CHANGEABILITY AS A QUALITY IN TEXTILE DESIGN

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The tendency to wear out and change is inherent in most materials, but – aside from a few exceptions – has been considered to be undesirable by both the industry and consumers. The work presented in this licentiate thesis suggests that, due to change in some form being an inherent property of textiles, it may be viable to look for alternative ways of designing and perceiving textiles that accept change as one of their qualities.

The experimental work explores change as a quality in textiles from the perspective of the textile material, and examines irreversible changes in textiles from three different perspectives: form, use, and teaching changeability in the field of textile design. Changes in colour, pattern, texture, and structure were explored by developing knitted and woven textiles using materials with pronounced changeable properties, and exposing these to various stimuli, such as outdoor conditions and use in workshops.

The experiments suggest that the combination of material and structure defines how textiles change when exposed to various stimuli. A material’s properties define what the textile reacts to and how, while the structure of the textile influences how it changes through the amount and placement of materials. In addition, time and the handling of a textile shape the exact changes that take place.

Designing with changeability as a quality in textiles opens up for alternative possibilities as regards creating expressions, wherein time and change are design variables alongside more traditional qualities, and could encourage a diversity of lifespans and changes over various timescales, better connecting textiles to the properties of their raw materials. This may mean that an alternative method for evaluating quality based on change instead of permanence could be viable, wherein the notion of permanence as a sign of quality in textiles is questioned.
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This licentiate thesis has grown from my personal interest in the textile materials that we are surrounded by in our everyday lives. Textiles come the closest to our skin, are worn on our bodies, and we sleep between them. They are experienced with more than just one sense: sometimes it is enough to look at something to experience what touching it would feel like. Yet we seem to be losing touch with their materiality. Textiles, as with so many other materials, possess an inherent property of changeability: they wear out and change over time and during use, but are generally designed to retain their expression for as long as possible. Changes in the expression of a textile are rarely seen as a sign of good quality, and the development of production techniques has enabled the production of exact copies by the metre. The wide geographical distribution of production and the development of new materials and technologies have, according to Borgmann (2000: 420), made goods readily available and easy to enjoy, but at the same time have abstracted the product and its usage from the efforts of its production. According to Borgmann (Ibid.: 419), this, in turn, leads to paradigmatic consumption, enjoyment without effort, which lessens people’s engagement with material reality. In addition, Albers (2000: 6) notes that through industrialisation we seem to be losing first-hand experience of the material world. Borgmann (1999: 198) describes this loss of our ability to truly engage with material things, and the practices of mastering, understanding, and committing to them, in favour of desiring and consuming commodities, as a “scarcity of focal things”. More recently within the field of fashion and textiles, Edelkoort (2018), among others, claims that, although some signs of change can be seen, the worlds of art and design still have a lack of knowledge of the very materials they work with every day: textiles. These thoughts reflected my own feelings when I observed my surroundings and the textiles and other materials that I come into contact with in and out of my work.

During my Bachelor’s studies in Textile Design, I quickly ran into the issue of what to design in a world that is already filled with things; there did not seem to be a need for another pillowcase. In search of meaning in my own design work, I began looking into sustainability and what that might mean in the context of textile design. I started in the most obvious place: replacing regular cotton with organic, and avoiding synthetic fibres, such as polyester and acrylic, in favour of natural ones, such as wool and linen, in the hope of creating textiles that would last longer. I soon realised that there was more to sustainability in materials than simply choosing natural materials or alternatives whose production processes involved less pollution. Textiles are desired and discarded for their appearance – their colour, pattern, texture, and form – and the actual properties of the materials that they are made of seem to have...
1. INTRODUCTION

little importance. Yet, the properties of raw materials are crucial to how a textile is experienced: how it feels on the body, how it behaves and ages, how long it holds our interest, and how it can eventually be disposed of when it is no longer wanted.

For me, this became tangible through two duvet covers. Both were made of cotton and by the same company, and had the same pattern: one of them was from the 1970s, and the other a reprint from the early 2000s. Visually, the duvet covers were very similar. The real difference emerged during use: the older duvet cover was very soft to sleep under, its surface silky after years of repeated use and washing. The tactile experience of the newer one was the opposite: its surface was rough and prickly against the skin, and this did not improve following years of use and washing. This made it an unattractive choice when changing the bedsheets, in spite of its nice pattern. For me, this was an example of how a material’s actual tactile qualities – how it was experienced using other senses than sight – along with what happened to it in the long term, were as relevant as the type of material when considering a textile’s expression in its entirety. To me, the material of the newer duvet cover had a tangible presence that was difficult to ignore. This raised the question of whether a material’s actual properties should be given more thought in the design process. Perhaps our relationships with materials, both old and new, need to be re-examined, and the properties of materials explored for what they are.

One alternative for reconnecting with the inherent qualities that materials possess could be to re-examine the fundamental notion of a textile’s expression as something static, and approach textile expressions as things that evolve and change over time and during use. Textiles undergo changes during their lifespan; colours may fade, and materials wear out. Wear and tear, however, is usually not considered during a design process, other than attempts to delay signs of ageing and retain the textile’s appearance for as long as possible. This means that the lifespans of a textile object and the material that it is made of are not necessarily the same. Cotton, for example, which in itself is a relatively durable material, can be processed into a low-quality jersey and sewn together hastily, and a t-shirt that is made in this way will likely become physically and aesthetically outdated before its material. A winter coat, on the other hand, is often made out of wool so as to be warm, and its structure is more complicated than that of a t-shirt, making it more expensive. Due to being more expensive to purchase it is replaced less often, making it less trend-sensitive. This suggests that a winter coat can last for a long time, but if it is made out of a low-quality material, such as one with high percentage of acrylic, the material may well wear out before the jacket does. As an everyday example of the mismatch of a material and its intended use, McDonough and Braungart (2002: 105) discuss packaging, such as shampoo bottles; in their current state, these outlast their contents by far, whereas decomposable alternatives could better match the lifespan of the contents. Alternatively, packaging that can be recycled multiple times could be used.

How long should the visual appearance or the structure of a textile remain unchanged, and should all textiles last as long as possible? What happens to them when they eventually begin to show signs of wear and tear? Could textiles and garments, as Fletcher (2014) proposes, have several different lifespans depending on their purpose, and could the properties of materials fit these lifespans? The imbalance between textiles and raw materials eventually became the starting point for the experimental work presented in this thesis.

With a starting point in two basic textile design variables – material and structure – this work focuses on exploring designing with changeability as a quality of textiles. The experiments approached changeability as a quality of textile materials, and explored these textiles in relation to form, use, and teaching in the field of textile design. The aim of the work is to explore how materials with an inherent property of changeability can be combined in textile structures to create textiles with an inbuilt ability to change in various ways, over various timespans, and in response to various stimuli.

This compilation thesis consists of an introduction chapter and four appended publications (two papers, one book chapter, and one exhibition). The practical experimental design work carried out during the studies is presented in the ‘Experiments’ chapter, the first part of which approaches changeability from the perspective of the textile material and introduces all textile materials produced during the studies. The latter part of the chapter explores these materials from the perspective of creating form in garments, in relation to various types of use, and as a material for teaching. The appended publications focus on specific topics relating to changeability in textiles: the basic variables of designing textiles with changeable expressions (Publication I), teaching changeability to fashion and textile design students (Publication II), using textiles with changeable qualities in conjunction with moulding to simultaneously create form and surface in garments (Publication III), and change as another quality of textiles (Publication IV). For the purpose of summing up the outcomes of the research so far, the individual experiments are not presented in chronological or-
der. Instead, they are grouped based on the context in which changeability in textiles is explored. The implications of the experiments and possible future directions for the research are discussed in the ‘Discussion’ chapter.
In this chapter, the roles of materials and structure in the forming of a textile’s expression and qualities are explored, as are approaches to the design of changeable textile expressions and sustainability in the field of fashion and textiles. Material and structure, together with finishing treatments, define a textile’s qualities (Albers 2000: 57). Smart textiles have opened up the design of textiles for changes in expression or function occurring over time and/or through handling. The use of dynamic materials, sensors, and actuators enables textiles to go through various stages or expressions, and sense and react to their surroundings. Increased production and consumption of garments and textiles, their impact on the environment, and violations of workers’ rights connected to production have placed the focus on issues relating to sustainability with regard to improving production processes, end-of-life reuse, recycling, and developing alternative materials. More attention is even being paid to approaching material choices in textiles from the perspective of the context in which the textiles are placed and how this affects the manner in which they change with age and use.

