure 4.4). Each slit was pulled apart creating more rounded openings through which the pieces were successively turned in on themselves creating 3-D shapes. The Icewool strips were then lightly sewn or pinned under tension to the nylon crystal organza base. Samples were then placed on glass plates whilst a stiff brush was used to apply chitosan solution along the edges of the Icewool strips. The samples were secured on glass plates with wooden pegs to prevent movement and put in the oven at 50°C. When dry, the samples were neutralised in sodium carbonate solution for 20 minutes, rinsed then dried in the oven.

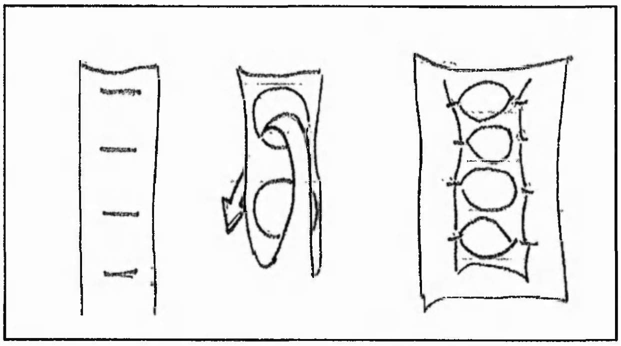


Figure 4.4: Construction of Icewool strip.

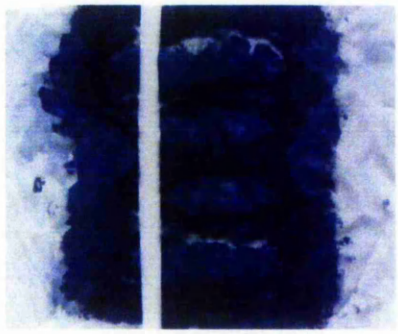
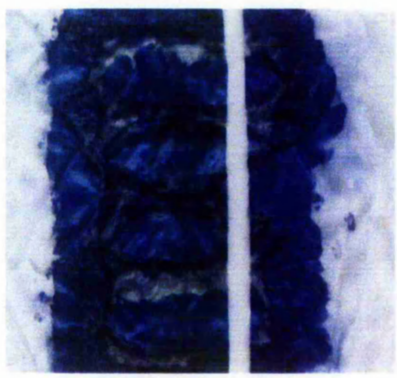
P3.1.3 Results

Tables 4.14 and 4.15 illustrate the range of samples in which chitosan solution bonded Icewool to NCO. Resulting characteristics include;

- Slight yellowing where chitosan solution was applied
- Shiny film effects where the chitosan solution dried next to the smooth glass surface
- Fabric retained new shape in the position processed

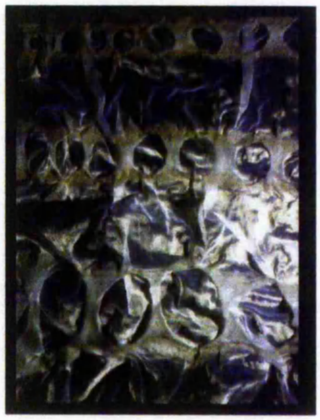
- When dyed, the dye only took to the areas covered with chitosan film not surrounding fabric (sample 2a and 2b)
- The cut the edge remained sharp with no visible fraying

Table 4.14: Initial developments of Icewool and NCO bonded with chitosan.

Results	Image of sample
The Icewool retained the new shape and successfully bonded to the Icewool.	 Sample 1
Comparison of the contrasting shiny and dull surfaces where the chitosan solution has dried on smooth surface. Dye took to the areas only covered by chitosan film. No fraying where the sample was cut, leaving sharp edges. Dye recipe: 10ml direct cotton 0.5%Solar Blue 10ml 20% sodium chloride Made solution up to 200ml with distilled water.	 Sample 2a  Sample 2b

The effects varied as a result of inconsistent sample developments, the positioning and size of Icewool strips and the area covered by chitosan solution. Samples in Table 4.15 illustrate the binding effects on larger scale samples.

Table 4.15: Further developments of Icewool and NCO bonded with chitosan.

Results	Image of sample
A thin strip of Icewool was bonded to the NCO using chitosan solution. The solution was also brushed across the fabric creating horizontal bands of film.	 Sample 1
Large scale sample. Increasing sized strips of Icewool were bonded across NCO substrate. The piece was processed in stages due to restricting size of oven. Samples 2b and 2c are photographs of sample 2a in a 3-D context.	 Sample 2a
 Sample 2b	 Sample 2c

P3.1.4 Conclusion

The samples in Tables 4.14 and 4.15 illustrated the potential of chitosan solution to bond Icewool and NCO. The concept of combining diverse substrates was realised using chitosan which not only acted as glue but also encouraged a layering effect. The translucent solution was applied along the edges of the Icewool to selectively join the materials. The scale of production was determined by the oven size and the ability to develop the sample in sections to maximise the scale of the piece. Following this group of experiments the work explored the effects of chitosan solution bonding Icewool to other substrates.

P3.2 Icewool on various fabric types

P3.2.1 Aim: To bond Icewool strips to various fabric types using chitosan solution.

P3.2.2 Method

The samples were produced using the method developed in P3.1. The Icewool strips were applied vertically in the centre of the fabrics.

P3.2.3 Results

All samples gained structural rigidity to variable degrees where the chitosan solution was applied. The Icewool strip did not successfully bond to the acetate or the wool delaine.

P3.2.4 Conclusion

All the samples resulted in more rigid horizontal bands across the fabric where solution was applied. The shiny film effects were not consistent on all samples and the Icewool strip did not bond successfully to all substrates. Part of the attraction of the transparent fabrics used in P3.1 was the layering effects of the individual components. This was less effective with the sample in Table 4.16 as the base fabrics and Icewool strips contrasted rather than producing subtle combinations. In sample 4 the film produced a transparent effect along the chitosan spines whilst the uncoated Icewool showed signs of felting. This contrast of textures was more subtle against the light-coloured surface of the undyed silk.

Table 4.16: Icewool bonded to various fabrics.

Sample description	Results	Fabric samples
Predyed cotton muslin.	Icewool strip stayed on fabric. Added structural rigidity. Shiny film effects on cotton.	 Sample 1
Predyed Acetate.	Thicker fabric – more difficult for chitosan solution to soak through. Icewool strip came off easily perhaps due to shiny surface.	 Sample 2
Undyed wool delaine.	Icewool strip came off after processing.	 Sample 3
Undyed silk crepe de chine.	Icewool remained firmly attached after processing. Flexible chitosan bands across width of fabric.	 Sample 4

P3.3 Binding effects summary

The experiments in P3 explored the potential of using chitosan solution to bond Icewool strips to NCO and other substrates. Techniques developed in the small scale samples were applied to larger scale pieces considering the restricting parameters of equipment alongside required aesthetic outcomes. The resulting characteristics of the NCO and Icewool samples produced layered effects combining a diffused light surface, smooth, shiny transparent films with part-bonded, part-felted Icewool. Other samples (in Table 4.16) did not combine these elements as successfully.

P4 Sculptural effects

The following group of experiments considered the potential of chitosan solution to achieve sculptural effects on textile substrates.

The sub-sections under this heading include;

P4.1 Local application to substrates

P4.2 Fully submerged fabrics

P4.3 Development of Icewool and chitosan combination

P4.4 Sculptural effects summary

P4.1 Local application to substrates

P4.1.1 Aim: To explore the sculptural effects of local application of chitosan solution on textile substrates.

P4.1.2 Method (Outlined in Tables 4.17a and 4.17b).

P4.1.3 Results

Tables 4.17a and 4.17b illustrate the range of samples generated in this group.

In all cases where chitosan solution was applied the textile substrate became more rigid although remained flexible. The effects varied according to the characteristics of the textile substrates making the results difficult to generalise.

The sculptural effects included;

- Flattened 3-D textile (Heat-treated polyester)
- Chitosan film secured manipulated yarns generating possibilities of controlling yarn displacements (NCO)
- Surface texture effects depending on drying position of fabric. Possibilities of straight lines and uneven surface textures (Silk)
- 3-D sculptural forms (Icewool)

P4.1.4 Conclusion

All samples showed evidence of additional structural rigidity resulting from chitosan film formation. Interesting effects were generated by fabrics which responded to the characteristics of the chitosan film. This is illustrated by sample 5 (Table 4.17a) as the fluid nature of the silk did not resist the contracting properties of the film. Also, the yarns in the NCO (samples 3 and 4) were distorted before solution was applied then readily held their new positions. Table 4.17b illustrates the Icewool samples comparing areas of film which contrast to the surrounding open knitted structure. Noticeably the film protected the fibres from subsequent wet processing which felted the uncoated sections.

Table 4.17a: Sculptural effects of local application of chitosan solution on various textile substrates.

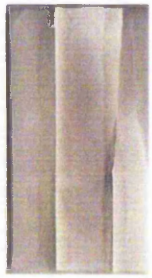
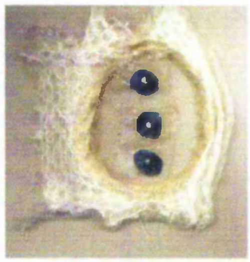
Sample and description of method	Results	Image of sample	
Heat set polyester with vertical pleats The fabric was held open and the chitosan solution was applied across the width. The sample was held in place until the chitosan was dry.	The chitosan film stiffened the heat set polyester but didn't completely flatten the fabric. No shiny film effect.	 Sample 1	
Cotton muslin Corrugated plastic sheets were used to hold the sample during processing. The sheets were initially clamped together using wooden pegs then separated towards the end of processing.	Corrugated shape from the plastic sheets. Vertical columns were cut out of the centre to see if fabric frayed. The cut edges were not as exact as the NCO in Table 3.13.	 Sample 2	
Nylon Crystal Organza The warp and weft yarns were manipulated to distort fabric creating irregular patterns. The samples were placed on a glass plate and chitosan solution was painted around the edge of the manipulated sections using a narrow soft brush.	Shiny film effect. Dyed only where chitosan solution applied. Distorted yarns held position once chitosan film was dry.	 Sample 3	 Sample 4
Silk crepe de chine Uneven surface: Solution was brushed on glass plate to hold in place. Fabric was distorted and chitosan was poured over. Straight lines: The edge of glass plate was used as a guide as solution was applied.	No shiny film on either sample. Uneven surface: Added surface texture effects and more dimensional structure. Straight lines: Produced straight edge with crease clearly defined down centre.	 Uneven surface Sample 5	 Straight lines Sample 6

Table 4.17b: Chitosan solution applied to Icewool.

Sample description	Results	Image of sample
Icewool strip (from P3.2)	Horizontal lines of chitosan film contrasted against non-treated areas. Icewool became narrower due to wet processing technique causing felting action.	 Sample 1
Icewool with pleated chitosan film Brushed on chitosan solution in lines across fabric. Once dried and neutralised sample was rinsed and washed in warm soapy water to see if icewool would 'felt'. Put back in oven to dry.	Chitosan held in place and Icewool began to felt. Contrast between areas with chitosan film and narrow Icewool substrate.	 Sample 2
Icewool with embroidered section. A long strip of Icewool was manipulated to form circles folded on top of one another. The sample was placed on a glass plate brushing chitosan around the inner circle of each layer. Put in the oven at 70° C until dry. Neutralised and dried. The embroidered section was added later from leftover samples	The Icewool felted and the chitosan film bonded the inner section together. The layers of fabric were gently pulled apart remaining joined at selected points. Icewool and chitosan combination produced a 3-D form. Inner section of the sample was significantly more rigid than the untreated Icewool.	 Sample 3a  Sample 3b

In previous experiments chitosan solution was applied to selected areas of fabrics. The following section explored the effects of total coverage on selected substrates.

P4.2 Fully-submerged fabrics

P4.2.1 Aim: To explore the sculptural effects of fully submerging fabric in 2% chitosan solution.

P4.2.2 Method

The fabric types were selected from those used in earlier experiments to facilitate continuity and comparison. The majority of the fabrics were woven with the exception of the warp knitted Icewool. The samples included;

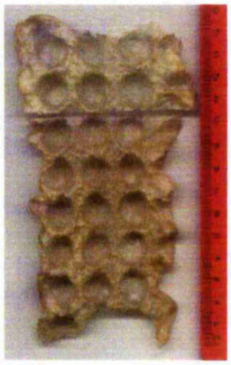
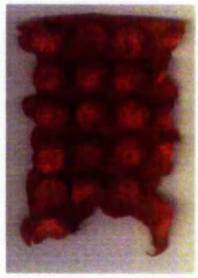
- Icewool
- Cellulose acetate
- Silk crepe de chine with nylon crystal organza
- Heat manipulated polyester

A small amount of 2% chitosan solution was poured into a beaker and the fabric samples were individually immersed in the solution until thoroughly soaked. Excess liquid was squeezed off before the samples were laid across the shaped plastic mould. The fabrics were pushed into the holes using a glass rod where necessary making sure the mould was evenly filled. The samples were left in the mould and put in the oven until dry. When dry and removed from the mould the samples were neutralised in 0.5% sodium carbonate solution for 15-20 minutes, rinsed and finally put in the oven until dry.

P4.2.3 Results

The woven fabric samples were more difficult to push into the plastic mould in comparison to the knitted fabric. These restrictions were demonstrated by the resulting woven samples being less well defined than the knitted sample. The woven fabrics creased and folded whereas the knitted structure allowed expansion and contraction to accommodate the 3-D shapes. All the samples retained their shape after neutralising and remained flexible however the Icewool (sample 1, Table 4.18) was the most rigid.

Table 4.18: Various textile substrates totally submerged in chitosan solution.

Sample description	**Results**	**Reverse**	**Face**
Icewool – warp knitted Sample 10 x 20cm before processing Top section not neutralised	Good definition of plastic mould. Most rigid sample but still flexible. Coarse texture. No shiny film. Dyed sample.	 Sample 1	
Cellulose acetate Woven	Not an exact shape of mould. Irregular take up of chitosan- hard and softer areas.	 Sample 2	
Silk with nylon crystal organza Both woven fabrics	Silk- well defined compared to other woven fabrics - springy feel. Nylon is loosely attached but not well defined – crunchy effect.	 Sample 3	
Heat processed polyester Woven – textured surface	Most difficult to place in mould. Least well defined shape. Harsh handle.	 Sample 4	

P4.2.4 Conclusion

The selection of samples chosen in this group illustrated the potential of chitosan solution to develop sculptural effects on textile substrates. Icewool proved to be the most accurate regarding shape definition and the most rigid. The variety of effects of fully submerged substrates in chitosan solution included;

- Visual – shape definition, matt surface, shiny surface, colour
- Handle – flexible, springy, coarse
- Sound – papery, crunchy sound

P4.3 Developments of Icewool samples submerged in chitosan solution

Resulting from the outcomes in P4.1 and P4.2, Icewool was chosen to be fully submerged to explore larger scale samples. The Icewool and chitosan combination produced strong, flexible, well defined forms.

P4.3.1 Aim: To develop a range of samples focusing on Icewool and chitosan.

P4.3.2 Method

The Icewool samples (Figures 4.5 to 4.8) were prepared using the technique described in P4.2 varying the shapes of the moulds and placement on the substrate. The samples were left to dry at room temperature as the plastic moulds might not withstand the hot temperature. Once dry the samples were carefully removed, neutralised, then left until dry in the drying cabinet.

P4.3.3 Results

Strong, flexible, textile forms were produced similar to the smaller scale samples as in P4.2. Samples developed in P4.3 reflected the shape and placement of the moulds used with no additional characteristics than those discovered in P4.2. The pieces were sufficiently rigid to hold a vertical position with no additional support. The original soft handle of the Icewool was now replaced by a rough surface texture.

Scanned images of Icewool sully submerged in chitosan solution.

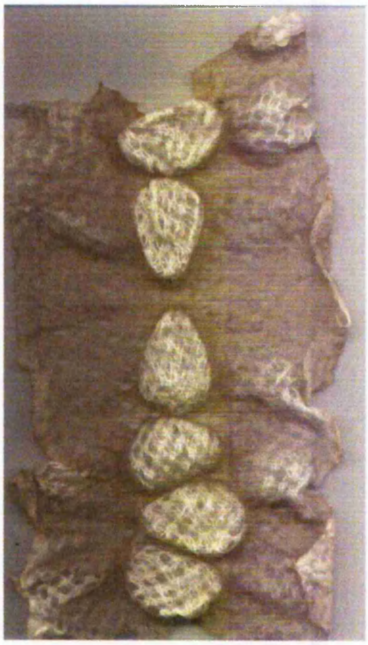


Figure 4.5: Irregular vertical Icewool column.

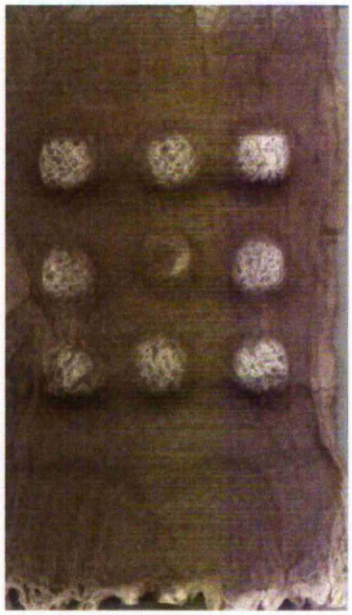


Figure 4.6: Icewool cube repeat.

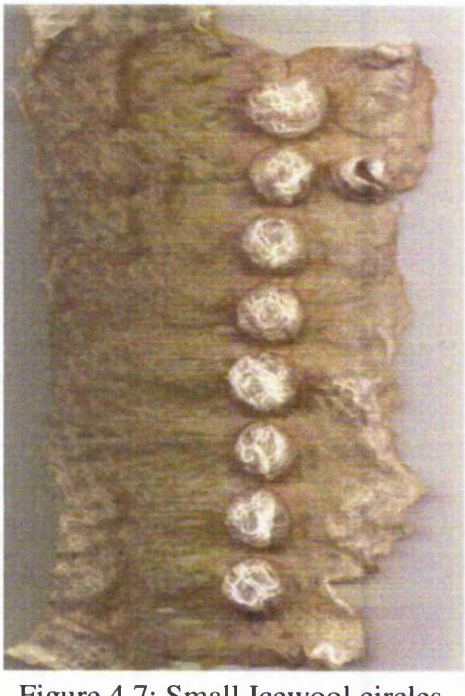


Figure 4.7: Small Icewool circles.

Figure 4.8: Icewool edge.

Images of CAD developments from sketch book composition.

Figure 4.9: Scanned sample from sketchbook.

Figure 4.10: CAD development of 3.9 in horizontal repeat.

Figure 4.11: Horizontal and vertical mirror repeat of 4.10.

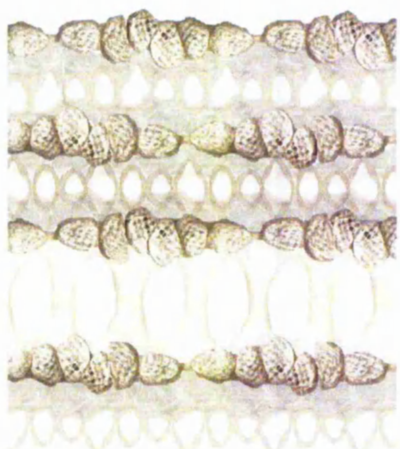


Figure 4.12: CAD developments combined to explore large-scale image.

P4.3.4 CAD developments

Having developed a range of samples idea generation continued combining small sections in embroidered samples (Figure 4.9). This was scanned into Adobe Photoshop 7.0.1 (CAD software) to explore visual effects using an efficient method without having to engage with more practical experiments. Figure 4.9 was scanned, cleaned up and put in to horizontal repeat expanding the image using mirroring and overlaying techniques, resulting in Figure 4.11. This sample was then combined with other images of Icewool and chitosan finally producing Figure 4.12 which included additional images of 3-D Icewool shapes.

P4.3.5 Conclusion

The chitosan and Icewool samples illustrated a range of moulding and sculptural effects using basic equipment and techniques. The resulting shapes depended on the definition of the moulds used with all samples retaining their new sculpted shape. Further sample developments could vary the placement and shape of moulds in addition to considering scale. The use of CAD allowed further exploration of visual effects considering how the characteristics might contribute to design concepts.

P4.4 Development of single large scale Icewool and chitosan piece.

P4.4.1 Aim: To produce a large-scale sample of Icewool and chitosan solution.

P4.4.2 Method

A variety of sizes and shaped plastic moulds were arranged at the same height and fixed to the surface to reduce movement. The Icewool was cut to 150cm long by 42cm wide, up to 1.5 times the width of moulds to allow for shrinkage. Chitosan solution was poured into a flat tray and the fabric was immersed in the solution. The excess solution was gently squeezed off and the fabric was laid over the moulds. Starting at one end the fabric was pushed into the shapes ensuring the fabric was soaked in solution. The sample was left to dry at room temperature.

P4.4.3 Result

The Icewool fabric soaked with chitosan solution was much more difficult to handle when working on a larger scale, ensuring the fabric was laid correctly in the moulds. The shape definition was comparable to the smaller-scale samples with the added benefit of a variety of shapes in one piece. The structural rigidity of the substrate even allowed the larger shapes to hold their form maintaining flexibility with less stretch.

Figure 4.13: Large-scale Icewool fabric.

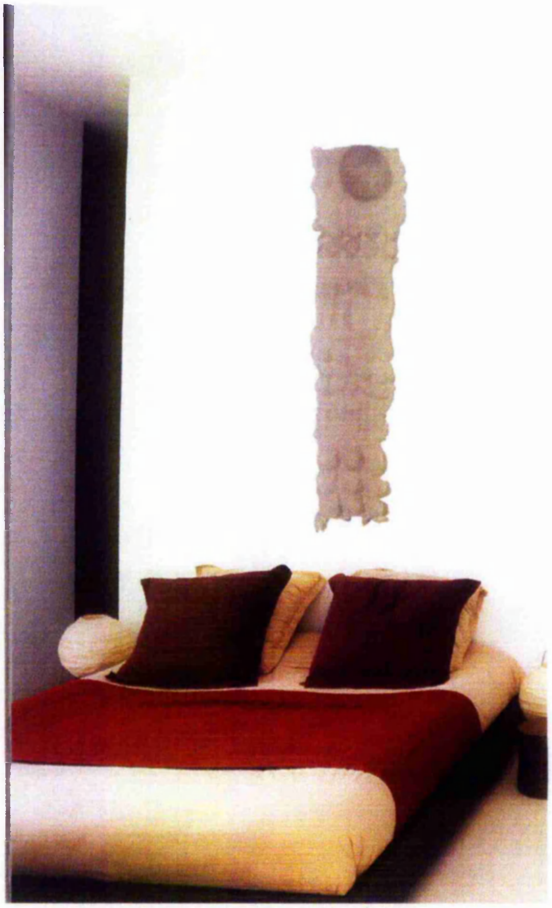


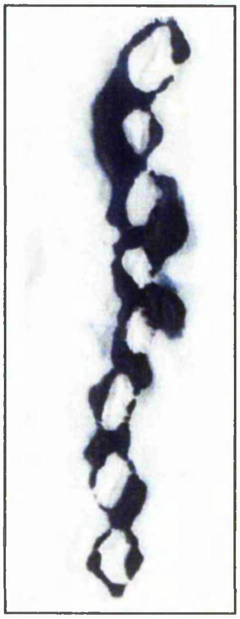
Figure 4.14: Visualisation of Icewool in interior setting

P4.4.4 Conclusion

Based on experiments P4.2 and P4.3 the combinations of Icewool and chitosan have the potential to produce a variety of well-defined sculptural forms. The smaller samples were easier to handle when soaked in solution and could possibly be joined to produce a larger composition.

P5 Design visualisations

Figures 4.15 to 4.23 were developed to enable a selection of samples to be visualised in design applications. Most of the samples were directly applied to end-use contexts based on aesthetic characteristics such as shape, surface textures, colour and 3-D forms. Figures 4.18 and 4.19 were included as visual explorations of the *palette of effects* which provided inspiration for surface pattern generation.



Sample 4
Table 4.17a.

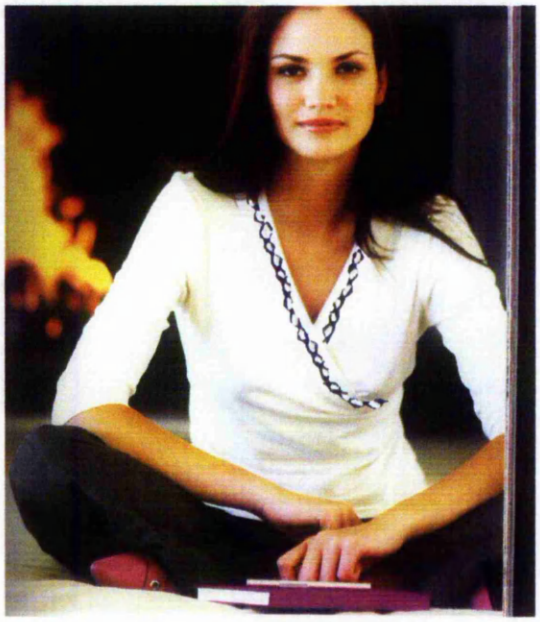


Figure 4.15: Blouse edge
(Ogundehin, 2005: 49)

Sample 4
Table 4.17a.

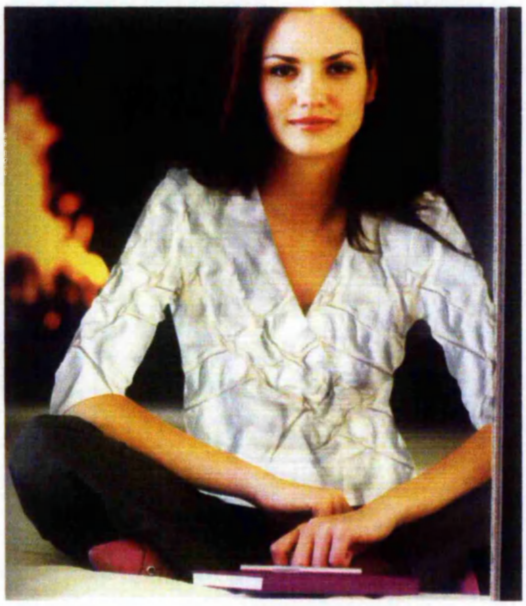


Figure 4.16: Blouse overlay.
(Ogundehin, 2005: 49)

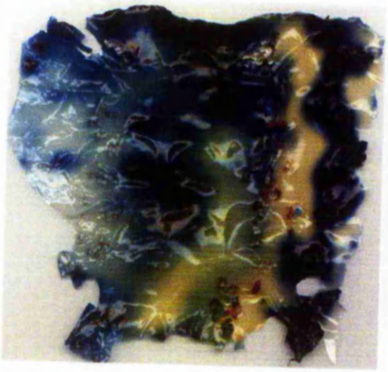


Figure 4.3: Vacuum formed chitosan film.

Figure 4.17: Blue interior screen. (Christiansen, 2005:168)

Figure 4.18: CAD development of Figure 4.3.

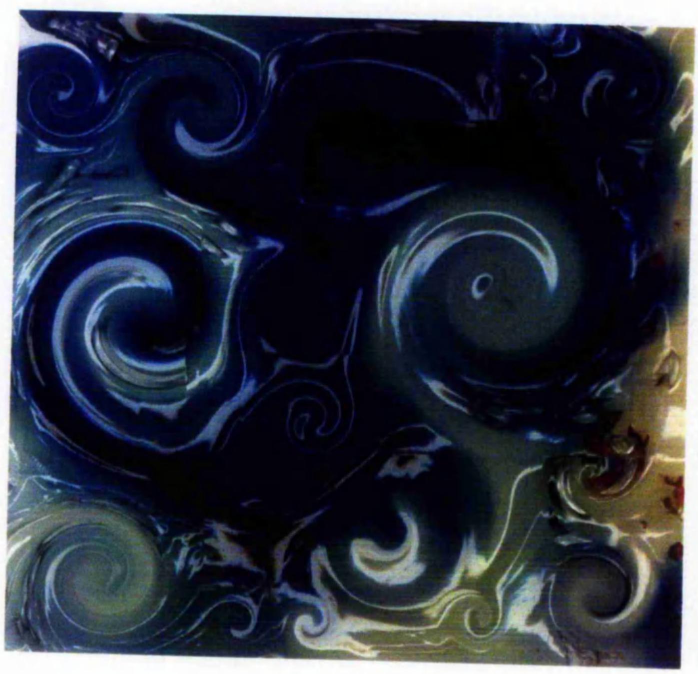


Figure 4.19: Large-scale CAD development of Figure 4.3.

Sample 3
Table 4.10.

Figure 4.20: Earth interior screen.
(Christiansen, 2005:168)

Sample 3
Table 4.18.

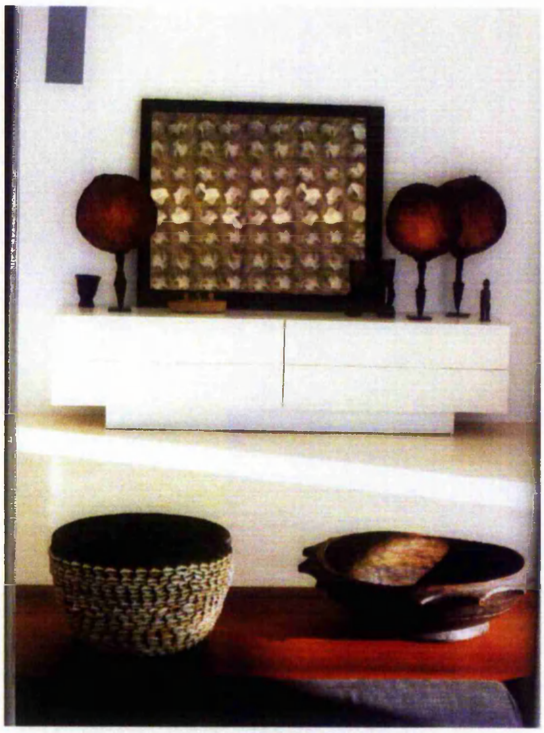


Figure 4.21: Framed sculpted fabric piece.
(Aiyer, 2005:146)

Figure 4.7: Small Icewool circles.

Figure 4.22: Lamp (Asensio, 2002:95)

Figure 4.10.

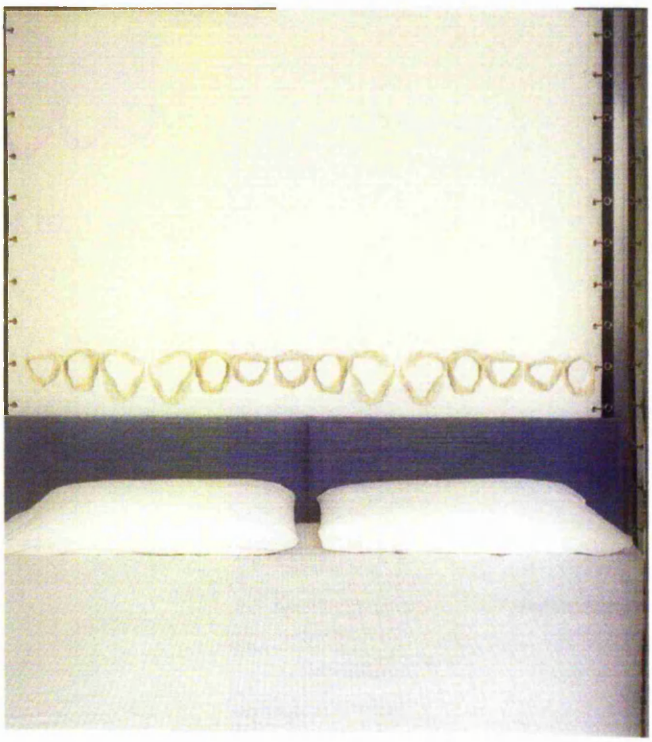


Figure 4.23: Bed head. (Asensio, 2002:138)

P6 Chapter conclusion

The physical effects chapter was divided into four main sub-headings including film forming effects, temperature effects and sculptural effects of chitosan. The development of ideas within these groups was based on initial film forming characteristics which were then explored through processing techniques in various material combinations. The inclusion of a range of materials was beneficial to generate a vocabulary of potential effects. However, it became progressively more difficult to identify results specific to chitosan due to the relationships between individual components within each sample.

The difficulty in producing uniform, consistent chitosan films was less obvious when applied to substrates. The textile substrates provided a supporting structure around which the solution could form and then dry as films. The characteristics produced with films alone were less predictable than those in combinations with other materials. Obviously, the resulting characteristics of the composite chitosan samples were dependent on the inherent characteristics of the textile substrates, requiring a compromise between the components to produce successful results. The aim was not to compile an exhaustive list of outcomes but to demonstrate the characteristics of chitosan within the theme of physical effects contributing to design potential.

Chapter 5: Colour effects of chitosan

The following section contains experiments (outlined in Table 5.1 and Mind map 5) which illustrate examples of chitosan contributing colour to the design potential of various combinations of materials. Chitosan solution has an attraction to dye (as documented in chapter 3), however various methods to apply chitosan solution to the substrates were considered, highlighting successful material combinations and resulting creative effects. C1 and C2 highlight the theory that chitosan film could be used as a tool in two ways. First to absorb dye acting as a barrier to protect the underlying fabric, second as decorative detail itself producing coloured film effects.

Table 5.1: Sub-groups in colour effects experiments.

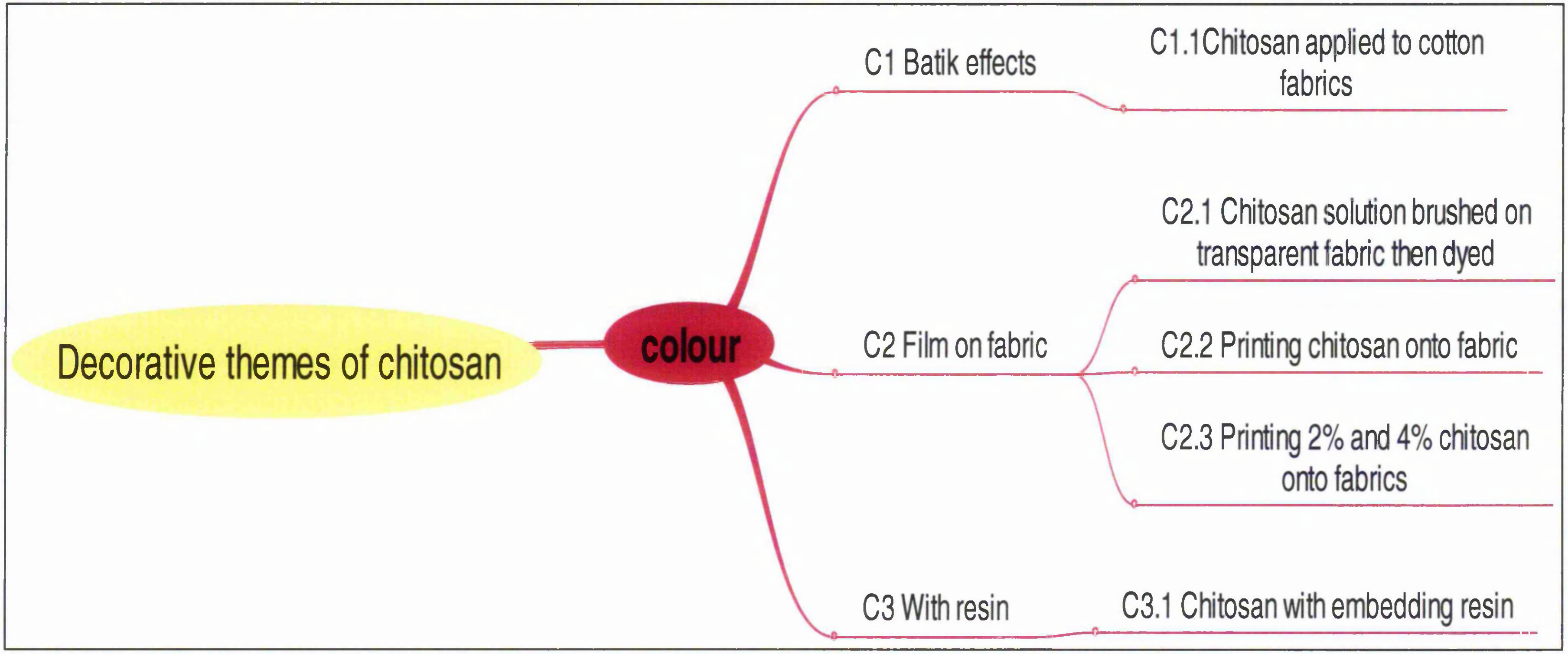
	Sub heading	**Sample descriptions**
C1	Batik effects	C1.1 Chitosan applied to cotton fabrics
C2	Film on fabric	C2.1 Chitosan solution brushed on transparent fabrics then dyed C2.2 Printing chitosan onto fabric C2.3 Printing 2% and 4% chitosan onto fabric
C3	With resin	C3.1 Chitosan with embedding resin

C1 Batik effects: Chitosan applied to cotton fabrics.

The first group of experiments explored chitosan as a barrier to dyes creating dye effects similar to batik. Traditional batik techniques use batik wax applied to cotton fabrics as a barrier to dyes, building up layers of pattern following the removal and reapplication between dying stages. One disadvantage of batik is that the wax melts at relatively low temperatures so cold water dyes must be used. This limits the fabrics to cotton, as only cotton fabrics have an affinity for cold water dyes.

C1.1.1 Aim: To explore the colour effects resulting from chitosan film applied as a resist to dyes on cotton fabrics.