2.1 Materials and techniques – basic textile design knowledge

Knowledge of material qualities and how different textile techniques function are basic notions in textile design (see e.g. Albers 2000: 39; Gale & Kaur 2002: 24). Form, colour, and texture are expressed by combining different materials in textile structures, often adding prints or other finishing treatments. Fibres have various properties relating to aesthetics, comfort, durability, and appearance retention: flax, for example, is stiff and strong in the direction of the fibre, but wrinkles and breaks easily when bent; cotton is durable and comfortable against the skin, but absorbs moisture in cool and damp conditions and may then feel uncomfortable (Kadolph & Marcketti 2017: 42, 70, 77-78). In addition, materials themselves may vary; there are different types of cotton and lengths of cotton fibre, and wool can be treated in different ways, e.g. it can be felted or treated so as to not felt. These properties are dependent on the properties of the fibre and treatments, and various fibres can be blended in yarns depending on the desired qualities of the textile (Wilson 2011: 4). Kadolph and Marcketti (2017: 34) argue that understanding these fibre properties is fundamental to working with textiles and textile products as they affect the aesthetics, durability, appearance retention, and sustainability of textiles.
Textile techniques follow different logics, providing both possibilities and restrictions. The technique of knitting builds on a one-yarn system that creates interlinked loops which form the fabric, while weaving builds on an interlinking two-yarn system (Humphries 2009: 125, 154; Wilson 2011: 11, 13). In non-woven materials, webs of fibres are bonded to one another using various methods, such as mechanical or chemical means or heat (Humphries 2009: 178; Wilson 2011: 15). The one-yarn loop system in knitting provides more flexibility to the material, while woven structures with two interlinking yarns at right angles to each other tend to produce more stable fabrics (Wilson 2011: 27). Printing can be done on all three kinds of materials, and focuses more on the relationship between the pigments and the fabric – which pigment fastens to which fibre, and how the texture or qualities of the fabric influence the print.

Different combinations of fibres, types of yarn, structure, and choice of technique give different qualities, such as drapeability, absorbency, and resistance to abrasion or creasing (Wilson 2011: 16–18). Adding elastane to a knitted single jersey, for example, produces a very elastic fabric that could be used in underwear, while adding polyamide to woollen yarn produces socks that are just as warm but more durable. The properties of the materials and the technique in combination with the proportions in which the materials are utilised define the fabric’s qualities (cf. Albers 2000: 33). There is an interdependence between material and structure: a textile structure may change the properties of a material, such as turning soft silk into stiff taffeta, or the properties of the material may change the structure of the textile, such as a water-soluble yarn turning a double weave into two single fabrics (ibid.).

The properties of a textile and the materials from which it is made affect its entire lifespan, from how it wears and ages to how it can eventually be recycled or reused and the impact on the environment of the textile’s production, maintenance, and discarding. For example, mixed fibres in garments, such as cotton and elastane, are difficult to separate, affecting the reuse and recycling of materials. The properties of the textile can even, to a certain extent, affect how a textile is experienced and how long it remains in use, which relates to perceptions of quality, aesthetic outdating, and societal values and norms with regard to textiles and garments. Properties also suggest different uses: very elastic knitted tricot fabrics are often used in underwear, sportswear, and t-shirts, while varying grades of stable woven fabrics are used in home textiles such as bed linens and pillowcases (Kadolph & Marcketti 2017: 330–331). Even the form of ageing and change are built into textiles through material, structure, and finishing treatments, though these have largely been neglected in the design of textiles, with focus instead being placed on other qualities such as durability, drape, tactile qualities, colour, and pattern.

With regard to changes and wear and tear occurring in textiles, the main focus of quality-control processes has been on prolonging the time before changes occur, i.e. ensuring that the appearance of textiles remains unchanged (see e.g. Bilisik & Yolacan 2009: 1625; Pegram 2000: 90). Kadolph and Marcketti (2017: 25) argue that ‘quality’ in textiles generally refers to the overall characteristics of the textile product – covering both material and e.g. the assembly of the product – and can include aspects such as appearance, use, and performance, comparisons to similar products, and the absence of defects in material and structure. ‘Appearance retention’ is a term that is used to describe how a textile or product retains its original appearance, considering aspects such as whether the textile retains its unused appearance after use and cleaning, and how and when changes such as pilling, stretching, and shrinkage occur (Kadolph & Marcketti 2017: 21). According to Kadolph and Marcketti (2017: 46), “[a] durable textile product should last a period of time adequate for its end use.” Defining what an adequate time of use for a textile product is, however, and what a textile should look like at the end of this period, are likely less straightforward propositions, and should perhaps include some consideration of how the textile has changed. Is the material worn out or has it become aesthetically outdated? What happens after its lifespan is over, and could the textile have more than one lifespan embedded in it? The changes that occur in textiles are often caused as much by physical wear and tear through use as by the passage of time: changes in tastes and values, and the development of technologies. Albers (2000: 39) argues that this “imprint of a time is unavoidable” but also unintentional, and suggests that ‘listing’ to a material’s properties and possibilities and limitation of techniques is a way to design more useful or less trend-sensitive products. From this perspective, taking into account a material’s properties, including how it changes and wears out, may be viable when designing textiles.

2.2 Dynamic materials and designing changeable textile expressions

Almost all materials that are used in textiles or other applications possess an inherent
property of changeability: they wear out or change in some way. Smart materials and textiles have qualities that enable them to sense and react to environmental conditions and stimuli, such as electricity, heat, light, pressure, and moisture (Tao: 2001). Some of these properties are relatively pronounced, as with wool's ability to shrink and felt during washing, and there are ranges of synthetic materials that respond to stimuli such as heat, water, or steam by shrinking, melting, stiffening, or evaporating, or change colour in response to temperature, moisture, or UV light. Some change the properties of the material, altering the properties and/or structure of the textile that they are part of, while others cause primarily visual changes, such as colour-changing pigments or a material's tendency to draw in dirt and pigment from the surroundings or during washing. Everyday stimuli such as light and heat can trigger changes in colour or shape, changing the ways in which textiles can be used and designed and proposing alternative uses, functions, life cycles, and ways of disposal (Quinn 2012: 6-7).

If textiles and their expressions and functions are to be seen as dynamic, their design must be approached from the perspective of changeability. In order to design expressions that are changeable or use materials with the potential for changeability, a designer needs to learn to understand and anticipate these changes, and to develop methods and a vocabulary with which to discuss them (Worbin 2010: 15). Both change and time as design variables have been widely explored in the field of textile design. Collet, for example, takes inspiration from natural functions, exploring how materials wear out at different rates by combining a biodegradable jute and sisal surface with a textured core of nylon to create a Suicidal Pouf, which features a surface and form that gradually changes over time (Collet 2009: 120). Persson (2013) and Dumitrescu's (2013) Touching Loops, knitted materials shrink, stiffen, and break, changing the texture and structure of fabrics. Brock's (2018) Jacquard-woven “self-assembling” textiles use the shrinking properties of various materials in combination with weaves structures to give fabrics three-dimensional form, with minimal finishing after they are removed from the loom, in a manner similar to Issey Miyake’s self-forming, three-dimensional weaves (Howarth 2014a).

Changeable qualities in textiles can be divided into two categories: reversible and irreversible (Worbin 2010: 40). Textiles that exhibit reversible changes have the ability to go back and forth between states. These changes in expression are often primarily visual, and utilise colour-changing pigments; Kooroshnia's (2017: 136, 202) patterns, for example, explore the range of possible colour combinations of leuco dye-based thermochromic inks with different activation temperatures and phases of colour transition. Similarly, Berzowska's (2005: 69-72) colour-changing soft textile display combines thermochromic inks with electronics which control changes in colours and patterns, while Taylor and Robertson's (2016) Digital Lace reinterprets traditional lace in a digitally controlled manner in the form of a colour-changing textile installation which combines optical fibres and thermochromic liquid crystal dyes. In Jansen's (2015: 27) Rhythm Exercise, braided optical-fibre textiles explore the composition of patterns over time through movement and light as part of a textile’s expression, while Worbin et al.’s (2010: 210; Persson 2013: 70) Spår (‘trace’) displays a temporary pattern using electroluminescent wire; here, a carpet lights up in the places where people step. More tangible forms of reversible change have also been explored: Mossé’s (2018: 1) research focuses on self-actuating, shape-changing textiles, with Photovoltaic Mashrabiya consisting of an energy-harvesting textile membrane which responds to changes in light by changing shape, and Adaptive Sediments, which explores the design possibilities of self-actuated shape-changing dielectric elastomers and textiles. Elastane’s ability to stretch and compress can also be said to belong to this category.

Other types of change are irreversible, i.e. the textile’s expression does not return to its starting point (Worbin 2010: 41). Such changes can affect the colour of a textile, such as Blond and Bieber’s (Howarth 2014b) algae-based prints, wherein the colours of a “biodynamic colour palette” change due to sunlight, or Worbin’s (2013) experiments with naturally dyed textiles, the colours and patterns of which evolve over time. Irreversible changes can affect both the appearance and structure of a textile, changing the expression in response to various stimuli. Landin, Persson, and Worbin’s (2008: 139) experiments with a non-chemical burnout technique feature a tablecloth that reacts to incoming phone calls by burning holes in the fabric in random places, building a pattern in the fabric over time. Storey, Ryan, and Belford (2008) investigated water-soluble synthetic PVA in order to explore materials that are capable of dematerialising at the end of their lifespans, such as dissolving bottles that offer a platform for germinating seeds and exquisitely crafted dresses that disappear when they are dipped in water. In the work presented in this thesis, the changeable qualities of textiles are explored in relation to the notion of altering the lifespans and forms of textiles. Therefore, the main focus is on irreversible changes, where the textile’s expression evolves in various ways over time and/or during use due to the inherent changeability of materials.
The inherent changeability of materials has been researched in other fields of design, such as in the context of shoes and tableware. Whiting (Chapman 2012) collaborated with Puma to develop a pair of white sneakers with a hidden pattern that gradually emerges as the shoe becomes dirty, while Wood (University of Brighton 2013) developed a series of coffee mugs and teacups that, through a pattern of glazed and non-glazed areas that are coloured differently during use, create patterns. Similarly, Dixon’s Eco Ware tableware (Fairs 2009: 61) consists of dishes made of biodegradable plastic that gradually wear out until they can eventually be composted. These examples consider the changes that occur in materials in a product context in relation to their expected use. All three turn wear and tear, which is traditionally seen to decrease the value of things, into something that is positive and which adds to the product’s value.

Wear and tear such as pilling, misshaping, or fading of colours occurs naturally in almost all textiles over time and during use. In addition to this gradual process, the aesthetics of wear and tear have been explored in the fields of fashion and textiles. The most typical example is perhaps jeans that, through wear, gain an individual fit and patina; a similar effect is often pursued through various treatments during the production of denim garments (Townsend 2011: 92-93, 105). The Japanese concept of beauty – wabi-sabi – has traditionally appreciated the aesthetics of ageing and imperfection of materials and objects (Koren 2015: 46-50; Sartwell 2004: 83). Also relevant are Japanese kintsugi, wherein broken dishware is mended with exclusive materials such as gold such that the repair works remains visible, and the tradition of boro, in which textiles are mended and patched due to necessity, layer upon layer, to make visible both repairs/wear and tear and an object’s history (Koide & Tsuzuki 2008). Nuno (Sudo & Birnbaum 1997: 15) has explored the aesthetics of ageing in textiles in their boro boro collection by speeding up the ageing process using various treatments of woven fabrics, including dévore, felting, removing warp or weft threads, and burning. Chalayan’s The Tangent Flows (Golbin 2011: 29) consists of a collection of garments that were buried with iron filings sprinkled on them, resulting in a new aesthetic through the process of decomposition. Margiela’s (HYPEBEAST 2018) pre-distressed sneaker, resembling a dirty white sock, combines an alternative aesthetic that is connected to the unwanted, dirty, and embarrassing and fresh out-of-the-box high-end footwear (see Sorkin 2000: 77).

2. BACKGROUND

The inherent changeability of materials has been researched in other fields of design, such as in the context of shoes and tableware. Whiting (Chapman 2012) collaborated with Puma to develop a pair of white sneakers with a hidden pattern that gradually emerges as the shoe becomes dirty, while Wood (University of Brighton 2013) developed a series of coffee mugs and teacups that, through a pattern of glazed and non-glazed areas that are coloured differently during use, create patterns. Similarly, Dixon’s Eco Ware tableware (Fairs 2009: 61) consists of dishes made of biodegradable plastic that gradually wear out until they can eventually be composted. These examples consider the changes that occur in materials in a product context in relation to their expected use. All three turn wear and tear, which is traditionally seen to decrease the value of things, into something that is positive and which adds to the product’s value.

We have expanded the range of fibres used in textiles, but the process of production and consumption has not kept pace with the increased variety of materials. The mixing of fibres and yarns makes end-of-life separation, and thus the reusing or recycling of fibres, challenging (see McDonough & Braungart 2002: 14, 106). For example, polyester and cotton are mixed to form polycotton, which is commonly used in hotel and hospital textiles (Palme et al. 2017: 2). Elastane is mixed with cotton for increased comfort and better fit, and polyamide is blended with wool for increased durability. Similarly, more expensive fibres, such as wool, are often blended with cheaper fibres, such as acrylic. There are also issues connected to the production of fibres: Cotton is durable and renewable, but its production involves a significant environmental burden (Grose 2009: 34); polyester is durable, versatile, and often inexpensive, but has poor comfort properties (Kadolph & Marcketti 2017: 177, 180). Due to its durability, polyester is a long-lived material, in practice often outliving the lifespan of the textile product that it is made into, and as it is a synthetic material does not degrade. However, although it can be recycled as a result of improvements in recycling techniques in recent years, the vast majority of polyester still ends up in landfills or is burned for energy (Ibid.: 183). The widespread use of polyester together with the increased consumption of cheap textiles and garments, has led to discarded textiles clogging landfills.