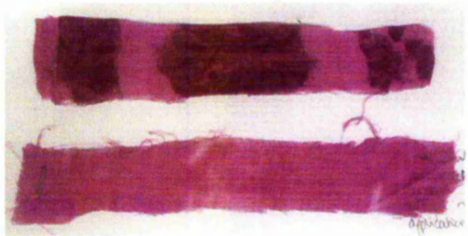
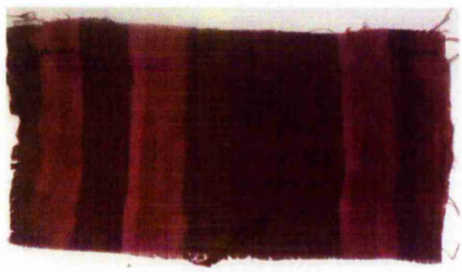
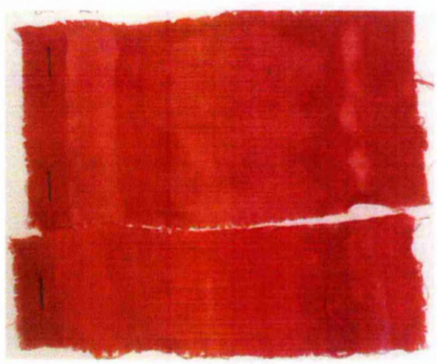
Mind map 5: Colour effects of chitosan



C1.1.2 Method

4% viscous chitosan solution was prepared and applied to cotton fabric samples using a spatula to ensure the solution soaked into the fibres. The samples were dried in the oven at 50°C, neutralised then dyed. Selected areas of chitosan film were removed using dilute nitrous acid illustrating the resulting colour of the underlying fabrics.

Table 5.2: Batik effects of chitosan film on cotton fabrics.

Description	**Images of samples**
Chitosan film on fabric following dyeing. Dyed cotton fabric with film removed.	 Sample 1
Dyed cotton fabrics once film was removed. Variable dye take up due to resist effect of film. Lighter shades where film was removed but no completely white areas.	 Sample 2
	 Sample 3

C1.1.3 Results

The process of applying chitosan solution, dyeing fabric samples then removing areas of film resulted in unevenly dyed surfaces. The theory behind the process was similar to batik where the wax resist protects the fabric. In contrast, the chitosan film did not completely protect the underlying fabric which resulted in paler shades of colour rather than completely undyed areas. The resulting colour effects highlighted a method by which tonal effects could be achieved however the range of colours seemed dull in comparison to colour effects in other samples. Chitosan was applied in these experiments as a tool to achieve dye effects however the chitosan film was removed to complete the process. One of the attractions of using the chitosan was the film-making effects on textiles however these characteristics did not contribute in the final pieces.

C1.1.4 Conclusion

Chitosan film was applied to cotton samples as a resist to dyes, resulting in tonal effects which were visible once the chitosan film was removed (Table 5.2). The chitosan film did not completely protect the underlying fabric from dye and the resulting effects produced uneven tonal variations. Future developments could capitalise on the benefits of being able to dye samples at higher temperatures, allowing other dyes and fabrics to be explored. The resulting samples did not illustrate any new visual characteristics to inspire further development resulting in familiar tonal dye variations on the cotton substrates. No further experiments were carried out.

C2 Film on fabrics

The following group of experiments included samples which highlight the effect of chitosan solution dried as film on fabric. The sub-sections in this group include:

C2.1 Chitosan solution brushed on fabrics then dyed

C2.2 Printing chitosan onto fabric

C2.3 Printing 2% and 4% chitosan onto fabric

C2.1 Chitosan solution brushed on transparent fabrics then dyed

C2.1.1 Aim: To explore the effects of dyed chitosan film on transparent fabrics.

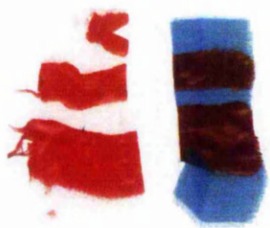
C2.1.2 Method

The samples were laid on cleaned glass plates and chitosan solution was brushed on using a stiff brush. The samples were then dried in the oven, neutralised in sodium carbonate and cut in two for comparison. Half the polyester samples were put in a dye-bath containing 10ml of 0.5% solar scarlet RL direct dye and 10ml of sodium chloride solution. Red direct dye was used to contrast against the uncoated fabric as polyester fibres. Pleats were also ironed into sample 2 to explore resulting effects.

Table 5.3: Chitosan film on polyester voile.

Comparison of dyed and undyed samples	**Ironed folds**	**Second application of chitosan film then re-dyed**
 Sample 1a and 1b	 Sample 2	 Sample 3a and 3b

Table 5.4: Chitosan film on nylon.

NCO Icewool composite	**Dyed NCO with chitosan film**	**Nylon voile with chitosan film**
 Sample 1	 Sample 2	 Sample 3a and 3b

C2.1.3 Results

The resulting images are in Tables 5.3 and 5.4.

- The side of the fabric nearest the glass plate was most shiny.
- Only the areas of fabric covered in chitosan solution dyed however a small amount of staining occurred.
- Contrast between the shiny film and fabric surface.
- Chitosan acts as glue holding the fibres in place.
- Coloured translucent film.

The translucent smooth, shiny films on the sheer fabrics allowed the characteristics of the underlying fabric structures to be seen. Illuminating rich colour was produced as the shiny film contrasted against the fabric surfaces. The polyester (sample 3b, Table 5.3) was coated with a second application of chitosan solution then re-dyed in a yellow dye. This resulted in subtle layered colour effects with slight staining on the surrounding fabric. The red dye on the blue nylon (sample 3b, Table 5.4) resulted in a darker shade as a result of combining with the original blue fabric colour.

C2.1.4 Conclusion

The application of chitosan solution to lightweight, sheer fabrics produced a fusion between film and fabric allowing each to contribute to the aesthetics of the resulting samples. In particular the rich colour of the dyed chitosan film was illuminated by the transparent fabrics in addition to the contrast between shiny film and dull fabric surfaces. Having defined this combination of aesthetic effects, the next phase explored printing as a more efficient process to develop the same results.

C2.2 Printing chitosan onto fabric

Up to this point, applying film to fabrics included brushing and pouring however these techniques did not allow accurate control of the chitosan solution. In the following section chitosan was printed onto the textiles with the aim of producing similar aesthetic effects as in C2.1.

C2.2.1 Aim: To investigate the results of printing with 2% chitosan solution.

C2.2.2 Method of processes

C2.2.2a Printing

Two samples of nylon crystal organza and cotton muslin were printed comparing application with a stiff brush or a printing squeegee. The samples were printed on a fabric printing table surface rather than a glass plate.

Sample one: (Table 5.5)

A small amount of chitosan solution was printed onto the cotton and nylon samples with ten passes of the squeegee to ensure it absorbed through the fabric.

Sample two: (Table 5.5)

Using the sample screen as a shape guide, chitosan solution was brushed on using the flat ended stiff brush ensuring adequate coverage.

C2.2.2b Drying and neutralising

The samples were placed on glass plates and dried in the oven at 50° C holding down the edges with wooden pegs to prevent contraction and deformation. When dry the samples were treated in 0.5% sodium carbonate solution for 15-20minutes then put back in the oven to dry.

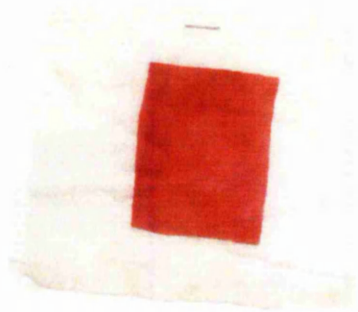
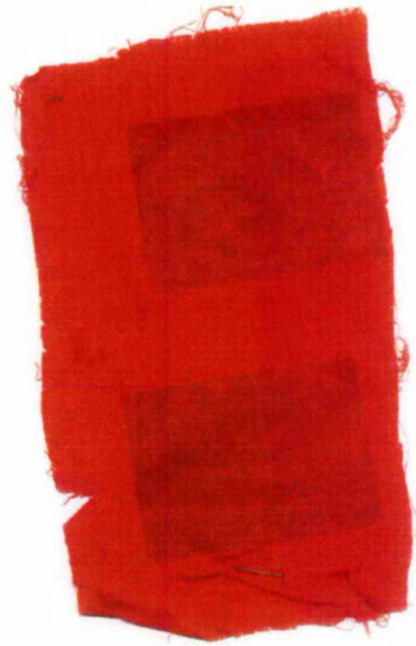
C2.2.2c Dyeing

Once dried the samples were put in a dye bath containing 10mls of a 0.5% solution of a direct dye (Solar Scarlet red) made up to 100ml with water and 10mls sodium chloride (NaCl) solution.

C2.2.3 Results

The edges of the printed square appeared to be accurate on all samples although no shiny film effects were visible. All samples were stiffer where chitosan solution had been applied with sample 2 (brush and print screen) being slightly stiffer than sample 1 (squeegee and print screen). On the cotton muslin, the printed chitosan square resulted in a darker shade than the rest of the sample as the cotton fibre also has an affinity to direct dye resulting in more dye being absorbed in this area.

Table 5.5: Initial samples of 2% chitosan solution printed on fabrics.

NCO	Cotton muslin
 Sample 1	Sample 1  Sample 2
 Sample 2	

C2.2.4 Conclusion

The chitosan solution was successfully printed using a print screen and squeegee. The chitosan film was dull rather than shiny highlighting the importance of the underlying smooth surface during application and drying. The chitosan coverage looked even and dyed equally on both sides of the substrates. The NCO samples produced more contrasting visual effects making it easier to differentiate between the characteristics of the film and the substrate. The outcomes of C2.3 led to question the processing parameters, in particular would the viscosity of the chitosan solution influence the resulting print definition? Also could the same printing technique be modified to produce shiny films on the fabrics?

C2.3 Printing 2% and 4% chitosan solution

C2.3.1 Aim: To explore the contrasting effects of printing with 2% and 4% chitosan solution to produce similar aesthetic effects as produced in C2.1. Nylon Crystal Organza was chosen to contrast the shiny film against the diffused light effects of nylon crystal fibres. Silk crepe de chine was also chosen to explore the effects of printing chitosan solution as an opaque substrate in contrast to the transparent characteristics of the NCO.

C2.3.2a Method: Developing the print image

The image for the screen print was based on the concept of connecting irregular structures, specifically leaving areas of the underlying substrate unprinted. In earlier research chitosan film contributed structural rigidity to the underlying textile. This would influence the resulting fabric characteristics allowing the areas of unprinted fabric to contribute to the resulting decorative and structural effects.

Figure 5.1: Image developed for print.

As can be seen in Figure 5.1, the final print combined three main areas of pattern which varied in scale and thickness of line. These were included to contrast structural elements in addition to visual film effects.

C2.3.2b Printing

In contrast to C2.2 an acetate sheet was laid under the fabrics to encourage shiny film effects to develop and maximum solution to be absorbed onto the fabric. The fabric samples were taped around all edges to secure to the surface of the acetate sheet. A squeegee was passed 4 times over each sample in contrast to 10 times for 2.2 to compare results. A fan was used to blow hot air over the surface of the samples until dry. When dry, the samples were removed from the printing surface and neutralised in 0.5% sodium carbonate solution for 15-20minutes. A sample of NCO was dyed red to highlight the print definition.

Table 5.6a: Comparisons of 2% and 4% chitosan solution printed on NCO.

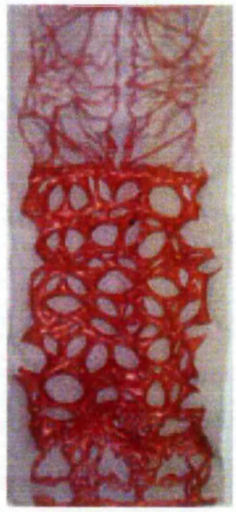
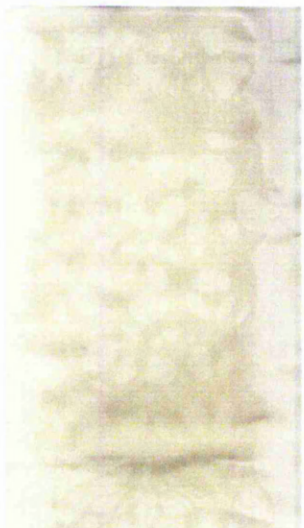
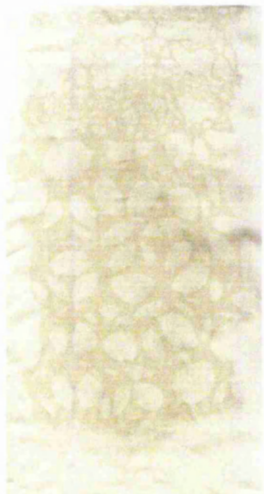
2% chitosan	4 % chitosan	4% chitosan and dyed
 Sample 1 Too liquid to achieve accurate print.	 Sample 2 More defined lines.	 Sample 3 Red dye highlighted the contrasting lines.

Table 5.6b: Comparisons of 2% and 4% chitosan solution printed on silk.

2% chitosan	4% chitosan
 Sample 1 No shiny film effects but fabric is more transparent where printed.	 Sample 2 No shiny film effects. More accurate print definition than 2% solution.

C2.3.3 Results

The 2% and 4% chitosan solutions were different viscosities which influenced both the sharpness of the printed image and the feel of the fabric. The 4% solution was the most viscous, resulting in poor line definition in the finer details at either end of the image, compared to more defined lines in the middle section. The variation in line thickness produced contrasting sculptural effects across the printed image; in particular the broader structure in the middle section of the NCO enclosed pockets of unprinted fabric developing slight puckering effects. Both fabrics appeared to have less drape, with an additional crunchy, papery sound when the fabrics were handled. The 2% solution was possibly too liquid as although it passed through the screen readily, the final prints were less accurate than the 4% solution. Only the NCO resulted in shiny film effects whereas the silk became more transparent where the solution was applied. The dyed NCO highlighted the varying print definition allowing the composition of the image to be more easily assessed.

C2.3.4 Conclusion

The aims of C2.3 were to re-produce the aesthetic effects identified in C2.1 by printing chitosan film onto fabrics. The resulting method identified the key components which influenced the technical and aesthetic outcomes. These included image development, in which the thickness of line and negative spaces were compared; the viscosity of chitosan solution, which influenced the print definition and resulting structural effects; the underlying printing surface which influenced the smooth finish on the film surface and the textile substrate whose characteristics determined the response to the process. Parameters for further investigations would be based on the resulting effects of the 4% solution printed on NCO, with a print containing similar broad lines of the middle section of image. Potential questions resulting from this experiment include the range of dye effects that could be achieved in combination with layering prints in addition to exploring the implications of re-producing the technique on a larger scale.

C3 Chitosan with resin

Throughout the research, the rich translucent colours of the chitosan films were consistent outcomes. The final section on colour presents a variety of samples which illustrate coloured chitosan film in two main contexts. In the first group, chitosan film and dye powder was applied to the uneven surface of transparent resin forms. In the second group, coloured chitosan film composites produced in earlier experiments were embedded in resin forms.

C3.1 Chitosan with embedding resin

C3.1.1 Aim: To explore the resulting colour effects of chitosan samples with embedding resin.

C3.1.2 Method.

Embedding resin was mixed up and poured into appropriate plastic trays. For the embedded samples, pre-processed films were chosen and arranged on the resin before the final layer of resin was applied. The surface coating technique involved directly pouring chitosan film onto the dry resin forms before dye powder was applied and mixed according to the desired colour and texture effects. Surface coating was applied in Figure 5.2 and Figure 5.6 contrasting film effects on a flat resin surface (Figure 5.6) against an uneven resin surface (Figure 5.2). Blue and yellow dye powder was lightly sprinkled onto both coated surfaces. Using a stiff paintbrush, the dye powders were mixed with the chitosan solution in the circular shapes in 5.2. In 5.6 the colours were initially mixed on separate sides before applying a fine spray of blue dye powder across the surface.

C3.1.3 Results

The following groups of images present the colour effects of chitosan film in combination with dyes as coloured surface coatings in addition to samples embedded in resin forms. The resulting surface coating in the circular areas of Figure 5.2 did not peel away from the surface or separate. The uneven application of dye powder resulted in various depths of shade covering a range of colours between blue and yellow. The surface coating in Figure 5.6 could be described as a speckled blue finish on a two-tone base colour. Surface tensions are evident as the film dried resulting in small creases over the surface. The various films and composite forms embedded in the resin were held in suspension with no visible changes to original features.

C3.1.4 Conclusion

In Figures 5.3 to 5.8 embedded samples highlight shape, colour and texture elements. These characteristics are not evident when the solution is applied to the textile substrates as the film forms around the structure of the yarns, producing smooth, even films. Layering the samples in resin provided a solution to protect the fragile films allowing the decorative colours and texture effects to be illuminated through the transparent material. The application of the surface coating illustrated layering effects contributing texture from both the underlying substrate and the surface tensions of the dry film.

C4 CAD developments and design applications

Design developments from the *palette of effects* are illustrated in Figures 5.9 to 5.11. In particular the illustrations provide an appreciation of how these samples would contribute to large-scale panels in interior applications, allowing light to illuminate the range of effects in each piece.

Chitosan solution and dye combination applied to resin forms.

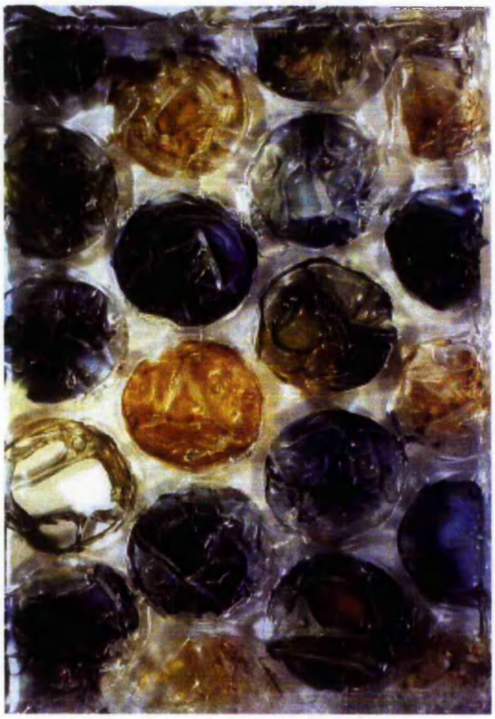


Figure 5.2b: Detail 1.

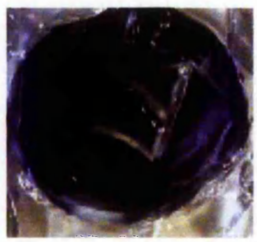


Figure 5.2a: Chitosan and dye surface coating.

Figure 5.2c: Detail 2.

Chitosan film combinations embedded in resin.

Figure 5.3: Various Chitosan films in embedding resin.