2.3 Sustainability in the field of textiles

With the rapid expansion of the textile and apparel industry, the range of fibres used has (with the exception of technical textiles) shrunk, with polyester and cotton dominating the market (Grose 2009: 22; Humphries 2009: 23, 25). This has led to a reduced choice of materials for consumers. Garments come in a variety of different styles and are made using a relatively small collection of materials or structures, such as denim or jersey, raising concerns about a future that lacks variety in terms of the aesthetic, tactile, and functional properties that textiles possess (Edelkoort 2015: 2). The mixing of fibres and yarns makes end-of-life separation, and thus the reusing or recycling of fibres, challenging (see McDonough & Braungart 2002: 14, 106). For example, polyester and cotton are mixed to form polycotton, which is commonly used in hotel and hospital textiles (Palme et al. 2017: 2). Elastane is mixed with cotton for increased comfort and better fit, and polyamide is blended with wool for increased durability. Similarly, more expensive fibres, such as wool, are often blended with cheaper fibres, such as acrylic. There are also issues connected to the production of fibres: Cotton is durable and renewable, but its production involves a significant environmental burden (Grose 2009: 34); polyester is durable, versatile, and often inexpensive, but has poor comfort properties (Kadolph & Marcketti 2017: 177, 180).

Due to its durability, polyester is a long-lived material, in practice often outliving the lifespan of the textile product that it is made into, and as it is a synthetic material does not degrade. However, although it can be recycled as a result of improvements in recycling techniques in recent years, the vast majority of polyester still ends up in landfills or is burned for energy (Ibid.: 183). The widespread use of polyester together with the increased consumption of cheap textiles and garments, has led to discarded textiles clogging landfills.

Expanding economies and population growth have increased usage of fossil fuels and natural resources (Blackburn 2009: xxi). These resources are limited, and nothing truly leaves the system even if it is discarded; rather, it changes form, potentially into something that is unusable (McDonough & Braungart 2002: 103). At present, more resources are being used than the planet is capable of producing (Lin et al. 2018: 1). Moreover, according to Rockström et al. (2009) three out of nine planetary boundaries have already been exceeded, with yet-unknown results. Scientists generally agree that climate change is caused by human activities, and has widespread consequences for both humans and natural systems (IPCC 2014: 2). The climate is already approximately 1°C warmer than in the pre-industrial period, and a 1.5 °C increase is
generally agreed on as the critical limit after which the severity of the consequences for the ecosystem and humanity will rise steeply (IPCC 2018). Significant changes in how products are made and how people currently live, travel, and consume are thus needed globally to cut CO2 emissions and prevent a temperature increase of greater than 1.5°C (Ibid.).

The ecological footprint of the whole planet is currently 1.7, meaning that at the rate at which resources are currently being used, 1.7 Earths would be needed to replace these (Lin et al. 2018: 1). In the Western world, this footprint is even larger: the average Finn’s ecological footprint would require 3.6 Earths to sustain it, meaning that the resources required for the living, travelling, and consumption of an average person in Finland are over 3.5 times greater than the raw materials the planet is capable of producing (Earth Overshoot Day 2019; Global Footprint Network 2018). In Finland’s case overconsumption is outweighed by the country’s biocapacity, although this does not indicate that no changes in living and consumption habits are needed; on a global level, overconsumption of the Earth’s resources was reached in 2018 on August 1, with China and almost all of the Western countries using the most resources (Ibid.). This suggests that the current Western lifestyle requires more resources than is sustainable.

In order to sustain the growing world population, changes are needed to balance human needs with the limitations of nature – or, as Brundtland (World Commission on Environment and Development 1987: 8) formulated it, to meet “the needs of the present without compromising the ability of future generations to meet their own needs”. Ever more resources are being used and product lifespans are becoming shorter, as increasing numbers of objects are produced, consumed, and discarded. Growth is connected to production and consumption, requiring fast turnover and leading to products being designed to be replaced in order to sell new ones – a practice that is referred to as “planned obsolescence” (Packard 1961). There is thus a need to rethink how we relate to and use garments, textiles, and raw materials to cut down on ecological impact.

The textile industry is one of the largest in the world and constitutes a global and complex system, with a significant impact on the world economy (Kadolph & Marcketti 2017: 11). The continuous expansion of production and pressure for low prices push standards in the field down with regard to workers’ rights, production processes, and environmental issues (Fletcher & Tham 2015: 2). As a result, it also has a large impact on the environment, which has led to an interest in the impact of the production processes, usage, cleaning, and disposal of textiles, particularly due to the continuous growth of the industry (Blackburn 2009: xxii). In recent years the sustainability issues connected to fashion and textiles have moved from the margins of consciousness to the mainstream, as is evidenced by the creation of The Sustainable Apparel Coalition (2019), which several major garment, apparel, and footwear brands and producers are members of, and which strives to set common guidelines for more sustainable production. The collapse of the Rana Plaza garment factory in Bangladesh drew international attention to the poor conditions experienced by workers in the clothing industry and led to demands for improved worker safety and an end to unfair working conditions such as excessive overtime and low wages (ILO 2019). The Clean Clothes Campaign has demanded that large fast-fashion companies take responsibility for ensuring that their suppliers pay living wages to their workers, but issues still exist (Clean Clothes Campaign 2016).

Production processes have been improved through innovations in material choices, resource flows, and supply-chain efficiency (Fletcher 2014: xv; Wilson 2011: 28). This development is important, although Fletcher (2014: xv-xvi) and Fletcher and Tham (2015: 6) argue that sustainability is far more than simply a production issue: rather, focusing on improving individual components in a system does not address the issues relating to how fashion and textiles are produced and consumed on a systemic level. Even the ‘WWF Living Planet Report 2016’ (WWF 2016: 89) states that solving complex problems such as those relating to environmental and societal issues requires a “deeper understanding” of the causes and drivers within systems. Comprehensive changes in the fashion system are needed and given the complexity of the mechanisms behind and reasons for the production and consumption of garments and textiles there are multiple “possible approaches to change” to take (Fletcher & Tham 2015: 6, 293). This would make, as Collet argues, “[s]ustainability […] a natural part of the design process, not something you try to add to the process later on” (Quinn 2012: 112). Fletcher (2014: xvi) states that how fashion and textiles are perceived and valued on an individual level, in the industry, and generally in society needs to shift for real change to occur. According to Börgmann (2000: 420), consumption may already have become detached from the context of production. Growth too, however, needs to be dissociated from increased consumption (of physical goods, at least), and alternative measures for improvements should be developed (Blackburn 2009: xxi; Fletcher & Tham 2015: 13). Fletcher and Tham (2015: 6) map out some of these alternative roles for fashion, such as the creation of identity,
creative practice, the collective norms of everyday practices, the ‘craft of use’, and longer-lasting clothes.

One example of systems thinking is circular design practices, which have received increasing interest in recent years (see e.g. Goldsworthy 2017: S1963; McDonough & Braungart 2002: 104; Moorhouse & Moorhouse 2017: S1949; Smith, Baille & McHattie 2017: S1938-S1939). In cradle-to-cradle thinking, products are designed to be used in a cyclical manner as raw materials for another purpose, e.g. to safely biodegrade or be up-cycled as new raw materials (McDonough & Braungart 2002: 109). According to Fletcher (2014: 193), considering only how long a material lasts is not sufficient, as its period of active use and maintenance should be taken into account. This in turn is connected to issues such as durability, user behaviour, and appropriateness, suggesting that the most durable option is not always the most sustainable (Ibid). Fletcher (2014: 192-193, 201-202) and Goldsworthy (2017: S1961-S1963) propose that garments could instead have lifespans ranging from short to long, depending on their purpose and intended use. They further suggest that the purpose and actual lifespan of a garment should be considered when choosing materials, meaning that short-lived, recyclable materials, for example, could be used for trend-sensitive garments that will only be used for a brief period of time, while garments that are expected to be used for longer could be made of durable materials that improve with age (Fletcher 2014: 206-214; Goldsworthy 2017: S1961-S1963). This would open up for a diversity of materials, complexities, speeds of life cycles, and uses of garments, similar to the fast and slow rhythms that can be found in nature (Fletcher 2014: 206).

This suggests that how different materials age, change, and can be recycled at the end of their lifespans should be considered during the design process in order to create a better balance between the lifespan of an object and the material that it is made of. McDonough and Braungart (2002: 169-170) argue that materials, particularly blended ones, have wide variety of properties; there are positives and negatives to all options, and – although it is often difficult to know what raw materials a textile is made of and how it was made – choices have to be made with the information that is available. Thus, holistic thinking that considers the probable purposes, uses, lifespans, and recycling of garments and textiles requires knowledge of materials, processes, and finishes on the part of the designer, even though all of the consequences of material and structure choices cannot be anticipated in advance.

Many designers have explored alternative materials of both synthetic and biological origin and reconsidered the inherent properties of traditional natural fibres (Quinn 2012: 110). For example, Crane (Ibid.: 118) and Storey, Ryan, and Belford (2008) explore matching the lifespans of materials to those of the objects that they constitute. Quinn (2012: 118, 126) describes that Crane creates garments using biodegradable and edible hybrid materials in an effort to minimise material waste in fast-changing fashion, while Storey et al. explore materials that can sense and adapt to their surroundings or different needs, such as those that biodegrade quickly. Several projects explore the possibility of growing biodegradable, low-impact materials and products, such as packing and building material or garments made of mycelium. For example, the MycoTEX project explores mycelium as a material for garments in order to match raw materials to their actual period of use (NEFFA 2018). Similarly, Valле Noronha’s (2017) WEAR\WEAR project takes another view on garment lifespans by embedding pre-determined physical and visual alterations into garments through water-soluble PVA threads, non-woven PVA fabrics, and thermochromic and UV-reactive inks to encourage interaction and increase awareness of the materiality of garments.

Solutions for up-cycling materials and using mixed fibres and materials in textiles and garments have also been developed. ‘Blend Re:wind’ is a process that separates and recycles polyester and cotton from mixed polycotton textiles, and was developed as part of the Mistra Fashion Futures programme (Palme 2017: iii; Palme et al. 2017: 1). Regeneration has developed a method called ‘Resortecs’ for disassembling garments and separating zippers and materials for reuse or recycling using stitching thread that dissolves at high temperatures (Resortecs 2019). The Agraloop (Circular Systems 2019a) bio-refinery up-cycles food crop waste into high-value fibres and yarns. The company also produces materials using pre- and post-consumer textile waste (Circular Systems 2019b). Re:newcell (2018) has developed a process for turning used cotton, viscose, and other natural textiles into new fibres. A non-toxic technique called ‘Ioncell’ for up-cycling waste cellulose materials such as old newspaper and cotton textiles into high-quality textile fibres (Asaadi et al. 2016: 3250; Ma, Tanttu, Asaadi, Hummel & Sixta 2018: 44) was developed as part of the Design-Driven Value Chains in the World of Cellulose (DWoC) project. Mono-materials and recyclable and biodegradable alternatives were also developed within the project, including all-cellulose composites and cellulose coatings, such as wholly wood-based cast materials, nanocellulose structures including solid tubes, honeycomb structures, a prototype for a bicycle, and hard cellulose structures laminated with nanocel-
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Lulose for interior architecture that facilitate the recycling and reuse of materials (Härkäsalmi 2018: 47, 50, 52; Kataja & Kääriäinen 2018: 119; Kunnari et al. 2018: 70; Turunen 2018: 76).

If garments and textiles have a lifespan which they change over the course of, the purchase of a textile is, according to Chapman (2005: 133-134), only the first step in its life. For example, a pair of jeans acquires a customised fit through use, adding to the product’s value and narrative (Chapman 2005: 116; Townsend 2011: 93, 98, 105). Riisberg and Grose (2017: 457) have explored the possibility of designing garments that evolve over time, with a focus on including time as a dimension in the design, production, and usage of garments in order to suggest alternative modes of fashion which are decoupled from declining resources. Chapman (2005: 116) and Niinimäki (2011: 84) argue that improving or customising textiles or garments through extended use could also encourage a more personal relationship with them, and prevent their early disposal.

Such an approach may, however, require a reconsideration of how quality in textiles is defined (Chapman 2005: 130-131). Some changes, such as the softening and appearance of a patina that occur in leather during use, how jeans form themselves on the wearer through use, and how old bedsheets soften through repeated washing, are generally seen as desirable or are even imitated in new textiles or garments through pre-treatments such as stone washing or sand blowing (see e.g. Chapman, 2005: 131; Townsend 2011: 93). Most use- and age-related changes are not, however, generally seen to be acceptable: pilling, misshaping, fading of colours, stains, and holes are generally felt to decrease the value of a textile (Chapman 2005: 129). Stains and other markers of past events in textiles and garments are generally unwanted (Sorkin 2000: 77, 79). Such signs of wear and tear often render a textile aesthetically outdated before it is physically worn out, and there may be other, subtler reasons behind aesthetic outdatedness, relating to social norms, trends, colours, cuts, surfaces, patterns, and finishes, all of which can lead to styles being felt to be either new or outdated (Chapman 2005: 131, 133; Cooper 1961). Durability is seen as a sign of good quality: Dixon, for example, has reported that his Eco Ware (biodegradable dishware with a lifespan of approximately five years) has met with resistance from consumers who feel that a designer product should not have a limited lifespan (Fairs 2009: 61).

The work presented in this thesis attempts to participate in the discussion regarding sustainability in textiles by exploring the idea of designing with changeability as a textile quality. This is explored through the inherent property of changeability of materials in combination with textile structures, suggesting an alternative perspective on textiles in which they are seen as changeable, rather than static.
The work presented in this licentiate thesis is experimental design research that explores an alternative way to relate to and design textiles as changeable objects through material and textile structure. It builds on experimental practical work carried out in the Weaving Lab at the Swedish School of Textiles, involving treating fabrics in various ways, making prototypes, and holding workshops. Experimental practical work forms the core of the work presented in this thesis (see also Koskinen, Redström, Wensveen, Binder & Zimmerman 2011: 5; Seago & Dunne 1999: 16). The sometimes-unexpected outcomes of the practical experiments influenced the direction of the individual projects, but the process of conducting these experiments also influenced how the research unfolded, refining the research question and providing suggestions as regards areas of further inquiry. For example, the discovery that relatively small differences in material and structure in woven textiles led to differences in how their expression changed when exposed to outdoor conditions and usage in workshops in turn led to the definition of the basic design variables of embedding changeability in textiles on the level of structure: material and structure (see Publication I). The discovery that variations in the conditions under which materials were dyed caused differences in how they were dyed suggested the possibility of textiles developing different expressions from one starting point (see Publication IV). Similarly, the different ways that the expression of water-reactive knitted fabrics could be formed by fashion design students, together with a woven sample that could be treated in various ways, provided a context relating to how the textile is changed as the third primary factor with regard to changes that occur in the expression and/or structure of a textile (see Publication I). Schön (2003: 78, 135) describes these unintended consequences of actions as a situation’s “back talk” to the practitioner, who may then reframe the situation by reflecting on them, opening up for new knowledge and alternative directions for further exploration, thus defining “designing as a conversation with the materials of a situation”.