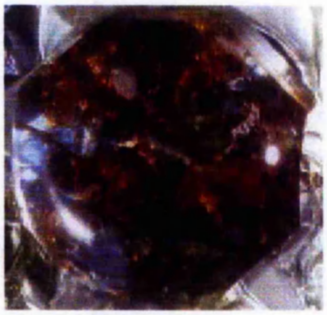


Figure 5.4: Heat processed chitosan in resin.

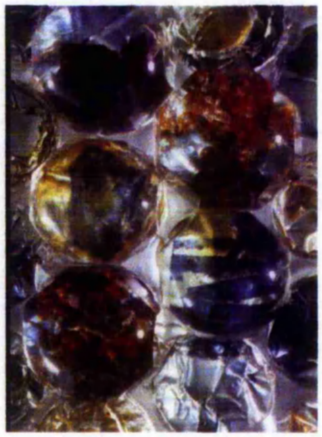


Figure 5.5: Layered effects of coloured chitosan films and surface coatings.

Embedded chitosan samples with dyed chitosan surface coating

Figure 5.6a: Chitosan and resin form with surface coating.

Figure 5.6b: Detail 1.

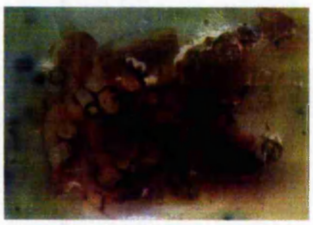


Figure 5.6c: Detail 2.

Figure 5.6d: Photo of chitosan and resin form.

Large-scale chitosan, fabric and composite form

Figure 5.7: Large-scale chitosan and resin form.

Figure 5.8: Large-scale chitosan and resin form with fabric overlay.

CAD developments of samples

Figure 5.6d

Figure 5.9: CAD development of 5.6d.

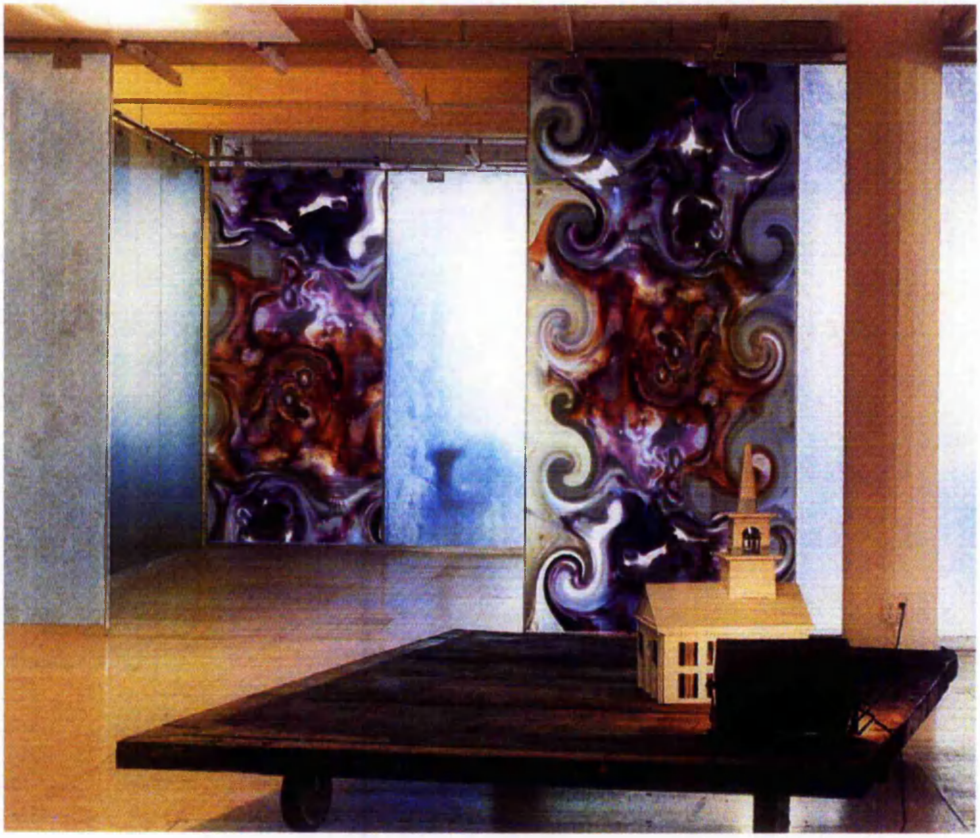


Figure 5.10: Interior panels (using Figure 5.9).
(Asensio, 2002:127)

Figure 5.11: Interior panels combining Figure 5.8
with CAD development of 5.6d. (Asensio, 2002:82)

C5 Chapter conclusion

The colour effects chapter was divided into three main sub-headings including batik effects, film on fabric and colour effects with resin. The experiments which explored the colour possibilities of chitosan were originally based on the knowledge that chitosan had an attraction to dye however this was explored considering the implication of application methods and combinations of other substrates. The least satisfactory group in terms of new aesthetic effects was the Batik group. Chitosan was simply used as a tool to develop colour effects on cotton fabrics. In contrast to other experiments the colours were dull and the samples did not capitalise on the film forming characteristics of the chitosan for their aesthetic potential. Instead films were applied to fabrics to absorb dye thus protecting underlying fabrics.

Richer colour effects were developed in the Film on fabrics section. Two substrates were initially explored, cotton and NCO, however the chitosan did not produce shiny films on the cotton. Technical aspects of application were considered, from brushing on solution to printing, identifying the main elements which determined the resulting aesthetic effects. NCO was highlighted as a substrate which successfully combined the effects. In the final section chitosan samples were embedded in resin forms combining the aesthetic elements of the chitosan coloured films with a compatible material that protected the structures and textured forms. Chitosan films applied as surface coating contributed final colour and texture to the embedded samples. The resulting samples provided starting points for CAD developments in addition to visualisations within interior spaces.

Chapter 6: Surface texture effects of chitosan

This section includes experiments which illustrates a range of surface texture effects of chitosan solution applied to smooth even surfaces. The question originated from earlier work in which the production of continuous films had been difficult to achieve and often resulted in broken surfaces. These irregular film formations were reconsidered as potential design effects under the theme of surface texture. The samples were generated on inflexible, smooth, transparent substrates specifically chosen to both resist the contraction of chitosan film and to illuminate the resulting effects through transparent substrates. Granular substances were introduced to encourage chemical reactions to create crystal-like effects. These were combined with dye powder to add to the palette of effects. Table 6.1 and Mind map 6 identify the experiments in this section.

Table 6.1: Sub-groups in surface texture effects experiments.

	Sub-heading	Sample descriptions
S1	Surface texture effects of chitosan on smooth, inflexible substrates	S1.1 Textured, dyed film S1.2 Chitosan solution with granular substances S1.3 Chitosan solution with granular substances and dye powder

S1 Surface texture effects of chitosan on smooth inflexible surfaces

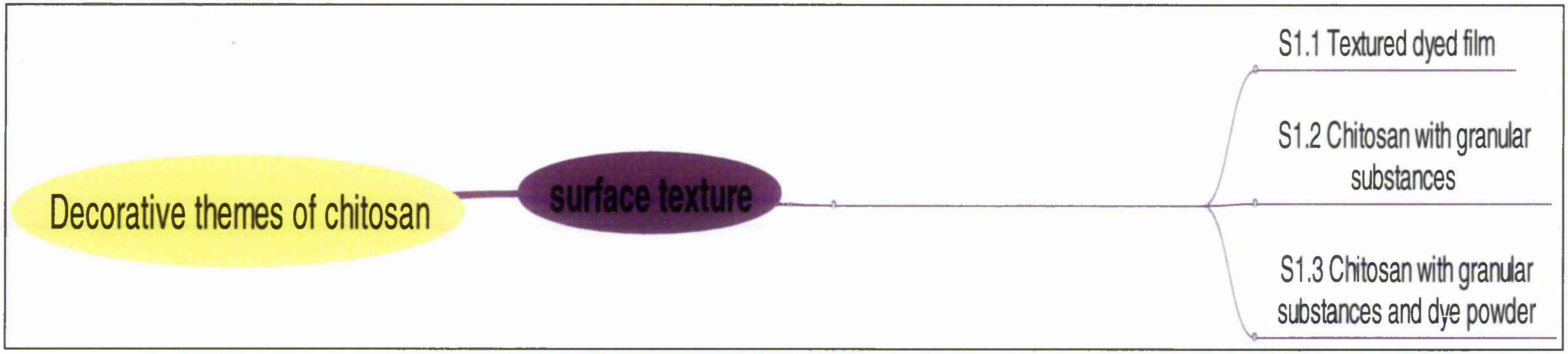
S1.1 Textured, dyed film

S1.1.1 Aim: To explore texture effects of dyed chitosan film on smooth, inflexible, transparent surfaces.

S1.1.2 Method

4% chitosan solution was applied to the surface of a 25mm thick acrylic block and two cleaned glass plates. Glass sample slides were used as tools to distort the solution by lifting off the surface to create texture effects in the chitosan solution. The samples were put in the oven at 50° C until dry. Once dry, the samples were neutralised in 0.5% sodium carbonate solution for 15 – 20 minutes then rinsed and put back in the oven to dry. The samples were dyed using 20mls of 0.5% Acid Blue 158 dye and left for 20 minutes in the dye bath.

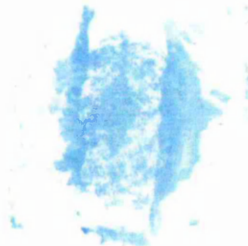
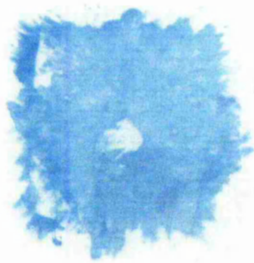
Mind map 6: Surface texture effects of chitosan.



S1.1.3 Results

The images in Table 6.2 below illustrate the surface texture effects generated by the experiment. The texture effects were illuminated once dyed as light could easily pass through the transparent substrates. The thin layer of chitosan produced a subtle textured coating in a light blue colour.

Table 6.2: Dyed chitosan film on transparent surfaces.

<table>
<tr><th>Acrylic block</th><th>Glass plates</th></tr>
<tr><td rowspan="2">
Sample 1</td><td>
Sample 2</td></tr>
<tr><td>
Sample 3</td></tr>
</table>

S1.1.4 Conclusion

The difficulty with chitosan solution in many previous experiments was the production of continuous films; characteristically the solution often separated due to surface tensions leaving holes and irregular shapes. Rather than forcing the production of continuous films, experiment S1.1 focused on the development of irregular surface textures on inflexible, transparent substrates. As a result of these samples further enquiries might explore the possibilities of building up effects of colour and texture in layers. For example applying chitosan, neutralising, dyeing and reapplying different colours; placing blocks next to one another to build up layered colour effects; dyeing opposite faces of the surface different colours.

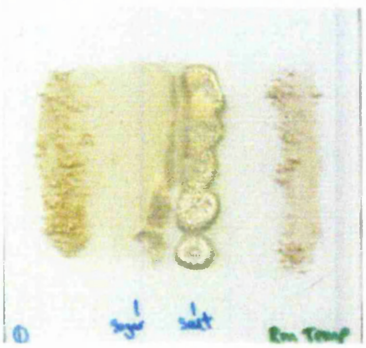
S1.2 Chitosan solution with granular substances

S1.2.1 Aim: To explore the effects of chitosan solution with granular substances to make crystal-like effects. The samples produced in experiment S1.1 provided textural effects based on uneven chitosan film; S1.2 focused on what additional surface texture effects could be produced with chitosan film and various granular substances.

S1.2.2 Method

A small amount of 4% chitosan solution was poured onto two glass plates and rolled with a glass rod to distribute evenly. Before the chitosan solution was dry, granular materials including chitosan flakes, salt crystals and sugar were sprinkled onto each plate in parallel lines to the edge of the plate. The samples were left to dry overnight. Sample 1 was left at room temperature; sample 2 was put in the drying cabinet. The resulting effects are compared in Tables 6.3 and detailed in Table 6.4.

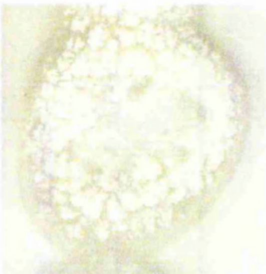
Table 6.3: Chitosan solution with granular substances.

Sample 1: Dried at room temperature	**Sample 2: Dried in drying cabinet**
 Sample 1	 Sample 2

S1.2.3 Results

Both plates contained surface texture effects. Each type of granular substance developed visual effects, for example the circular shapes from the salt crystals compared to the smoother surface of the sugar. The oven-dried sample took on an amber colour compared to the sample dried at room temperature. The heated sample generated more intense chemical reactions resulting in more defined visual effects as shown by comparing salt crystals and chitosan flakes in sample 1 and 2.

Table 6.4: Details of chitosan solution with granular substances.

	Sample 1 Room temperature	Sample 2 Drying cabinet
Chitosan flakes	 Less dissolved than heated sample. Flakes visible on surface anchored in the film	 Smoother film but not all chitosan flakes dissolved
Salt crystals	 Overall less definite circles than heated sample. Salt deposition more spread out than heated sample.	 Circular shapes formed in round salt crystals. Film developed deep cracks in centre of circles.
Sugar	 Less defined crystal effect as heated sample. A slight surface texture	 Surface texture effect resulting in lines from crystal formations. Opaque effect at furthest point of sugar and chitosan solution.

S1.2.4 Conclusion

A variety of textural effects were generated by mixing chitosan solution with various granular substances with the most outstanding surface texture produced by the chitosan and salt on both samples. The samples generated questions as to how these characteristics could be further manipulated. What outcomes would result from varying the viscosity of the chitosan solutions within one piece? 4% chitosan solution could be combined with 2% solutions in one sample to vary film thickness to produce novel texture and colour effects.

S1.3 Chitosan with granular substances and dye powder

S1.3.1 Aim: To explore chitosan solution and granular materials with dye powder.

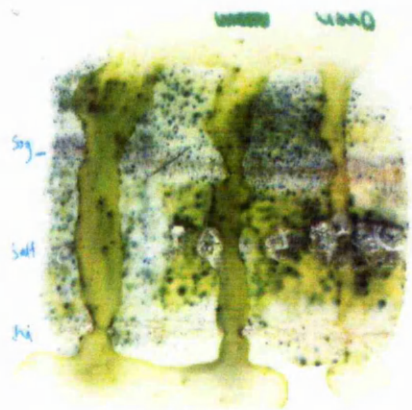
S1.3.2 Method

The glass plates were prepared using a similar method as described in experiment S1.2. After chitosan solution was rolled over the surface, Acid Blue 158 and Acid Yellow 99 dye powder was applied using a stiff brush in a spraying action creating uneven colour patterns on the surface. The solution was then separated using alternative brush strokes up and down the plates before the powdered materials were sprinkled over. Sample 3 was left to dry at room temperature while sample 4 was put in the drying cabinet overnight.

S1.3.3 Results

Various surface texture effects were generated as a result of the chitosan solution mixed with salt crystals, sugar, milled chitosan and dye powder. The dye powder diffused less on the oven-dried sample as explained by the theory that the samples which dried at room temperature had more time for the particles to dissolve into the chitosan solution. In the oven-dried sample the materials were not as dissolved as a result of evaporation of the chitosan solution in the hotter temperature.

Table 6.5: Chitosan with granular substances and dye powder.

Sample 3: Room temperature	Sample 4: Drying cabinet
	

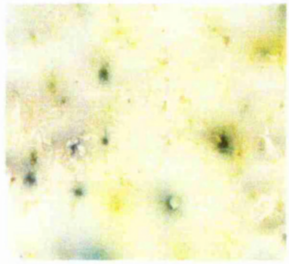
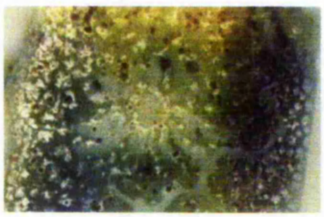
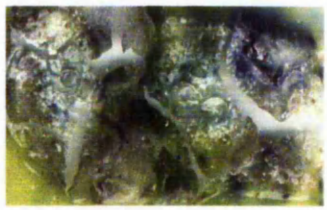
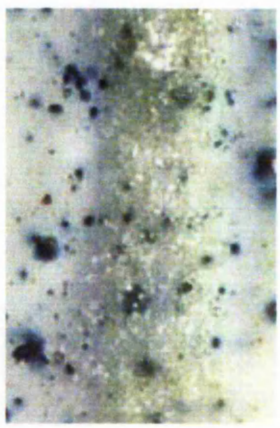
S1.3.4 Conclusion

The textural effects resulting from the chemical reactions between chitosan solution and granular substances were highlighted by the addition of dye powder, which gave depth and definition to the resulting surfaces. The images in Table 6.6 illustrate these effects in more detail. These effects could be protected by re-coating using a quick drying organic solvent to prevent disturbance (cellulose acetate in acetone). During the development of these samples a deeper chemical knowledge would have been beneficial in order to understand the chemical reactions between chitosan solution and the granular materials.

S2 Chapter conclusion

The surface texture chapter was divided into three main sub-headings under the title Surface texture effects of chitosan on smooth, inflexible substrates. Although surface texture effects were a common feature of many other samples, chapter 6 included the least number of experiments. The interpretation of results was limiting as a non-scientist carrying out scientific investigations between materials. As with earlier experiments the results were described using non-scientific vocabulary focusing on elements such as resulting colour, textures and patterns. The aim was not to reach an understanding at this point but to ask the question *what would happen if...?* This section in particular highlighted the limits of my scientific knowledge, restricted by the inability to suggest the next phase of development based on a background of textile design rather than science. The compositions of the films on the glass plates were more fragile than in earlier experiments with sections easily flaking and falling off. However a range of unusual textures and colours were generated inspiring the question if these concepts could be translated as surface effects on fabrics.

Table 6.6: Details of chitosan with granular substances and dye powder.

	Sample 3	**Sample 4**
Milled chitosan flakes		
Salt crystals		
Sugar		

S3 Chitosan conclusion

Chapter 3 included the results of practice-based research which explored the decorative design potential of chitosan. The initial focus was to develop suitable formulae to generate chitosan films which were then explored in combinations with other materials, substrates, processes and equipment. These samples were later categorised within decorative themes as a means to generalise and analyse the outcomes of such a diverse range of materials and processes. The titles of the decorative themes were chosen to reflect the main effects chitosan had on a particular combination of materials. These were classified as;

- Physical effects
- Colour effects
- Surface texture effects

The main themes were then divided into sub-groups (Table 6.7), with physical effects contributing the largest number of explorations and surface texture the smallest. Each stage of processing developed a better understanding of the limitations of effects and processes with insights for further explorations.

Table 6.7: Decorative themes divided into sub-groups.

Physical effects	**Colour effects**	**Surface texture effects**
Film forming Temperature Binding Sculptural	Batik Film on fabric Resin	Dyed, textured film Film with granular substances

The design aesthetics were generated by interpreting the characteristics of the resulting samples which were categorised into the main decorative themes. The technical understanding of the materials and processes provided the knowledge to allow further exploration of selected concepts combining aesthetic and technical parameters. The aim of the research was to illustrate the range of decorative effects however the range of effects and samples became difficult to generalise and evaluate.