The majority of the experiments were conducted on an industrial Jacquard loom, although some of the experiments used knitting machines or hand looms. Working on an industrial loom, as compared to working with a hand loom, allows one to work with pattern weaving and large bindings, and for variations of bindings to be developed and tested flexibly. Hand-weaving, on the other hand, allows for flexibility as regards material choices and the specifics of the sample during weaving. Developing bindings using computer software instead of paper allows multiple layers to be designed and multiple bindings to be combined in different areas of the weave, facilitating the creation of both patterns and textures. Developing bindings for hand weaving,
3. Method

on the other hand, allows complicated structures to be fitted in simple forms. Rather than seeing hand weaving and industrial weaving as opposing techniques, this research follows Albers (Danilowitz 2000: xii) in seeing the two as complementary, offering different possibilities and restrictions that suit different purposes. The core of both techniques is the dialogue between the material and the structure; as Albers (2000: 33) notes, the structure of a fabric can alter the properties of a material, and material properties, together with structure, allow for new qualities to emerge in fabrics. The weaver’s task, then, is to explore this relationship by learning to listen to the material and the tools in order to develop novel expressions and functions in textiles (Albers 2000: 26).

Exploring material combinations in structural weaving and knitting techniques formed the basis of the experimental work. These design variables – material and technique, which are characteristic of textile design – and the qualities that they provide to fabrics, may be seen as Schön’s (2003: 270) “constants”: the media and language used to conduct and describe the experiments, the evaluation of and reflection on the framing of the problem and the outcomes, and the overall theories by which phenomena are made sense of. These give the practitioner a grounding in which their reflective conversation takes place (Schön 2003: 271, 273). The researcher’s appreciative system has an internal logic; in the case of this work, this logic relates to textile structure and the resulting qualities in textiles, within which the methods chosen, decisions made, conclusions drawn, and results achieved can be considered to be objective – although this may not be the case when considered from a different frame of reference, such as that of another discipline (Hallnäs & Redström 2006: 130; Schön 2003: 272). For example, with regard to the possibilities and limitations of the weaving technique, it may make sense to construct a fabric in a certain way, or to choose certain materials. An interior architect, on the other hand, may look at the same fabric from the perspective of how it fits within a space, or whether it is e.g. flame retardant, and thus place entirely different requirements on it. Similarly, a product designer choosing a fabric for a product may approach the fabric based solely on its durability, colour, and/or pattern.

Textiles is a field of research in its own right, but they are often used as a raw material for something else, and so placed in a context – garments, interiors, vehicles, architecture, landscaping, interaction design, healthcare, and so on. The explorations presented in this thesis touch upon different textile contexts – creating form in garments, and how textiles can change or evolve during use and over time. Two collaborations were carried out as part of the research: one explored the context of use of textiles with Linda Worbin from IKEA of Sweden, and the other explored their form-giving qualities in the context of garments with fashion designer and fellow PhD student Karin Peterson (see the ‘Experiments’ chapter and Publication III). In addition, holding workshops with design students on the subject of changeable materials was part of my practice during my PhD studies so far, as the materials I work with are often quite open and can be used as raw materials in several contexts by others. The workshops undertaken with students exemplified the idea that how materials are treated and formed has an impact on the changes in their expression, and what they are composed of presents certain possibilities and limitations with regard to possible applications (see Publications I and II).

However, practical experimental work alone is not sufficient, and reflection is required in order to conduct a systematic exploration. As Biggs (2002: 113) suggests, both writing and making are needed in practice-based research to “represent a whole concept”. In my work, the practical experimental work and writing have alternated with each other during the process. I explore through practice, developing bindings or knit structures on computer software and using hand looms and knitting machines to fine-tune quantities, combinations, and placements of the materials in the structure. Writing is a way to reflect on these experiments – a process of formulating and defining what the experiments are about – and a way of placing them in a context in which they can be evaluated, which Hallnäs (2010) and Biggs (2002) suggest is necessary for arriving at valid conclusions. The process then becomes, as Hallnäs (2010: 110) argues, an interplay between exploratory, practical work in which examples are found and conceptual work involving writing and formulating principles.
The experiments presented in this licentiate thesis suggest that, when choosing a material and structure, textile designers should take into consideration a material’s potential for change and ageing, how the textile structure may either limit or enhance this changeability, and how these variables affect the textile’s expression, structure, and function. In this work, circularity is approached from the perspective of the textile continuously building up its expression – and in some cases function – and it is proposed that designers accept and work with change as a part of a textile’s expression. Textiles usually change over time and during use, and consciously designing with change as an inherent quality could encourage a diversity of lifespans and changes over various timescales, better connecting textiles to the properties of their raw materials.

Designing with changeability as a quality in textiles has been approached from the perspective of the textile material, focusing on the interplay between material and structure in creating textiles with the inherent capability to undergo changes in expression or structure over various timespans. Therefore, the focus was on exploring irreversible changes that build on a textile’s expression continuously, rather than reversible changes. The experiments explored changeability as a quality in textiles through gradual changes in colours and patterns, as well as tangible, more explicit, changes in texture, structure, and physical dimensions. The experiments further explored changeability as a quality in textiles in three different contexts; as materials for creating form, during use, and in relation to teaching changeability.

The work presented in this thesis primarily explores materials that possess pronounced properties related to change, such as heat- and water-reactive shrinking and hardening yarns. Subtle changes in expression were explored through the accumulation of colour or stains on materials, but in these experiments materials that were known to absorb colours and pigments, such as wool and paper yarn, were generally used. The materials were chosen for the explorations due to their potential to open up for alternative expressions and functions in textiles based on how their properties can be modified by alternative, easily accessible, and everyday means, at several stages after a textile has left the loom or knitting machine.

Materials with more pronounced properties relating to change were combined with less reactive materials, primarily using the structural techniques of knitting and weaving. These techniques allow for change to be built into the textile on the level of the structure, influencing e.g. how a woven pattern may change due to its materials
changing, in which direction materials may shrink, where layers may detach from one another, and how these changes affect the overall expression and structure of a textile. Working with several independent but interlinked yarn systems in weaving allows for layers of materials to be bound together in certain areas of the structure, while not meeting in others. Due to the individual warp and weft threads, parts of the structure can be removed without breaking the overall structure. Weaving also allows dynamic materials to be inserted in specific places in the structure in both the warp and weft directions, enabling control over which part of the fabric is changed and how. Many of the explorations were conducted on an industrial Jacquard loom, which enabled the creation of more complex structures and explorations of patterns that combined different materials in different areas of the fabric through the ability to control each thread in a repeat individually. Some experiments were also conducted using knitting. The one-loop system in knitting allows materials to be combined flexibly, in that all of the materials of the structure can be changed, facilitating e.g. breaking lines in the fabric.

The following chapter describes the experiments from two perspectives – designing the quality of changeability in textiles, and applying the quality of changeability in textiles – and so are not presented in chronological order. The division is based on the duality of textiles; they are a thing or material in themselves, and can be used for different purposes, as a material to make things (Hallnäs 2018). The first part of the chapter introduces all of the textile materials developed during the various projects. Change was approached from the perspective of the textile material – changes in the surface expression or structure of the textile, relating to e.g. colour, pattern, texture, tactile qualities, opacity, length, thickness, or number of layers. The second part places the changeable qualities of textile materials in three different contexts, exploring the materials presented in the first part from the perspectives of creating form in garments, various types of use, and as a material for teaching. The different perspectives highlight how various types of change in textiles may be designed in textiles, and explore the possible ways in which these might be applied in different contexts.

All of the changes that occurred in the materials were irreversible, suggesting an alternative view on textiles as objects which are generally considered to be fundamentally changeable. Some of the experiments described in the first part and in the categories of form and use are not further discussed in the appended publications, and so are presented here in greater detail.