What exactly dose the chitosan case study deliver? It highlights the value of practical explorations of materials to discover hidden creative characteristics of materials. The aesthetic characteristics were continually modified according to the combination of materials and processing parameters. Rather than looking for a defined set of values it would have been preferable to present the outcomes as potential options for manipulation according to specific parameters. Where experiments were carried out on several substrates resulting in unique results for each, the results were difficult to compare and inform the logical next step of development. In general the limitations of the research and the resulting samples included:

- Scale of samples due to size of ovens
- Processing equipment
- Difficulty in producing consistent, uniform films
- Performance data not included
- No frame of reference to other materials which may produce similar effects

In addition to the case study producing novel samples, the work is also an example of knowledge transfer between science and design and the context within which this transfer took place. Although the majority of the knowledge transfer was from science to design, transfer from design to science also occurred, in particular the vacuum form experiment in which thermoplastic properties of chitosan film were produced. The work also highlights the opportunity for further transfer beyond the research context.

The research was driven by the opportunity to question the materials and the process parameters within the knowledge transfer infrastructure. Working at the design / technology interface highlighted the opportunities for development of materials with the support of specific scientific knowledge. This scientific knowledge provided the formulae for initial exploration of materials from which creative elements were discovered covering a range of outputs. This context reflects the need for an infrastructure to enable exploration in order to discover the latent design potential of those materials and processes currently beyond the textile design discipline. This implies a fusion of skills and knowledge combining material characteristics and processing parameters informing the potential aesthetic vocabulary.

Further recommendations:

- Further explore methods of application for example spraying on chitosan
- Understand the effects heat has on chitosan and identify colour changes according to temperature
- Explore stiffening and contracting effect of chitosan in combination with the properties of the substrate contrasting and combining effects
- Explore film forming effects as design opportunities
  - Chitosan film to reduce frayed edges
  - Could a pattern be cut to generate lace-like effects similar to laser cutting?
  - Producing straight edges cutting through chitosan film on fabrics
- Colouration potential contrasting effects in particular layering effects building up colour layers on transparent substrates

Chitosan offers an extensive range of decorative effects dependant on the combination of processing parameters and material combinations.

Chapter 7: Evaluation of the practice in relation to Knowledge Transfer

The aim of Chapter 7 is to respond to aim 4:

To evaluate the practice in relation to knowledge transfer.

The chapter evaluates how the laboratory-based production of small scale, hand-produced decorative materials, contributes to our understanding of knowledge transfer between science and textile design. Following presentations to external groups, feedback suggests that the knowledge transfer also extended beyond the primary textile design context. The chapter presents an in-depth evaluation of the research providing evidence to respond to the following key questions;

1. What can this practice contribute to the knowledge transfer debate?
2. What is the knowledge transfer framework developed from the practice?
3. What are the examples of knowledge transfer resulting from the research?
4. What are the benefits of knowledge transfer specifically with reference to textile design?
5. What are the barriers identified in this research that prevent knowledge transfer?
6. What are the constraints of knowledge transfer in the context of this research?
7. How might outcomes and conclusions be influenced by the limitations within the research?

The chapter builds on the definitions of the term knowledge transfer as discussed in Chapter 1 which outlines the development of the research model in comparison to theoretic models and examples of knowledge transfer resulting from existing textile design practice. This helps to evaluate the research from a wider perspective and begin to identify its unique contribution to the knowledge transfer debate. Chapter 7 identifies the main components of the knowledge transfer framework giving specific examples of the methods developed in the practice. In particular this research emphasises the cross-disciplinary knowledge transfer between textile design and science which extended beyond the research context to selected external groups. This allows the practice to be considered as a valuable tool in knowledge transfer in a wider context than textile design. The production of novel material samples and processing techniques alone contribute unique outcomes however the practice provides a knowledge transfer framework in which unexplored combinations of materials were explored for decorative characteristics.

7.1 What does this practice contribute to the knowledge transfer debate?

Knowledge transfer was identified as product of the practice (Chapters 2 to 6) as a result of overcoming knowledge barriers at the science and textile design interface. The knowledge barriers were highlighted by the need for a scientific expert, firstly to access scientific data through face-to-face discussion, then to help initiate practice using practical demonstrations and help interpret initial results. In order to access and interpret data one must be able to speak the language or have the information translated using a relevant vocabulary. For example chitosan was known for its performance characteristics but could not be assessed for its decorative potential as the scientific data did not communicate decorative characteristics. In order to enable the material to be interpreted and questioned in a design context, samples were generated to develop a vocabulary to illustrate decorative characteristics such as texture, colour and sculptural properties. Throughout the practice the transfer of knowledge evolved over several stages as outlined in Table 7.1, illustrating how the scientific expert initiated the process allowing the researcher to gradually engage with the experiments through practice. The resulting knowledge transfer framework developed in the research is further discussed in 7.2. Overall, the process began with a multidisciplinary team of experts from science and textile design in which an exchange of ideas and discussions identified initial potential. Practical experiments were carried out by the researcher, resulting in technical reports with details of materials and process alongside evaluation of the samples according to decorative potential. The final stage of knowledge transfer (7.4.3 to 7.4.7) involved presenting the resulting body of work to selected external audiences. Using the focus group format, feedback informed the evaluation of the practice as a model to transfer knowledge between science, textile design and beyond to other design disciplines.

7.2 What is the knowledge transfer framework developed from the practice?

Components of the knowledge transfer framework are identified and discussed with reference to the following categories which provided the basic infrastructure. These included;

- Facilities
- Specialist background knowledge
- Processing skills

7.2.1 Facilities

The majority of the practical research involved experiments which were carried out in the laboratory or workshops which were suitably equipped for small scale explorations. This facility allowed the researcher to investigate the processes under the guidance of the scientific expert until initial knowledge of materials and processes was established by the researcher. The unusual location of the practice in a laboratory environment also stimulated the researcher to ask new questions about the materials and potential processing methods. Limitations such as oven size and processing equipment influenced the scale of the samples produced.

7.2.2 Specialist background knowledge

A team of diverse specialists with combined background knowledge was required to transfer the scientific data into a vocabulary and language that communicates decorative characteristics. This interface was explored through conversations and discussions leading to practice as a catalyst in the knowledge transfer process, linking technical and scientific data to potential decorative characteristics. Specific expertise included:

- Understanding of textile materials and processes
- Appreciation of scientific language
- Scientific knowledge
- Knowledge of processing techniques
- Textile design knowledge and skills

7.2.3 Processing skills

The materials and processes drove the inspiration for creativity and questions evolved around concepts of potentiality. Hands-on engagement with the materials and processes was crucial to enable full exploration and understanding of processing variables and the ultimate goal of translating the scientific knowledge as decorative potential. In order to respond to concepts of potentiality it was necessary that the researcher developed a basic understanding of the materials and techniques in order to devise potential processing methods. In addition to these skills suitable methods to record and catalogue outcomes were necessary to categorise and evaluate samples, communicating new knowledge in a non-scientific format. The range of processing skills developed through the practice included;

- Recording technical descriptions of processes
- Recording results as written descriptions of samples alongside images
- Developing evaluation criterion based on varying combinations of technical and aesthetic considerations particular to the experiments
- Characterising the resulting samples within appropriate design themes

7.3 What are the examples of knowledge transfer resulting from the research?

The most tangible knowledge transfer examples fell into the following groups; science to design, design to science; methodologies used for explorations and transfer from the research context to external groups. Each of these are explained illustrating specific knowledge transfer events.

7.3.1 Science to design and design to science knowledge transfer

As outlined in chapters 2 to 6, case study 1 and 2 produced novel outcomes being transferred from science to design. Selected samples in case study 1 were exhibited at Surtex (2000), the international textile trade fair in New York and selected samples in case study 2 were presented to external focus groups for feedback (as outlined in 7.4.2). Most of the knowledge transfer occurred from science to design originating as scientific formulae transferred into a vocabulary to assess decorative potential. However both cases resulted in knowledge transferring from design to science illustrating previously unexplored decorative characteristics. The following points reflect the value of the practice as a method to communicate scientific data and encourage the use of non-scientific vocabulary to reinterpret scientific concepts to new audiences

Table 7.1: Comparison of the knowledge transfer process within case studies.

Stage	Case study 1 Sodium hydroxide on substrates	Case study 2 Chitosan
1	Exploration potential of the technique suggested by scientific expert	Exploration potential of the technique suggested by scientific expert
2	Formulae for initial experiments *invented* by scientific expert	*Existing* scientific methods formed the basis of initial film-making experiments
3	Practical research carried out in laboratory by researcher	Practical research carried out in laboratory by researcher
4	Initial samples were produced Resulting *design* characteristics were identified Technical details recorded	Initial samples were produced by researcher Resulting characteristics were identified Technical details recorded
5	Initial outcomes analysed by team Selection of fabrics *reduced* to focus on the most responsive substrate	Initial outcomes analysed by team Changes were made to processing parameters and the range of materials further *expanded*
6	Processing techniques focused on *one fabric* Samples produced by researcher	The *wide range of processes and combinations of materials* continued to be explored by researcher
7	*Design effects* were identified by researcher	The resulting characteristics were categorised according to *decorative themes* developed by researcher
8	Results were written as descriptions of process, descriptions of samples and images to communicate design potential Technical reports produced by researcher	

In case study 1 chemical reactions between sodium hydroxide and selected substrates were explored for design potential. The diverse dye outcomes, transparency and textural effects were identified as the key aesthetic components providing design potential. In addition process developments produced new scientific and technical data. In case study 2, existing scientific methods formed the basis of initial film-making experiments. Scientific knowledge introduced chitosan as having film making properties with an attraction to certain dyes. These elements were explored and translated through sample development, analysing the resulting characteristics in terms of aesthetics such as texture, colour, shape and form. These outcomes did not knowingly advance the science but allowed the data to be seen in a new context using non-scientific vocabulary In contrast the vacuum form experiment (P2.5) resulted in thermosetting chitosan film which was not an expected outcome. The knowledge transfer from design back to science was a surprising development and a possible result of naïve questioning whereby a lack of expectation allowed all possibilities to be considered. This supported the value of exploring concepts from new perspectives to gain unexpected insights. The transfer process completed a full circle contributing to both disciplines, less to science and more to design. As illustrated in Table 7.1 the exchange of knowledge from science to design affected the role of the scientific expert from that of initiator to advisor as the knowledge had a new context. This illustrates the interplay between researchers (need for exchange between people as cited in AHRC model) as the knowledge moves from science domain into design through conversations, demonstrations and practical experimentation.

7.3.2 Methodology of practice as knowledge transfer

Table 7.1 demonstrates the evaluation of the practice in relation to the knowledge transfer process. Comparison of the sample development process highlights the differences between the methods used in case study 1 and case study 2. Case study 1 centred on one specific chemical reaction restricting the substrates to a defined range. From stage 5 in Table 7.1, case study 1 focused on one fabric type whereas the research parameters in case study 2 continued to include a more diverse range including several processes and substrates. This is illustrated in mind maps 1 and 2. Mind map 1 (case study 1), produced a more structured format, illustrated as three distinct directions of enquiry. These represented the three fabric types initially explored and the processing parameters which varied around the exploration of a specific chemical reaction on each. By comparison, case study 2 initially presented mind map 2 which lacked a defined structure as many substrates and processing parameters were included. Mind map 3 was then developed with a framework which categorised the data according to decorative themes rather than type of substrates. This allowed the data to be interpreted according to potential design characteristics and links to be made between samples. The contrasting methodologies developed in these case studies highlight the value of practice in discovering individual material processing techniques for specific contexts. The methods chosen to explore the materials equally offer new outcomes as new processing techniques developed within the knowledge transfer process.

7.3.3 Knowledge transfer to external groups

In order to critically evaluate the methods used to transfer knowledge samples from case study 2 were presented to three selected external groups to gain a variety of inputs and perspectives. Case study 2 was chosen as it provided a more diverse body of work than case study 1. The material had no former links with decorative applications and previous knowledge was of scientific nature. The inclusion of external feedback was important to encourage a dialogue to inform and challenge the limitations of the research context in addition to illustrating the benefits beyond the textile design discipline. This evidence of knowledge transfer from the research to external sources showed the success of the methods employed whereas feedback highlighted areas for improvement. The data was interpreted by non-scientific disciplines resulting in both positive and negative feedback to the research. The important factor was that the three groups could relate and respond to the data in the format presented confirming knowledge transfer had occurred. The three groups were selected to evaluate the research from different perspectives and included;

1) Group 1: Interior architect students
2) Group 2: Focus group with selected textile industry representatives
3) Group 3: Representatives from the AHRC and Nottingham KTP

Interior architect students were chosen in order to explore if the samples illustrated decorative potential outside the discipline of textile design and if new questions would be raised about the materials produced or the work carried out. The focus group with textile industry representatives was selected to provide a more commercial industry-focused perspective. Building on the response from the interior architect students in which creative potential was highlighted; feedback and comments from the focus group were more specific to market potential and commercial products. Finally, feedback from the representative from the AHRC and the representative from Nottingham KTP considered the work in the context of knowledge transfer rather than considering the work as an example of design practice or commercial product.

7.3.4 Feedback from Interior Architect students

Nottingham Trent University, 10th February, 2003

The aims of the presentation with the interior architect students were;

- To introduce the idea that exploring processes and materials offer new perspectives to design outcomes.
- To give the students the opportunity to develop concepts based on the research samples
- Gain feedback from the students, future recommendations, complete questionnaires with their perceptions of the materials
- To demonstrate the evaluation of the practice in relation to knowledge transfer in an unfamiliar design discipline

Interior architects combine a wide range of interior products and substrates with a rich vocabulary of materials and processes, providing useful comparisons for the research. This presentation offered a chance to explore if new issues and questions would arise in addition to finding out if they thought the work had creative potential. Selections of samples from case study 2 were presented to the group not only to generate external feedback to the research outcomes but also to provide the students with ideas for concept development within the context of a design brief for an interior space. Following the presentation of work the students completed questionnaires.

7.3.4a Questionnaire results (see Appendix 2)

The questionnaires were specifically designed to allow the respondents to comment freely although the subjective responses were difficult to categorise and achieve consistent analysis. 26 questionnaires were completed in which the students were asked six questions. The questions were developed to assess if any knowledge transfer had occurred following the presentation and how the practice of material exploration and development could be improved as a result of the feedback. The questions included:

1. Have you ever come across chitosan before this project?
2. Do you think any of the samples have potential application in interiors?
3. What were your first impressions of the materials?
4. To what extent is sustainability a key consideration in your design proposals?
5. Do you explore the characteristics of materials and processes for their creative input in design development?
6. Do you have any further comments?

The introduction of chitosan as a material was novel to all students especially used in design. This supported the originality of the research to the wider design disciplines not just within textile design. All of the students suggested at least one potential application of the samples in interiors, ranging from decorative applications of current samples, to more structural applications following additional research. The students' first impressions of the work generated interest based on visual, textural and sculptural characteristics describing the samples as inspiring, creative and innovative. The need for further research was confirmed in particular testing behavioural properties in order for suitable applications to be considered. When students were asked if they currently explored characteristics of materials and processes for their creative input 53% said sometimes and only 4% said always. An interesting response was that the students were inspired to apply similar modes of investigation to explore the design potential of other materials and processes rather than accepting materials in their given form. This was later supported by the programme leader and confirmed by the final work submitted, demonstrating more innovative investigation of process and materials.

The students had no previous knowledge of chitosan before this presentation regarding either its performance characteristics or aesthetics. The samples successfully communicated potential design application as shown by the innovative suggestions for interior applications based on concepts inspired by the aesthetic effects. These included lighting, hangings, blinds, setting materials in panels as room dividers offering new qualities to the interior spaces. These reflected similar concepts often considered during samples developments. The students also suggested that additional useful information would include data on behavioural properties in order for specific applications to be considered.

Suggestions also included larger scale samples to consider effects of scale and any restrictions on production. The interest in material explorations as concept development was taken up by some students rather than accepting materials in their given form. The students evaluated the samples from the perspective of potential use in interiors although limited data on performance and production parameters resulted in a more conceptual response rather than specific applications.

7.3.5 Focus group

Nottingham Trent University, 8th June 2004

In order to evaluate the research from textile industry perspective, a group of people were chosen to represent diverse links with textiles, so that their attitudes and opinions could be considered in response to the research as a model for knowledge transfer. The overall aim was to generate feedback and comments on the research, the methodology and research journey from their individual perspectives. Those present included the managing director of a company specializing in textile chemicals; managing director of a luxury garment design company; a biochemist expert and a lecturer in textile design and critical studies. The focus group format was chosen as an exploratory session to provide insights into the way people think and behave in response to the samples and the processes.

> The value of focus groups is their potential to discover information that might otherwise have remained hidden with other, more formal research methods. (Langford and McDonagh, 2003:15)

Rather than send out questionnaires and generate individual response the idea was to stimulate discussion and debate amongst the group and to generate new questions. The event began with a 30 minute presentation (Appendix 3) giving an overview of the research to date followed by a guided discussion with the opportunity to have a closer look at the samples (Appendix 4). The discussion was initiated with a question to provoke thoughts around the research topic. The question 'Is design potential limited by a lack of understanding of materials and processes?' opened the discussion during which semi-structured questions were put to the group. The aim was to generate a better understanding of the issues and implications of the research from a commercial perspective.

7.3.5a Key issues identified

The key issues raised can be summarized as:

- The importance of understanding materials in order to design with them.
- The methodology was considered suitable to explore the creative potential of the materials within the research context (without commercial restrictions such as durability, reproducibility and cost)
- Not having had previous understanding of the materials and processes was seen as a positive benefit to the outcomes.
- Only the creative potential of the materials were explored and existing performance characteristics such as anti-microbial and antibacterial were not considered. The work was seen as purely aesthetic (as explorations focused on colour, texture and form which guide the visual aspect of design) without exploiting the benefits or characteristics of the chitosan. Emphasis was put on the additional benefit of building on its performance characteristics with aesthetic interest.
- The industry representatives were looking for new knowledge which could be applied to end products (which was not the goal of the research)
- In a market context it would be necessary to identify what this product gives that other products cannot give, Unique Selling Point (USP)

Chitosan was previously only known by the textile chemical specialist for its function properties, confirming the originality of the chitosan samples exploring its aesthetic properties. It was concluded by the external panel that the exploration of the aesthetic characteristics of chitosan would have been more appealing if the existing unique performance characteristics were combined with the design effects. It was recommended that in any future work, emphasis should be put on the concept of adding value to a product by creating multifunctional textiles combining functionality, performance and aesthetics rather than divorcing the elements and considering them separately. The discussion emphasised the need to combine these elements if applying the same question to other materials with known performance characteristics. If the performance characteristics of the material are taken away it is just a medium that can be used to create different effects. It will then be judged in comparison to many other existing products that produce the same effects, perhaps cheaper or better.