4.1 Designing the quality of changeability in textiles

This section approaches the quality of changeability in textiles with a focus on the textile material. The changes that occurred in the colour, texture, pattern, and/or structure of all of the textiles were irreversible, meaning that their expressions were built up in linear increments. These changes, however, took one of several paths and forms from one starting point, depending on the conditions the materials were exposed to. The changes in the expression and structure of the textiles were approached without specific applications or contexts in mind, even though possible changes were explored by placing textiles in various contexts to see how they were affected.

4.1.1 Initial experiments with material and structure

The initial experiments explored changes in the visual expression, texture, tactile qualities, and physical properties of textiles that were exposed to various types of stimuli, and defined the basic elements involved in creating textile expressions with embedded changeable qualities: material and structure (see Publication I). Woven and knitted textiles with a selection of different changeable qualities were developed for the experiments (see Fig. 4 for an overview and Figs. 1-3 for technical details).

Materials with the inherent property of changeability – ranging from water-reactive, shrinking, melting, and hardening PVA yarns which created explicit changes in expression to uncoated copper wire, which undergoes subtler changes in colour when it comes into contact with oxygen – were used in the experiments. The PVA was actively formed by spraying or pouring water onto it, or ‘painting’ or steaming using water, as well as by leaving it out in the rain. The uncoated copper changed colour gradually when it was left outdoors. The yarns were combined with other, less reactive materials such as cotton in woven and knitted textiles.

The first experiment compared different treatments and durations of exposure using knitted, uncoated copper. A piece of the material was buried for one year, and three other pieces were exposed to vinegar for one day, two months, and one year, respectively, creating a turquoise patina (see Fig. 5 for images of all of the samples). The samples underwent a variety of gradated changes, ranging from subtle changes in
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colour to total transformation of the copper wire into hard turquoise crystals.

In the second experiment, two samples of industrially woven fabrics of the same density and weft and warp material (uncoated copper in the weft and cotton in the warp) were woven to compare the influence of structure on changes in expression; one had a satin binding, and the other had a rep weave binding (Figs. 6-7). In the second part of this experiment, the satin binding was used to produce two samples with different weft materials – PVA and uncoated copper in one and only PVA in the other – to compare how material combinations affect changes in a textile’s expression (Figs. 8-9). The textiles were hung outdoors for one month (see Fig. 1 for details and Figs. 6-9 for images of all of the samples).

In the third experiment, a triple-layered weave combining a water-reactive upper layer with a hidden stainless steel middle layer was woven, and pieces of the textile were treated in one of three ways – hung outdoors for one month, sprayed with water, and machine washed at 40°C – to explore the influence of the chosen stimulus on the resulting changes in expression (see Fig. 2 for details and Figs. 10-13 for images of the samples).

After exposure to different stimuli, the samples used in experiments described above exhibited different types of change in visual and tactile expression, relating primarily to textural and tactile qualities. The appearance of these changes varied depending on the material and structure of the textile. For example, looser woven structures were changed by wind more than tighter ones, and a sample combining water-reactive shrinking yarn with non-shrinkable materials gained a new texture due to the fact that only some parts of the weave shrank (Figs. 7, 9).

The fourth experiment explored how material properties related to change influence changes in a textile’s expression and structure when the material is more actively formed, and so three knitted materials with different changeable qualities were developed. The fabrics contained water-reactive PVA, which was combined with less reactive materials in varying ratios and structures, ranging from pure PVA and single jersey to a two-thread fleece combining stainless steel and PVA in a roughly even ratio, to a slipstitch pattern in wool and stainless steel with single threads of PVA holding parts of the structure together (see Fig. 3 for details and Figs. 14-17 for images of the materials). The fabrics were used in workshops with students and a form experiment (see Sections 4.2.3 and 4.2.1.1).
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Fig. 2: Details of the woven material used in the third experiment.

**The third experiment - Comparing treatments**

<table>
<thead>
<tr>
<th>Type of structure</th>
<th>Binding</th>
<th>Material weft</th>
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<tbody>
<tr>
<td></td>
<td>woven</td>
<td>triple-layered weave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PVA (purple), stainless steel orange</td>
</tr>
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<td></td>
<td></td>
<td>and cotton (black)</td>
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Fig. 3: Details of the knitted materials used in the fourth experiment.

**PVA single jersey**
- **Type of structure**: knitted
- **Structure**: single jersey
- **Material**: PVA (purple line)

**PVA and stainless steel two-thread fleece**
- **Type of structure**: knitted fleece
- **Structure**: two-thread fleece
- **Material**: single jersey base PVA (purple line), fleece thread stainless steel (black line)

**A wool, stainless steel, and PVA slipstitch pattern**
- **Type of structure**: knitted
- **Structure**: slipstitch pattern
- **Material**: single jersey base wool with stainless steel (black line), thread connecting the ridges PVA (purple dot)
The outcomes of the experiments described above show that material and structure can be used to create changeable expressions in textiles. Both the choice of materials and how they are combined in the structure of a textile influence how the textile changes. The material’s qualities and structure can also indicate how the textile may change; in the second experiment (Fig. 9), a surface which combined a stiff, non-shrinking material with a shrinking one was prone to developing a hairy texture as a result of shrinking. Similarly, a stiff copper wire was combined with a loosely woven satin, leading to a wavy texture (Fig. 7).

The qualities of the three fabrics in the fourth experiment ranged from a total breaking and melting of the fabric to a transformation from soft to hard, entirely changing its visual and tactile expression, and a fabric that was possible to stretch in terms of length. The properties of all of the materials were easily manipulated with water or steam.

In the case of the PVA single jersey, the material structure did not limit the PVA’s ability to shrink and melt, leading to the entire fabric shrinking and becoming hard and akin to plastic, and translucent when exposed to water. The stainless steel in the double-thread fleece prevented the PVA from shrinking in the horizontal direction, leading to the fabric shrinking primarily vertically and breaking horizontally between the lines of the steel wire. The slipstitch pattern in wool prevented the occurrence of loose stitches when the PVA thread dissolved, and so the structure transformed from a gathered roll-pattern form to regular single jersey. This suggests that both the material and structure of a textile influence the changes that occur to varying degrees.
Fig. 5: Uncoated copper. The fresh, minty smell of vinegar seeping into the copper's pores over one year of submersion is evident in the images. The copper surface shows a gradual change from a metallic shine to a duller, more corroded state after one year of submersion in vinegar against the background.

No treatment, buried for one year, submerged in vinegar for one day, submerged in vinegar for two months, then submerged in vinegar again for one year.
Fig 6: Effect of structure: Copper rip weave before and after one month outdoors.
Fig. 7. Effect of structure: Copper satin before and after one month outdoors.
Fig. 8: Effect of material: PVA/cotton before and after one month outdoors.
Fig. 9: Effect of material: PVA/copper/cotton before and after one month outdoors.
Fig. 11: Comparing treatments: Sprayed with water.
Fig. 12: Comparing treatments: One month outdoors.
Fig. 13: Comparing treatments: Machine was-hed at 40°c.
Fig. 15: PVA single jersey – a fabric that can break and melt entirely, capable of changing from soft to hard.
Fig. 16: PVA and stainless steel tow thread fleece – a multifunctional changes in visual and tactile expression.
Fig. 17: A wool, stainless steel, and PVA slipstitch pattern—a technology that can be directly layered.
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4.1.2 Further experiments with different types of change

Further experiments explored the design of multiple expressions from one starting point, with a focus on visual changes in plain, woven fabrics and Jacquard-woven patterns (see Publication IV). Two methods were used to create visual changes in woven textiles: dyeing patterns through degradation (burial underground and immersion in salt water) and adding colour or pattern to the textile through use (usage of prototypes in various public and private contexts) (see Fig. 22 for an overview). The experiments explored both intentional changes, such as dyeing during washing, and unintentional changes, such as stains and marks occurring through use.