In addition to communicating novel aesthetic characteristics of chitosan, knowledge transfer also related to a processing technique developed in the research. Screen printing chitosan was explored in the research as a potential method to process film effects on fabrics. Commercially, techniques currently employed to apply chitosan to substrates included either encapsulation or cross-linking to cellulose fibres. Printing chitosan solution had not been considered however the research inspired a new technique to be explored with direct commercial application.

Throughout the discussion it was also suggested that the starting point for future material explorations would be to investigate the properties of the materials and the process before exploring the potential aesthetics. Surely the aim would be to combine the two, allowing interest in aesthetic effects equally inspire investigations. In order to carry this out however, it would be necessary to have the appropriate facilities to process the materials.

Additional considerations for future work would be to develop a basic structure to outline the range of performance characteristics that are required for different end-use applications. Although this would help locate the materials within a wide spectrum of end-uses aesthetic characteristics could not be separate if both aesthetic and technical criteria are to be evaluated.

In summary, the explorations of chitosan were put before a panel from the textile industry to see how the model would fit in practice. The overall feedback from the focus group offered useful suggestions for further development for future case studies although their requirements for commercial applications were too defined for the samples to contribute in their current form.

7.3.6 Discussion on knowledge transfer

Yvonne Hawkins from the AHRC

Dr Chris Bridges, Technology Transfer Manager from Nottingham KTP

Nottingham Trent University, 19th May 2004

Earlier events with external groups considered the novel samples in terms of the direct application to their specialist fields. Their thoughts and opinions on the research outcomes as methods of practice and resulting sample developments were obtained and considered for future recommendations. By comparison, this final group discussion centred on the research as a model of knowledge transfer, in particular how the model could be advanced. It was stated that the definition as to what constitutes knowledge transfer was relatively new therefore no strategies were yet in place to facilitate or support it. Steps were being taken to explore what facilities, structure and infrastructure would be required, by finding out what initiatives were happening such as that invented in this primary model. The discussion recognised the contribution of the practice-led enquiry in particular for similar contexts within the creative industries. It was agreed that knowledge transfer had taken place, with the existing samples representing the knowledge that had been learned and the journey that had been undertaken. Further recommendations included extending the model as a materials workshop event in an environment such as a creativity lab where people from other disciplines could attend and explore the materials to see what questions they come up with. This would expand the knowledge transfer across several disciplines allowing direct interaction with materials and processes to excite and inspire new concepts.

7.3.7 Summary of feedback in relation to knowledge transfer

Presenting the data to three external groups evaluated the practice in relation to knowledge transfer in two ways. Firstly as a means to reflect on the success of the practice as knowledge transfer between science and textile design. Secondly, to transfer knowledge beyond the scope of the research context to related disciplines, which included interior architecture, commercial textiles and knowledge transfer context. As discussed throughout this chapter interpretation of the feedback highlights inconsistent responses to the role and value of the practice as a method to transfer knowledge. This emphasises the significance of requesting feedback from only the most relevant groups as interpretation of data reflects their intended application of the knowledge learned depending on areas of expertise.

In particular interior architect students requested specific data on performance and production parameters although they recognised the potential application of the decorative characteristics of the samples. They also adopted the concept of the potential of material exploration, recognising the role of practice as a means to engage with unfamiliar knowledge contexts to explore potentiality. The focus group however was less responsive to value of the practice as a means to generate questions; rather they were considering the research in terms of answers, preferring direct commercial applications. Commercial products require specific materials with precise performance characteristics which restricts the selection of variables being explored. As identified in the focus group discussion the questions often came out of the practice which does not always conform to restrictions imposed by commercial factors. Finally as discussed in 7.4.6, the definition as to what constitutes knowledge transfer in the creative industries is relatively new, therefore suitable methods and infrastructures are still being established. This primary model contributes to this expanding subject through the practice-led enquiry which resulted in knowledge transfer both within textile design and to external groups.

In summary the main feedback points in relation to knowledge transfer include;

- Performance of material to be considered with process exploration, then aesthetic potential to develop multifunctional textiles
- Application of similar exploration techniques to other materials and processes
- Develop samples as larger scale pieces
- Interest in chitosan with aesthetic characteristics
- Interest in the printing method developed to apply chitosan to existing commercial products

- Knowledge transfer could be expanded by extending the model with a materials workshop or creativity lab inviting people from other disciplines to explore the materials and see what questions arise

The feedback from all three groups illustrated the benefit of sharing knowledge beyond specialist disciplines to gain alternative perspectives.

7.4 Benefits of knowledge transfer resulting from this research specifically with reference to textile design

The research originated from a researcher with a background in textile design and an interest in the creative opportunities of manipulating materials using heat and chemicals. This interest was realised as a result of the knowledge transfer context (as outlined in 7.3) allowing the science / textile design interface to be explored through practical experiments in a laboratory. The benefits of this practice could be directly applied to existing techniques employed in the textile industry where many processes are not presented using a vocabulary that communicates decorative characteristics. Scientific knowledge is contained rather than transferred. For example the literature contains necessary technical and scientific data which restricts its dissemination to non-scientists and does not excite or generate interest from a design perspective, as the language does not refer to design potential. Also the objectives within textile manufacturing for example that of the finisher, to produce uniform effects across the fabric surface allows fixed formula to be developed and adhered to rather than encouraging exploration to discover new aesthetics.

The research addressed the issue of communicating design potential providing an alternative format in which decorative effects linked processing knowledge with aesthetic outcomes. In case study 2, results from open-ended investigations were categorised into decorative themes, giving the data a sense of logic. The research explored the design potential of the materials, illustrating the creative potential of a material previously recognised for its functional properties, taking the research beyond techniques currently used in textile design.

7.5 What are the barriers identified in this research that prevent knowledge transfer?

- Vocabulary and scientific language were the primary barriers to knowledge transfer as illustrated by the need for a scientific expert firstly to access scientific data, then help initiate practice and help interpret initial results. Scientific knowledge is contained rather than transferred. For example the literature contains necessary technical and scientific data but does not excite or generate interest from a design perspective, as the data was not easily recognisable in terms of design potential.
- Knowledge limits of individuals. A team of diverse specialists with combined background knowledge was required to transfer the scientific data into a vocabulary that communicates decorative characteristics.
- Restricted creative interplay between researchers where limited exchange between people prevents research questions to be addressed for example restrictions of commerce and fixed agendas.

7.6 What are the constraints of knowledge transfer in the context of this research?

- Individual barriers which influence the ability and willingness to deal with new situations, events, information and contexts.
- Organisational barriers and restrictions
- Limitations of interpretation of knowledge transfer by selected groups reflects their intended application of the knowledge learned depending on areas of expertise.

7.7 How might outcomes and conclusions be influenced by the limitations within the research?

Varying any aspect of the knowledge transfer framework would result in different outcomes. In particular

- The contribution of specialist knowledge influencing the management and direction of the research journey
- Limitations on facilities – such as ability to produce larger scale samples to consider effects of scale and any restrictions on production

- Limited data on performance and production parameters resulted in a more conceptual response rather than specific applications.
- Selection of panel for feedback influenced results. For example the inconsistent subjective responses from interior architect students were difficult to analyse and inform conclusions.

7.8 Chapter conclusion

This chapter has evaluated the practice produced in this research in relation to knowledge transfer. It has considered how the production of small scale, hand produced decorative materials contribute to knowledge transfer from science to textile design and beyond to external groups. The definition of knowledge transfer developed in this thesis builds on the concepts supported by the AHRC (outlined in Chapter 1) whereby the dynamic exchanges between researchers provide unknown outcomes throughout the research journey. This non-linear path provides opportunities for unexpected outcomes which inspire new questions and new opportunities if pursued. As a result of evaluating the practice-based case-studies the work contributes to the knowledge transfer debate by;

- Recognising the method of collaborative teams to develop hybrid materials to expand the discipline of textile design into flexible systems of existing processes including those beyond current textile design practice.
- Encouraging research strategies that include simultaneous exploration of aesthetic and performance characteristics allowing both decorative and technical aspects to inspire investigations. Adding value to textiles by creating multifunctional textiles combining functionality, performance and aesthetics rather than divorcing the elements and considering them separately.
- Developing non-scientific methods to communicate and present data to non-scientific specialists providing a format in which decorative effects link processing knowledge with aesthetic outcomes.
- Reconsidering scientific laboratories as potential design studio. New environments stimulated new questions about the materials and potential processing methods.

- Encouraging knowledge transfer outside the discipline to excite and inspire new concepts from the research such as a materials workshop in a creativity lab where people from other disciplines could attend and explore the materials to see what questions arise.

This work is no longer just about sample and process development. The samples and technical descriptions of process were the initial focus of the practice-based research; however they are the by-products of the knowledge transfer that took place from science to textile design. These are examples of why it needs to happen in the wider context of textile design on a larger scale towards new visions for future practice, not just in research projects. The most tangible knowledge transfer events which emerged from the thesis included; the science to design and design to science knowledge transfer loop, in which the decorative possibilities of materials were discovered. Knowledge was also transferred as a result of observing the contrasting methodologies developed in the case studies. The model for material exploration developed in the chitosan case study was less structured than sodium hydroxide whilst both producing successful results. Communicating the results from the research context to external sources transferred the outcomes beyond the academic environment. Feedback from a wider audience which included industry representatives, Interior Architect students and a representative from the AHRC, contributed alternative perspectives to the value of the practice however cross-disciplinary knowledge transfer resulted in each group. The production of novel material samples and processing techniques alone contribute unique outcomes, however the practice provides a knowledge transfer framework for unexplored combinations to be considered. The knowledge transfer environment developed in this research included physical spaces in which innovations resulted from discussions and interactions between teams of specialists. Rethinking materials and processes provided an opportunity to educate, inform and question the potentiality of materials not necessarily definite finished products.

The skills and knowledge required by textile designers must then be re-assessed to accommodate these flexible systems. The research encourages textile designers to consider materials as having potential for change *...engaging with* *the new processes to evolve the new aesthetic* (Toomey, 2004); recognising textiles as part of the wider classification of materials according to characteristics and potentiality, rather than being restricted by industry traditions and specific uses, removing the boundaries that define traditional textile design. Within this context, similar practice-based research environments which engage with knowledge transfer are necessary to encourage exchange between multidisciplinary specialists to both disseminate existing knowledge and create new knowledge.

Chapter 8: Conclusion

Although the initial aim was to explore unknown decorative potential of materials and processes, the final body of work focuses on the context which allowed the knowledge transfer to produce the samples and be evaluated by design disciplines for decorative potential. The main findings are demonstrated by the following five key points.

1. Shifting boundaries are redefining the traditional definition of textile design, the textile industry, the materials and the technology.

This is briefly explored in chapter 1 which begins with examples of designers who are fascinated by the inherent potential of materials in combination with processing techniques to contribute new palettes of effects to design. Exploring polyester as a thermoplastic material in combination with the traditional shibori technique, Jun'ichi Arai created 3-D puckered dye effects on fabrics by re-thinking a traditional process with man-made fibres (Figure 1.1). Designers are also redefining the discipline by employing techniques not traditionally used for textile design, for example the use of Photon Laser technology, (Figure 1.4) and Ultrasonic welding (Figure 1.6). Designers are looking beyond materials traditionally associated with design, building on traditional skills adding new layers to the design process. Figure 1.11 illustrates the use of burned Elastoplast fabrics whilst in Figures 1.7 and 1.8, the use of neoprene rubber combines traditional textile skills of repeat pattern technique to generate 3-D structures. A move away from the use of traditional textile definitions was illustrated at INTEDEC 2003 where the theme *Fibrous assemblies at the Design and Engineering Interface* was established to include all fibre-based flexible and non-flexible structures, from fibres to fabrics, garments, composites and other made-up articles. The search beyond traditional materials and processes is resulting in the emergence of hybrid textile disciplines as illustrated by the sensory-appeal textile membrane (Figures 1.12a to 1.12d) which originated from a combination of design, technology, biology and material science expertise. The case studies explored in this thesis researched beyond the boundaries of the design discipline, providing an insight into unexplored creative opportunities. These included the exploration of sodium hydroxide on selected substrates and the exploration of chitosan, a material only known for its performance characteristics. Implications of these shifting boundaries include the need to re-consider what core skills are needed to support this emerging paradigm to take the discipline to unknown destinations. Potentially this would result in more textile specialisms as the interest in developing processes and techniques expands, requiring the textile designer to be aware of the impact on the subsequent stages of design. The implications of the use of new design techniques on fabric characteristics include the need to understand the range of properties and characteristics to anticipate their contribution to the final performance of the product. How would new characteristics translate into fabric characteristics such as drape, handle, weight, thickness, stretch?

2. The practice-based experiments in case study 1 resulted in unique design outcomes on cellulose acetate, supported by technical descriptions of process.

Key factors to the discovery of new design outcomes were the practical experiments which drove the enquiry. Resulting samples were assessed and the most responsive substrate was made the focus of future enquiries. Outcomes were recorded as technical descriptions of process allowing the research to be modified according to specific parameters. A clear understanding of these parameters allowed more defined links to be made between aesthetic outcomes and process as the *potentiality* of the combination of materials and technology was understood as predictable aesthetic effects. Examples of the creative effects on cellulose acetate included diverse dyeing effects, transparency, contrasting harsh fabric handle with fluid sections and 3-D effects caused by treated areas shrinking. The production of samples allowed the potential of a chemical reaction to be communicated as a range of aesthetic effects and a new vocabulary for design. These outcomes linked science to design producing exciting potential applications illustrated at the end of the chapter as ideas for design development.

3. That there is benefit to practice-based research to explore the design potential of materials previously not known for aesthetic potential.

Using a similar practice-based method the practical exploration of chitosan resulted in technical descriptions of process and a range of samples exhibiting decorative potential. The resulting samples were characterised according to three main decorative themes which were chosen to reflect the main effects chitosan had on combinations of materials. These included physical effects, colour effects and surface texture effects. Sub-groups were formed from these themes with physical effects comprising the largest group. The design aesthetics were progressively informed by the characteristics of the resulting samples generating a vocabulary of design effects appropriate to the particular material combinations. The technical understanding of the materials and processes provided the knowledge to allow further exploration of selected characteristics thus extending the creative dialogue. The research illustrated a range of potential decorative effects supported by technical descriptions of technique which developed into a framework of what parameters to explore and how. Examples were selected to illustrate design potential drawing on feedback generated from the presentation to interior architect students. The benefit of this extensive body of work not only generated a unique vocabulary of design effects but also highlighted the opportunities for similar developments across the expanding variety of technical and performance related materials.

4. The need for development of a model which combines aesthetic and technical parameters of textiles to promote knowledge development.

The evidence provided in the thesis reveals the shifting relationship between textile design and technology underlining the need for appropriate dialogue to encourage maximum benefit. Aesthetic and technical characteristics are not sufficiently combined or understood by diverse disciplines. The current format of scientific and technical literature does not excite or generate interest from a design perspective as the data does not link technical knowledge with aesthetic potential. In the wider context of material design, *Panelite*, (Chapter 1) have developed an in-house model which produces both aesthetic and technical criterion based on explorations of existing processes and manipulation of selected materials. This example successfully bridges the gap between the creative investigations and the technological limitations. The potential for such a model in textiles can be directly linked to the unbalanced context of the textile finishing industry (Chapter 1). The literature contained technical and scientific data however the aesthetic potential of the techniques was not evaluated. In order to allow a more diverse audience to access the knowledge the language used to communicate scientific data needs to be adapted to be less specialist and more descriptive. A simple solution might be to illustrate samples using visual and tactile methods to demonstrate decorative potential such as the methods applied in the case studies (Chapter 7). The generation of samples illustrating the visual effects of chitosan (Case study 2) was measured by the feedback and response from three external sources. In particular this method allowed the decorative potential of chitosan to be presented to industry representatives, one from design and the other whose company deals with chitosan for performance applications. Lack of previous knowledge of the decorative characteristics of chitosan was confirmed by both representatives. Contributing to the debate, a combination of aesthetic potential alongside performance characteristics was suggested as the key link towards the development of multifunctional textiles. Further evidence that this synthesis is required by designers was highlighted in the feedback from the Interior Architect students. Their interest in the creative potential of the samples was underpinned by an necessity for technical data, such as performance and production parameters to allow suitable end use consideration. Interest from individuals, groups and organisations demonstrate the need to improve the links between technology and design, highlighting that these issues are not resolved. This research provides examples which have reduced the boundaries. Beyond textile design material developments are communicated across the broad spectrum of design not categorising materials to specific end-use applications. The research illustrates the opportunity presented by removing the barriers that separate material systems, instead communicating their inherent characteristics and potential to be manipulated through processes.

5. Developing Knowledge Transfer strategies as a means to evolve the discipline of textile design into multidisciplinary teams producing hybrid materials.

As identified in Chapter 1 and evaluated in Chapter 7, practice-based research contains vital data regarding existing knowledge transfer frameworks in which information is transferred across and between disciplines resulting in new material and process developments. Identifying and improving knowledge transfer strategies is fundamental to enable the vision of multidisciplinary teams to continue hybrid material developments beyond existing practice. Within the context of this research different types of knowledge transfer elements were identified. The first included the knowledge transfer loop from science to design and design to science. Using scientific data alone, it would not have been possible to visualise the exceptional range of decorative outcomes from the variety of experiments carried out. The development of non-scientific methods allowed the data to be presented to non-scientific specialists in a format which linked decorative effects with processing knowledge. The scientific data was applied to practical explorations of materials, from which outcomes were produced. The knowledge transfer from design back to science was a surprising development, supporting the value of exploring concepts from new perspectives to reveal unidentified qualities.

Both case studies involved collaborative teams in which the design studio was replaced by the research laboratory. This environment stimulated new questions about the materials and the potential processing methods. The two case studies required different methodologies to carry out and evaluate the practical work; where case study one involved a more definitive linear path through the research, case study two initially took a less structured approach. This was due to the range of substrates being explored and the range of outcomes being produced. In order to interpret the outcomes, the data was categorised according to decorative themes linking potential design characteristics across the range of outcomes. The comparison of these diverse approaches highlighted the need to adapt to the requirements of the project; not the methods dictating the research rather the research dictating the methods. Both cases included methods from scientific and design contexts and were reflected in the decisions to include or exclude data. The written descriptions were not inclusive of all technical or scientific data and only the relevant information needed to progress the research was included.

Applying a knowledge transfer framework also allowed the practice to be located and evaluated beyond an academic context. The feedback from external sources included positive and negative responses reflecting diverse expectations from the groups. Each group was interested in elements of the research, however only the representative from the AHRC fully accepted the value of the knowledge transfer as a research package, without the need for translation into direct commercial applications. The value of the work was in both the knowledge learnt and the journey undertaken. In contrast to this, the industry representatives recognised the value of the work as research within a research context, but that it failed to provide the complete commercial package. Potential was recognised for future developments if certain modifications were addressed making the samples multifunctional rather than based on purely aesthetics. The interior architect students were inspired by the potential visual and textural characteristics of the samples however, key questions relating to performance and production possibilities could not be answered. Individuals from this group applied similar methods to explore other, more familiar materials, providing evidence of a tangible value to the research.

In conclusion, the potential for knowledge transfer is vast yet not sufficiently understood. The approach adopted in the research embraces the idea of knowledge transfer, providing a means to evolve the discipline of textile design beyond what we know to new disciplines and a new generation of materials. If the samples developed in a small-scale laboratory are a measure of the potential of this approach, then what would the possibilities be if this was escalated to encompass a universal approach towards material development? Most importantly what are the implications if we do not do this?

The following recommendations build on this research to expand further knowledge transfer strategies;

- Support the data with performance characteristics in the development of models which combine aesthetic and technical parameters
- Exhibit findings to extend the transfer potential to wider audiences possibly in galleries but also in scientific contexts to generate further questions
- Engage with existing manufacturing technology used for specific materials being explored. Can these processes be adapted or explored contributing new skills?
- Generate additional creative extensions of pieces
- Compare to knowledge transfer models from other industries
- Continue to develop an understanding of knowledge transfer as the subject evolves within the context of the creative industries

APPENDIX 1

Technical descriptions used in chitosan experiments

Table 1: Preparing 4 litres of 2% chitosan solution

Details of materials	80g milled Indian crab chitosan, 25ml glacial acetic acid 4000ml distilled water
Equipment	4000ml plastic container, glass rod, balance, pipette
Description of process	Put 80g milled chitosan into 4000ml container adding 4000ml distilled water. Stir with glass rod. Gradually add acetic acid stirring continuously. When finished stirring, cover and leave to dissolve for at least 24 hours, actually left for 48 hours. The solution was then filtered to remove impurities and left to settle while air bubbles were released. More time needed to settle as using more solution. Left over the weekend (52 hours approx)
Results and discussion	The chitosan becomes thicker as the acetic acid is added becoming difficult to stir. Make sure the solution is well mixed.

Table 2: Preparing 4% chitosan solution from chitosan flake

Details of materials	200ml of 2% chitosan solution 8g milled Indian crab chitosan 5ml acetic acid 200ml distilled water
Equipment	200ml glass beaker, glass rod, balance, pipette
Description of process	Put 8g milled chitosan into 200ml glass beaker and add 200ml distilled water. Stir with glass rod. Gradually add acetic acid stirring continuously, cover and leave to allow chitosan to dissolve for at least 24 hours.

Table 3: Preparing 4% chitosan solution from 2% solution made up

Details of materials	1 litre of 2% chitosan solution 20g chitosan 10ml acetic acid
Equipment	Glass rod, balance, pipette, 1litre container
Description of process	Wet out chitosan flakes with water (could also use methanol and make a slurry). Filter to remove excess water. Add acetic acid to chitosan solution and stir. Break up chitosan pieces, add to solution and stir. Cover and leave to dissolve for at least 24 hours. Filter the solution, cover, then leave to settle for another 24 hours. (4% solution may be more difficult to filter due to viscosity of solution in addition to impurities)

Table 4: Neutralising samples

Details of materials	0.5% sodium carbonate solution made up to 2 litres with distilled water = 10ml if 100% sodium carbonate = 100ml if 10% sodium carbonate
Equipment	Deep tray
Description of process	Soak fabric samples in 0.5% sodium carbonate for about 15-20 minutes. Rinse then check pH using red litmus paper. Neutral solution should turn paper blue. If needed add more sodium carbonate and stir. When neutral, rinse and dry sample either in the oven, iron, or leave to dry at room temperature.

Table 5: Filtering chitosan solution under vacuum pump

Details of materials	200ml of 4% chitosan solution Allowed to completely dissolve over 48 hours. 24 hours might have been sufficient.
Equipment	Filter pump, retort stand, buchner flask, buchner funnel, polyester monofilament mesh circle.
Description of process	Attach buchner flask to filter pump with plastic tube. Place polyester monofilament mesh in base of funnel. Pour chitosan solution into funnel and switch on pump. Stir chitosan solution to prevent holes becoming blocked with particles allowing viscous solution to pass easier.
Results	Chitosan solution was quite viscous and took a while to pass through filter. Need to check pump does not become too hot. Stirring the solution helped. Final amount was 150ml from initial batch of just under 200ml. Noticed there might be some dark fibrous contamination from filter pump in the solution, should be ok as only producing test samples. Also need to leave mixture to de-gas (over weekend). The solution is clearer leaving undisolved particles in the funnel.

Filtering equipment used

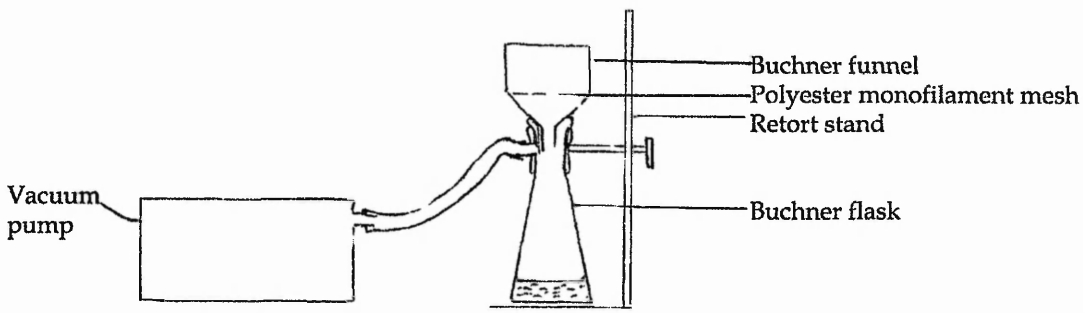


Table 6: Template for recording laboratory work

Title:			
Summary:			
Introduction:			
Type & weight of materials / fibre / yarn / fabric / substrate			
Dyes /chemicals used	% from recipe (P)	Concentration supplied (C)	Amount taken (A)
Sample before:		Sample after:	
Method:			
Results and discussion:			
Future implications / questions			
References:			

APPENDIX 2

Questionnaire feedback from presentation

2nd year interior architect students - Nottingham Trent University
10th February 2003
Total 26 completed questionnaires
Presented to interior architect students, as it was a chance to explore if new issues would come up and what questions would arise.

Question	**Answer**
1 Have you ever come across chitosan before this project?	Yes = 0 No = 26 (100%)
2 Do you think any of the samples have potential application in interiors?	Yes = 26 No = 0 Additional comments: • All samples had potential to be applied to interiors • Images were beautiful from the slides of the coloured resin – less so by themselves • Other fabrics could be used • Decorative purposes – anything with lighting • Can't imagine the samples would work on a large scale without being expensive • Suspension of delicate materials could work as screens for divisions of space / installation / pieces/ flooring/ hangings / blinds / under glass with light • Setting materials in squares/ panels • Slabs of chitosan stacked as a wall, chitosan as solid blocks instead of glass bricks • Light reflecting / absorbing qualities • Potential pf chitosan pieces if slightly hardened to make it more structural • Chitosan + light give interesting effects • Interesting sculptural properties, fabric + structure gives rigidity – not normally associated together • These materials / treatments offer the potential to give a space very different qualities • Use of transparency + organic patterns for use in lighting – or in small scale ideas • Exciting if applied on larger areas • They are pieces of art on their own • New type of stained glass window – interesting surface texture, sensory qualities • Perhaps use in a museum / exhibition where touch and feel create different feelings • Jewellery • Translucent qualities – stimulating visuals (for disabled childrens etc)

<table>
<tr><th>Question</th><th colspan="3">Answer</th></tr>
<tr><td>3 What were your first impressions of the materials?</td><td colspan="3">• Still very experimental
• Need to be developed further
• More interesting on close inspection than at a distant
• Beautiful slide projections
• Innovative and original
• Tactile
• Could create emotions in a contained environment
• Temporary use
• Samples shown were small scale – what if they were larger scale pieces, how would they contribute to the experience of the environment?
• Interesting aesthetic qualities
• Creative use of sculpture
• Initially critical as to properties / purpose however first hand investigation recognised the samples had various aesthetic qualities including flexible / soft / hard/ opaque / transparent
• Blue samples quite delicate, fragile but interesting
• Resin pieces and stiffer samples have most potential
• Pure image
• Smell (not good)
• Colours and unusual textures, transparent qualities, different ways they absorb and diffuse light
• Makes them want to start experimenting and exploring how materials could be explored to produce interesting designs
• Began to think about different new ways materials could be used
• Varied effects
• Potential for expanding ideas
• Would like to see the materials in a real environment
• Potential with 3-D design
• Chitosan inaccessible
• Resin – tactile, vibrant, durable:
• Fabrics – delicate, flimsy, decorative</td></tr>
<tr><td rowspan="2">4 To what extent is sustainability a key consideration in your design proposals?

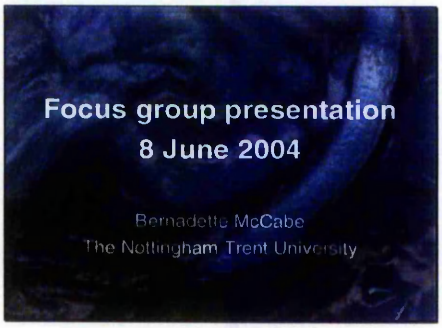
Additional comments:</td><td>1 = never
2 = rarely
3 = sometimes
4 = often
5 = always</td><td>0
5
12
7
2</td><td>0%
19.2%
46.1%
27%
7.7%</td></tr>
<tr><td colspan="3">Currently do not have enough information – important consideration for the future
Trying to increase awareness</td></tr>
</table>

Question	Answer		
5 Do you explore the characteristics of materials and processes for their creative input in design development?	1 = never	1	3.9%
	2 = rarely	5	19.2%
	3 = sometimes	14	53.8%
	4 = often	5	19.2%
	5 = always	1	3.9%
Additional comments	Not enough Interested in exploring more		
6 Do you have any further comments?	• Would like to see further developments of project – still very experimental • Suggestions to give the samples more structural and sculptural qualities – perhaps coat with harder substance • Try different dyes / finishes to offer a variety fo experiences in an environment • Still craft-like – try larger scale pieces • “we often use things which already exist but if we are introduced to these new processes more we would probably use them more” Catherine White • Would find short notes useful; with samples as a reminder of how each was made • Useful for interiors – without the smell! • Inspiring form and texture – opportunity to consider lesser known materials • Wonderful • Jewellery design • Dramatic		

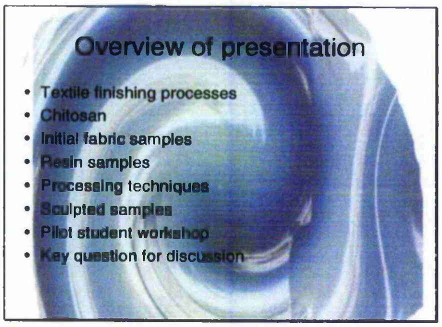
APPENDIX 3

Presentation given to focus group

Slide 1



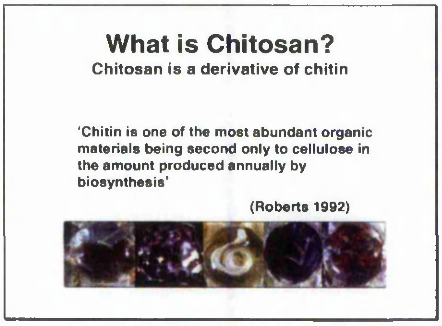
Slide 2



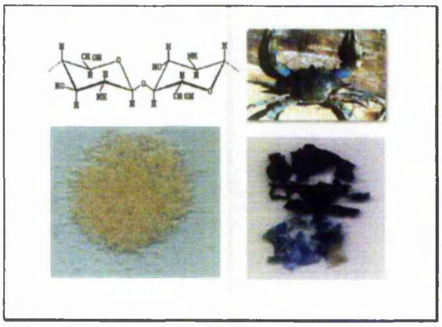
Slide 3

Performance	Finish applied
Ultraviolet protection	Ceramic molecules in surface finish
Antibacterial protection	Chitosan coating
Weatherproof treatment	Resin or silicone coatings
Reflective textiles	Microscopic glass beads with reflective backing

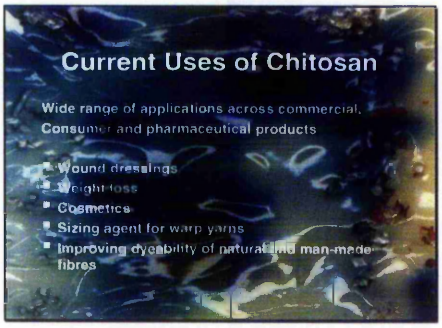
Slide 4



Slide 5

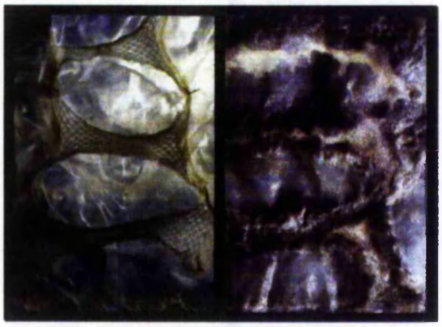


Slide 6



Slide 7

Slide 8



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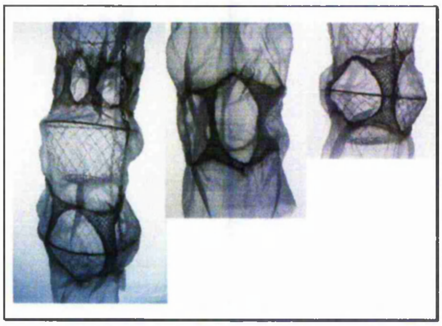

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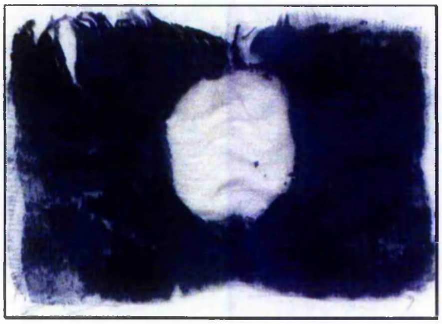

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APPENDIX 4

Focus group transcript – 8 June 2004

Group members:
Managing Director of a company which designs & manufactures luxury products
Managing Director of a company specialising in micro encapsulation onto textiles
Lecturer in fashion and textiles and critical theory in art
Biopolymer specialist

The focus was changed from just considering the aesthetics to the underlying implications of the work in an industry context and what kind of questions might arise as a result of more investigations of this kind. The objective was to generate feedback and comments on the research, the methodology, and research journey from their individual perspectives.

The day included a 30 minute presentation of the research to date finishing with a key question for consideration. Break for 20 minutes to individually explore the work, asking the group to consider any questions they had, ranging from technical data to where they would like to see the samples developed further. Reconvene to discuss and explore the arising issues.

Presentation of research to date
Background to research, UMIST, MA
The hidden potential in the Textile Finishing industry led to further creative explorations of materials and processes. Initially chitosan was introduced as a material which is widely used for its performance characteristics. The research question asks if it has creative potential. Work developed into 3 main areas, chitosan coloured film with resin forms, printing with chitosan, and sculpted forms.

Finding out what can it do for me in a design context?
Existing technical Finishing processes are known for their performance characteristics – what about their potential aesthetic contribution to design?
Not putting it into a box too early but trying to find out what it can do
We don't know yet what the material is capable of for design
Sculpted pieces – referred to composites but less rigid
Use CAD to draw the link from the initial explorative processes to begin to design images and simple repeats. Don't have to reproduce samples to explore ideas but scan existing samples.

The materials science group at the Nottingham Trent University developed a body of knowledge about casting and dyeing chitosan films. My research incorporates this work communicating these findings as aesthetic outcomes. Stages of process development included understanding the materials and processes for example by looking at the film in isolation from other materials also different processing techniques (vacuum forming, put between glass tiles and fired in kiln)

Pilot workshop - interior architect students' response to the materials, not enough time for them to use the materials but still good to hear their initial reactions to the materials. A novel material to them but still felt the samples had potential application. Not having information on performance properties was a down side. Presented the students with new ways to explore materials rather than just accepting materials as they are.

A final question was asked to bring the presentation to a close and to provoke thoughts around the research topic. The following is a transcript of the focus group which was taped and typed up after the event. The tapes were not always clear so that not every detail has been captured although all the main points are included. The discussion was led by the researcher with some semi structured questions which were prepared before the event. It was hoped that the questions would help to generate an in-depth understanding of the issues and implications of the research form the perspective of those present.

Is design potential limited by a lack of understanding of materials and processes?

DH Why would performance characteristics come up at the end and not at the beginning of the creative process, as performance is very much a part of the creative process? I don't see it necessarily as separate

BM Possibly because the first research question was, does it have creative potential? You have to ask this question first, I'm still answering the initial question to find out if it does have creative potential. Carried out wash fastness test but no others and due to the range of materials developed it was decided not to test samples as the end use determines what tests should be carried out on them. That is not the focus of the research, the research is the question or the methodology and if it is relevant to look at materials in this way (creative). That's the difference between academic settings where you can ask the open question, to explore the material.

DH What are the recognised performance characteristics of chitosan?

LG Mainly antibacterial. There are many uses for them. If you look at many so- called weight control tablets in pharmacies it's in an ingestible form because it has an ability to absorb fat, up to 100x its own weight in fat and oil. One use which wasn't on there is that it's used in Geotextiles on oil rigs to absorb oil spills in the sea because of this ability to absorb oil. So you can see its potential for ingestion for diet control, how that works in reality I don't know. But from a textile point of view, we apply it onto textiles but we actually cross link it onto a cellulose, and it's there because it has fantastic antimicrobial properties and it will not support the growth of things like (names of) the main bacteria, not only does it not support the growth in that situation it actually positively repels antibacterial. It's a very interesting product which we use a lot. We actually combine it with other products like Aloe Vera to give other benefits. I was thinking in a similar way to Daniel probably with a commercial hat on. It was interesting to see how the chitosan added to the aesthetics but my question was immediately in my mind, why choose a product like chitosan, that as far as I can see you're only looking to use it from its' aesthetic forms. Is it going to give you durability? If you're using it to stiffen, why choose something like chitosan to stiffen a fibre or a structure when there is a whole host of other products out there which would stiffen them as well possibly even be more durable and probably be cheaper. But that's being very boring with a commercial hat on.

BM I'm coming at it from the opposite point of view. What does it do? Instead of saying I want something to do 'this' there are two ways to explore something. If you're exploring materials you need to first find out what it can do. Two most important things to me are one, it is biodegradable and one it's sustainable. They were two things I was interested in to start with but they can't support whether someone is going to buy it or not. What does it do that other things can't do, I think is another interesting question, perhaps George might be able to answer that one better.

LG It is difficult to see what part the chitosan is playing if you'd have used those films, if you'd have used a different polymer, would you have achieved the same things where you were melting them, putting colour in them, where you were freeze drying them, I'm not convinced looking at that, that the chitosan is actually having a major role in that.

GR The advantage of chitosan over a number of the commercial stiffening agents is biodegradability and also it really does have very interesting dye-ability properties, like the range of dyes that can be applied to it. In that respect it has possibly a lot to recommend it, but I suppose at the end of the day it was more simply the fact that nobody has really looked at it from a design point of view. So it was interesting to see if you could use it in design. Rather than going from the perspective we want to stiffen these fabrics what can we use, it was more we've got this materials what can we use it for?

LG How was the film made?

BM Dissolved in solution

LG Purely an aqueous solution made with chitosan powder?

BM Chitosan flakes.

PP I suppose the interesting issue that you've raised is an important question. What is the potential of chitosan in a commercial, design end product? Even if we like some of these ideas and I probably like them because of its range of possibilities on different surfaces, I don't know if other materials would give you that opportunity as a designer. But another big question is, how do we know when we arrive at a solution that it couldn't have been achieved more effectively and better, from a design point another way? Do we need to take it through to a design product anyway and then what kind of areas would that be in? Before on our research projects we've tried to avoid saying this is a design for a specific use. Perhaps this project needs to take that step forward. But it's a dangerous one. Do we suddenly say are we dealing with an interior fabric, are we dealing with a fashion fabric, is it going to be a sculptural piece that goes in an exhibition? Then we link back to your question why chitosan why not something else?

DH But the primary issue it that it is a research project and you chose chitosan for it and you've explored all the properties of it. The question up on the board is one that makes me shudder. Is design potential limited by a lack of understanding of materials and processes, as part of the process of designing is gaining an understanding of the materials and processes it's part of the whole process, it isn't an aesthetic process, a purely aesthetic process anyway, it contains all of the elements that you have included in your research project.

BM I think taking it back one stage earlier, is that one of the reasons I enjoyed working with chitosan is because I'd never done it before and it is such a new area bringing up novel issues. If you want explore a material that you've never looked at before and the only way you can understand it is by looking at a scientific body of knowledge, how do you connect the two, how do you work out what can you use and what you can't use? It is a little bit beyond just design processes or bringing the two areas together. The lack of understanding of materials and processes to me is about looking at materials not as textiles, not as resin, not as a hard or soft but what the materials do and there are materials out there that I haven't had the opportunity to explore yet.

LG I think it has been a positive benefit to you not having and understanding of the materials or processes. And it is very difficult for you (DH) and I, not to look at it from a commercial point of view because how often in your working life do you look at something where you say well that has got tremendous aesthetic potential, but we have to bring it down to a commercial level and it's when you get there that you have to make it durable and you've got to make it mass reproducible and you have to do all these things, then a lot of things fall by the wayside because of that I think that the beauty of what you've done is because you haven't had the restrictions.

DH Again the question (on the board) raises lots of questions, it provokes a lot of thoughts in my own mind that one of the real benefits of global manufacturing is that the designer now is no longer or very rarely the manufacturer, whereas traditionally the designer and manufacturer were a part of the same enterprise, so the designer actually gains an understanding of materials and processes through working with manufacturers, different manufacturers as opposed to working with their own manufacturing environment. So you as a designer would develop through working with a manufacturer that understood a process. Or going to a variety of different manufacturers and being presented with their manufacturing process and then answering a brief that fits in with their manufacturing process, that's how it works more and more so.

PP Can I pickup on your understanding of materials (BM) because you remember one of William Morris's quotes was that you cannot be a creative designer unless you understand the characteristics of the materials you work with. It would be difficult.

BM I agree. But then if the material that you want to use is not already in your vocabulary, you've got to look

LG You can't know the boundaries.
PP So in answer to your question, 'what's unique and special?' is that you're finding a well known material by the sounds of it that's used a lot, but nobody has used in the ways that you are exploring.

BM But also the research question is not just related to physical samples, but also as a research model if applied to other areas, in a practical way in an environment where you can work with manufacturers.

LG Chitosan is used extensively in textiles, in fibre production and all sorts of textile application but not in the sort of films that you're looking at, to my knowledge. It's an old product now in terms of textile application.
PP Is it expensive?
LG It's not overly expensive but it's not the cheapest product. A lot of it is the basic chitosan, then it's what you do to it in the process. It's difficult when you ask that question because in business things carry a premium because they offer a premium benefit, it doesn't necessarily even mean that it's an expensive product but it has a significant cost when you are applying it to a textile.

PP As a designer the excitement and surprise to me is that you can actually use something that you can apply to different substrates and I find that quite fascinating that it has that potential. Perhaps some of the effects, depending on fabric type, could almost be like devoré effects but obviously you would have to explore a lot of different fabric types, a lot of different solutions and it always is a problem how far you carry your research in any one of these areas. To have enough information to demonstrate and convince someone else that something important is going on here. You've got the three categories, they are exciting categories but would it be better to focus on one or come up with three or six? I suppose we are still in that stage, or do you feel you've got firm ground, the sculptural, the film, and the resin samples?

BM There are several different elements going on in the research question. Along with the design outcomes there is also the underlying issue of the way I now view the materials opening up a whole new world to consider. You've really got to work out what you want it for then you set your own parameters. When you're exploring something, you don't want to say what you don't want to pursue as you want to see what it can do. My understanding of the films now allows me to think of fabrics in a slightly different way, almost combines the two really but I think for the purpose of the research it is quite hard to select just one area when you're trying to explore the wider potential. Each investigation isn't going to be conclusive it's just an idea to what it can do. The research ends up asking more questions really. It is difficult to choose as I am not looking for an end product. Design is about finding a solution to a problem but the problem is changing all the time with this.

LG Naturally you want to bring things to a conclusion.

PP You've also mentioned aesthetics a few times. For me there's still a need to deal with this. I can follow it through technically and I can visualise technical information and samples, although I'm not quite sure how; restricting it to that kind of activity does aesthetics come or is that considered when you bring a more resolved solution to a problem? Or can aesthetics be contained within sample developments?

DH Aesthetics and markets are very closely linked. The moment you discover the aesthetic you're combining that with where the aesthetic is going to go and what you're going to do with it. Everything that is undertaken in a commercial, business environment is undertaken to generate, it's all part of the design process right down to the sale.

LG It's interesting that I have never considered chitosan to be an aesthetic product; to me it has always been a function product. It's been a moisture balancing, antimicrobial, antibacterial but I've never thought about it in an aesthetic light. It never has had any real aesthetic properties in the way we present it, it's there for its function, we put it on underwear for its' antibacterial properties but you wouldn't actually be able to look at a garment and be able to say that has chitosan, that doesn't. It doesn't give anything aesthetically.

DH If you talk about organic cotton which is a very topical issue, in its broadest sense it conjures up the most dull looking product but when you actually see what you can do with it, cotton and the finishing of it, which is what you're talking about, suddenly it becomes a very interesting fibre. But it's not the fact that it is organic it's the fact that it has been finished in a certain way, so when we're talking about chitosan we're talking about the same thing, it's not the fact that it's chitosan, we're talking about the finish that you're producing, it's only when you link the two that it becomes interesting.

LG It's almost incidental.
DH But it's fascinating that it is chitosan.

DH When you say its properties are that it is biodegradable, it absorbs fat, used for wound healing, suddenly there are a range of marketing issues and they do become marketing issues.

LG It's been a hugely marketed area for many years now it's not a new thing.

BREAK

The group looked at the technical notes to generate thoughts on information, how it was presented, is the relevant information provided? After looking at the samples and images came back to discuss initially the main question then leading into further issues.

BM From my perspective and the people I've spoken to throughout my research basically there is a lack of understanding and a lack of exploration of materials and processes. From your individual perspectives, do you think that there is a lack of understanding and if there is how can it be overcome, to start with if anyone has any questions?

GR Certainly on the design courses, students, don't have any wish to understand. And it has led over the years to quite a lot of problems in people starting on projects finding that 'no you can't dye a green polypropylene net pink' which they wouldn't expect if they had understood the materials. I don't see how you can work with a material unless you have a good understanding

BM I think that comparing it to something like architecture, where the emphasis is much more on the performance of the materials themselves. Architects have a different level of understanding of materials; part of their education is where they develop an understanding of the materials in a way that could be learnt and built on. As you were saying earlier Daniel that in order to design with a material you have to understand it first but I'm not sure to what extent people are willing to take that up or do take that up really.

DH We were talking about the Arkwright building which was designed for people to actually work in with their hands with raw materials ....that process will go on and I think visually between what you produce as a two dimensional, three dimensional object on the screen and how you actually achieve it, even though the two processes get further and further away. Because I don't know if it's at all related, I believe it's based on they way it's manufactured, how you manufacture.

BM I was talking to Stewart Collie from *Canesis* and they told me about a project called Duality, where their key message was basically that new materials and processes are being developed but how do you explore the design potential of them? A student fashion designer worked with these new processes and developed a range of garments, quite an exciting and interesting thing to do; the opportunity for that doesn't seem to exist in any other area. I just wondered how do we expect that to happen or would it be an ideal situation for ideas to be explored?

(One of the issues here is about exploring materials for a particular end use balanced with exploring them to discover its range of characteristics)

PP I support what George said initially. A fashion student came to the print room and basically he wanted assistance on his fabric (immediately). To separate all the different colours on the screens and then print can take quite a long time. Moving on, ink jet printers came and with Prof

Newton, his vision was to get rid of the flat bed printing tables replaced by banks of ink jet printers which had a direct relationship between the computer, your artwork and the production. Though not necessarily commercial.

LG Not on a commercial basis. Look at the production speed of the digital against the rotary.

DH It's about people being able to change the process.

LG I'm with George I don't think you can fully explore the potential of something unless you understand it. You need to know the parameters or there's no point in going down the road, so why waste time going down that road?

GR Is it possible to write a check list of the range of characteristics for any material in design?

BM At the conference I went to last year, INTEDEC there was a paper which discussed joining aesthetics with technology and the technical aspects. You always get one or the other but it is very rare that you get the two together, translate to two different groups of people. The information doesn't say the same thing to different people. Communicating what it does in a technical sense, a designer needs to understand that, and that might be conveyed through different ways of communicating it, whether in fabrics, or images.

GR It's up to designers to identify what it is they want? Does it melt, does it dissolve up, what does it dissolve in, what does it dye in?

BM There could be an endless list of what can it do but then it comes to point where you have to work out what you want, what's your end goal?

LG If you are an artist designing a piece of work, then that is a finite project, you then don't have to worry about all the factors. If you ultimately see your work going into fashion situation presumably the design of textiles the ultimate aim of it is so that it can go forward into production and see it out on the high street in some form or another. If that's your ambition I think you have to understand the technical constraints, you have to understand what's required of the fabric. If you understand at the beginning as George said, you save yourself a huge amount of work. Achieve what you actually wanted to achieve. I think it is fundamental to what you do is to understand the processes and the requirements. It depends on your objectives in design. If your objectives are functionality, if you're a textile designer it has to be.

DH I think that defining your brief is the starting point in the process. You have to understand the materials and processes to write it. As a designer working in any situation, in the university, with a manufacturer, with a retailer, first of all it is the brief that all the questions come before you write the brief. And when you're looking at the piece of machinery, can you do this can you do that, can you do the other, I go through a massive question, question, question, then you stand back, then you write the brief, then you design. And that's part of the process. The brief is critical.

BM In terms of comparing that to what I've actually done, in terms of the methodology that I've used, what other kinds of considerations do you think could or should be considered in the work that I've done. Do you feel that this research would have an application in your field or any other particular area?

LG I would like to see chitosans performance characteristics. It is a phenomenal product and has phenomenal capabilities, but I don't see any of those being exploited. What you see is purely aesthetic, the visuals or the graphics do not actually exploit the benefits or characteristics of the chitosan.

BM So perhaps if the work was carried out paying attention to performance aspect as well, do you not think that would be possible, to combine the two?

LG I'm sure it is possible to combine the two. But the aesthetic is coming from a different product, the chitosan is not contributing.

BM Does it open up questions in your mind of the material as well, even it's just questioning as a semi-finished product and does it open up any possibilities as to how you view what you're using? In terms of asking new questions of the material.

LG I am always asking new questions.

PP Can I mention it as a medical application? (this leads to a group discussion concerning wound healing properties, and chitosan in bandages and open wounds)

PP Is there interest in adding design to bandages and wound dressings?

BM You mean to combine the creative understanding of the materials with technology, putting the two together and see what they do. One of the things I've found quite hard has been that the technology hasn't been available so I haven't had any parameters to explore, I haven't had the parameters to restrict the investigations, instead I've been finding out what kind of outcomes I can develop. But when the technology already exists you're exploring something that is already there, you're finding out what the parameters are and I think that's the difference. It's more defined. Daniel, do you think that the work has any relevance to your field, or your area, your background?

DH No direct relevance. Research in any context is relevant. I am looking for an end product and that isn't necessarily what the research has been doing. In my mind I have a series of coloured plasters!! That's how I see it is going to go.

LG We're doing thermochromic, nanosilver combinations on stethoscope ends so it's antibacterial and it is changing colour.

DH I think there are two issues when you look at the fabrics and I can't make the link to why chitosan.

LG I have the same problem, I can't follow the chitosan part

BM In order to answer the question, you have to produce data first to make an assessment. I couldn't define why I wanted to explore its creative potential, I had to first see what it did. The investigation informs the question as well.

LG That's the important issue though.

BM I couldn't respond until I completed a body of research to be able to compare against what else exists that does this to fabrics. Then look at the other outcomes and repeat the comparisons. I haven't got a comparison for every sample. It makes me consider how would you investigate and explore new materials, what would be the future of material development and exploration? How could this be moved on in terms of processes and the questions I've asked?

LG With this you've got to identify what this gives that other things cannot give. I think that's why I struggle to see, what does the chitosan give that cannot be achieved with other things.

BM Perhaps it stands out to you as being unacceptable due to commercial viability.

LG I find it strange that there is a million and one ways to achieve that type of product. In terms of its printability, or putting it into a resin, off the top of my head I'd have thought that there are a lot of resins that you could put colour in to get these sorts of effects. I find it difficult to make comment on it looking at that when it's not focused on the commercial buyer, we just don't know how it is going to perform, is it commercially useful, all these boring things. For manufacture on a large scale it would never get off the ground.

BM But these initial investigations, were critical to explore its potential.

LG Everyone has to start somewhere. We don't know how many things are abandoned or don't reach commercial product.

BM An idea of a materials innovation centre for textiles including machinery equipment, expertise, where people could go in and explore materials and processes.

LG I'm sure they exist, more in the past than now. Example of wool fibre and how it is explored using various processing techniques, card it, spin it, weave it, knit it, dye it, come out with products

BM *Canesis* followed similar model in Duality project exploring wool through manufacturing techniques. *Materio* – database of semi-finished products open to all end use designers is a junction between end designer and the manufacturer. It takes away the boundaries allowing a wider exploration of materials and processes. Another question would be, what would be the wider implications of these kind of investigations being carried out? What is interesting about materials is trying to find out what it can do. Recognising where these applications are.

LG I struggle with the fact you've got a product that has tremendous depth and how to combine the aesthetic effects with the functionality.

GR Design effects with the chitosan as a textile finish.

LG That's something you need to look at, is how you can combine the design effects with functionality, at the moment you're saying to hell with the functionality, I'm just trying to use it for its aesthetic properties.

BM I guess it's because the knowledge already exists and is an area that I can't personally take forward at this point.

LG Take something that exists and add value to it, making it a more attractive proposition. Having a product that is now giving two things, it's giving functionality but also aesthetics, it's giving design possibilities. This is now a very interesting product. Looking at textiles now you've got handle, colour, all the traditional aesthetics, we're now adding a wellbeing aspect to textiles, anti-mosquito, moisturiser to the skin. Combine all the creative aspects with the wellbeing. Here it is as a medium that can stiffen or take colour; if you can differentiate it by combining with the functionality then it's very special.

BM How do you create the opportunity to do that?

DH The opportunity for that is there but perhaps it hasn't come out – the two elements have not mixed properly, aesthetics and performance into design. The process of designing is recognising and bringing it all together to make it work.

LG People are looking for multifunctional textiles in the market place now. Everyone wants to look at wellness. We want to put more into our textiles. This research is one element ignoring existing uses. Completely ignoring one element of its function. It's like a wonderful paint job on a car, saying it looks wonderful but you never drive it. You're completely ignoring one element of its function.

BM I don't know if I could have done it the other way either.

DH It doesn't matter

BM It's interesting to see if another research model is developed from it to try to explore both at the same time, not divorcing the two but bringing them back together.

DH I think that the starting point is investigating the properties of the materials and the process then use the aesthetics – bring them together so they are not divorced from each other or if they ever have been, on certain levels they are.

PP We now have decide how we're going to communicate the feedback to those members of the focus group who could not attend. Patricia Belford said she was happy to communicate via e-mail.

BM Patricia Belford asked exactly the same thing, what does it do that we can't already get, adding the commercial point.

DH It's not a commercial issue, it's a design issue. We're using words without reference to meaning; the whole of the design process is a consideration of all of the issues we've been discussing.

LG 99% of designers have one objective and that is to produce something that will be translated into a commercial situation, so whether it is a commercial issue or a design issue your ultimate objective from that design is to produce something for which there is a requirement, makes it commercial.

DH Is there a requirement for chitosan in fabric, yes there is, although we don't necessarily see the benefits of it.

BM What do you think you can pick out of the research that has been useful, what elements for further development?

DH The only thing that I can hold onto is the value of chitosan as a material, the properties are very interesting which have not necessarily been applied in this research.

LG I struggle a bit with that one. I think that probably the most interesting areas to look at from what you have here, is possibly printing chitosan on substrate. The way we apply it at the moment is either to encapsulate it, to actually cross-link it to cellulose fibre, we haven't yet done any work on printing and that is maybe in an interesting way, the most commercial element of the work. I struggle with everything else, can replicate the aesthetic elements in other products and come up with the same thing aesthetically without its functional properties

GR Perhaps combining the dyeing effects with some of the other properties anti-microbial effects. One other area which you haven't really explored is its ability to complex with heavy metal ions, copper, chromium, but it is used commercially for removing (cleaning) heavy metal ions from effluent. I don't know how you could maybe make use of that property or combine it in some sort of aesthetic effect. Also the fact that it is biodegradable is important in some areas. Whether or how you can actually include it in the market merely for its aesthetic effects I don't know yet.

PP The key elements I like are the resist (traditional techniques like batik) screen printing and graphics. Can you create a link between the jewel-like qualities in the images with screen printing chitosan to create seersucker effects, resist effects or graphics? Also how to control effects or the scale they can be done at on different fabrics. Would LG see the benefit in enhancing her products with decorative work?

LG I would be interested in applying it on the fabric face to reduce coverage, microcapsules increases the novelty factor and the cost. I am curious in the functionality of chitosan in the printed form but see how much functionality you have, look at its durability. Combine functionality, performance and aesthetics.

The session ends with a brief discussion about how the chitosan adheres to the fabric.

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