Two Jacquard-patterned double-face fabrics combining cellulose-based (cotton, paper), protein-based (wool), and synthetic (polyester) yarns were woven for the experiments. The triangle-patterned fabric consisted of multiple triangles, each of a different material (See Fig. 19 for details and Figs. 18, 25-35 for images of the samples). The circle-patterned fabric combined in a hopsack weave combined two materials in each part of the pattern (See Fig. 20 for details and Figs. 21, 36-54 for images of the samples). Pieces of plain weft-faced satin were woven in two types of paper yarn, wool, linen, and uncoated copper. The materials were chosen because of their abilities to draw in colour to different extents, and all were, with the exception of the copper wire, white in their original states. The fabrics were then either buried or immersed in the Baltic Sea for two months or used as textile products in various everyday situations, such as covers for seats in two public environments, lab coats in a textile printing lab, and a bag and an apron for private use (Figs. 23-24, 34-35, 46). The Jacquard-patterned fabrics were also washed with black, blue, and yellow laundry to test how the various parts of the pattern were dyed (Figs. 31-33 and 52-54). The treatments resulted in different changes in the expressions of all of the textiles.

Comments

The results of the experiments show that textiles can develop several different expressions from one starting point, depending on their material and structure and what they are subjected to. They further suggest that these aspects should be considered when designing textiles in order to factor in the inherent quality of changeability as part of a textile’s expression.

The materials reacted to stimuli differently; for example, in some samples the paper yarn was dyed most strongly, while in others the wool gained the most colour (Figs. 27, 30-31 and 44-45). The shade that the material acquired also depended on what it was exposed to: wool acquired a green shade outdoors, and a reddish-brown one in rusty water (Figs. 27, 29 and 30). Such differences in colour absorption could be seen in both the outdoor-dyed fabrics and washing-dyed samples.

In the prototypes, the changes in colour were generally subtle and local, and concentrated around the areas that were handled the most. In some cases these traces of use enhanced the existing pattern of the fabric, e.g. by being more visible around the edges of the pattern (Fig. 34). The results of all of the experiments, together with the workshops, also established the relationship between the changeable qualities of textiles and the context in which they are used, and how together they affect how a textile changes.

Fig. 18: The triangle fabric’s eight colour schemes: (a) Non-treated fabric, (b) after two months underwater, (c) after two months underground, (d) after two days in water with oxidised iron powder, (e) after four weeks in use as a bag, and having been washed with (f) yellow, (g) blue, and (h) black laundry.
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Fig. 19: Details of the triangle-patterned fabric.

Triangle pattern - details

- Type of structure: woven
- Binding: double-faced Jacquard pattern in weft-faced satin with an additional weft in either uncoated copper or cotton wool (black area), polyester (white area), paper yarn (white area), uncoated copper/cotton (black line)
- Material weft: cotton

Fig. 20: Details of the circle-patterned fabric.

Circle pattern - details

- Type of structure: woven
- Binding: double-faced Jacquard pattern in basket weave at the front and plain weave at the back
- Material: polyester/wool, polyester/paper yarn, paper yarn/linen, wool/paper yarn
- Material warp: cotton
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Fig. 21: The circle fabric’s four material variations (base material/circle): Variation 1 (polyester/wool), Variation 2 (polyester/paper), Variation 3 (paper/linen), Variation 4 (wool/paper). And their colour schemes (a) Non-treated fabric, (b) after two months underground, (c) after two months underwater, and having been washed with (d) black, (e) blue, and (f) yellow laundry, (g) after after two months in use as a seat cushion of a conference chair.
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![Experiments Table]

*Fig. 22: An overview of the experiments.*
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Fig. 23: Dyeing patterns through degradation.

Fig. 24: Adding colour and pattern through use.
Fig. 25: The triangle fabric non-treated.
Fig. 26: The triangle fabric buried for two months, unwashed.
Fig. 27: The triangle fabric buried for two months, washed.
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Fig. 31: The triangle fabric machine washed at 30°C with black laundry.
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Fig. 38: The circle fabric, variation 1 (polyester/wool): submerged in the Baltic Sea for two months; unwashed.
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Fig. 41: The circle fabric, variation 2 (polyester/paper) submerged in the Baltic Sea for two months, unwashed.
Fig. 41: The circle fabric, variation 2 (polyester/paper), submerged in the Baltic Sea for two months, without...
Fig. 42: The circle fabric, variation 3 [paper/linen, non-treated].
Fig. 43: The circle table, variation 3 (paper/linen). Buried for two months, unwashed.
Fig. 44: The circle taapa, variation 3 (paper/linen), buried for two months, washed.
Fig. 45: The circle tablet, variation 3 (paper/linen): submerged at the Baltic Sea for two months, unwashed.
Fig. 45: The circle tablet, variation 3, paper/linen, submerged in the Baltic Sea for two months, washed.
Fig. 46: The circle fabric, variation 3, used as a seat cushion for a conference chair for 2 months.
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Fig. 48: The circle fabric, variation 4 (wool/paper): buried for two months, unwashed.
Fig. 49: The circle fabric, variation 4 (wool/paper): buried for two months, washed.
Fig. 50: The circle fabric, variation 4 (wool/paper) submerged in the Baltic Sea for two-months, unwashed.
Fig. 51: The circle fabric, variation 4 (wool/paper) submerged in the Baltic Sea for two months washed.
Fig. 52: The circle fabric, variations 1, 2, 3 and 4: machine washed at 30°C with black laundry.
Fig. 53: The circle fabric, variations 1 and 2: machine washed at 30°C with blue laundry.
Fig. 54: The circle fabric, variations 3 and 4: machine washed at 30°C with yellow laundry.
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Designing textiles which have the ability to undergo multiple stages of transformation of expression and structure by altering or removing parts of the textile’s structure were then explored. In order to facilitate easy manipulation of the textiles’ qualities, dynamic materials that react to water and heat were used in the experiments. This allowed for the structure of the textiles to be altered by everyday means, such as washing, ironing, and steaming.

A heat-reactive yarn – the breaking and evaporating polyamide 6 and 66 alloy yarn Grilon – and a water-reactive, shrinking, and melting polyvinyl alcohol (PVA) yarn were used to create single-, double-, and triple-layered industrially woven structures with relatively inert base materials (paper yarn and cotton). As the yarns did not all react to the same stimuli, parts of the fabric were changed, while others did not. The heat-reactive yarns, for example, could be washed without changing, while the water-reactive yarn did not react to ironing (Table 1).

Together, the materials provided a toolkit for shrinking, forming, and dividing textile structures in order to alter a fabric’s texture, size, volume, division, thickness, or opacity. Based on the different properties of the yarns a list of possible changes was compiled, including: increases in size (or vice versa), increases in thickness (or vice versa), and changes in opacity, stiffness, texture, and the number of colours and layers.

With the possible changes as a starting point for the experimentation, fabrics whose structure and expression were possible to alter over different stages using heat and water (in the form of e.g. ironing, steaming, or washing) were developed. Experiments that combined dynamic materials with different base materials and in different proportions were conducted. The tested materials included either thin, high-twist paper yarn or cotton as the base weft, and cotton as the warp. Linen was also tested, but the paper yarn and cotton more effectively enhanced the structural changes caused by the shrinking and breaking yarns. Cotton produced softer changes in texture while paper resulted in clear, dense, thick textures.

The proportion of dynamic material to base material proved to be crucial; too little of the former meant that the fabric did not have the strength to e.g. draw together. In the flat to textured paper fabric, for example, two threads of PVA were twisted together in order to ensure that there was sufficient material for the change to be pronounced.

<table>
<thead>
<tr>
<th>Yarn</th>
<th>Stimulus</th>
<th>Washing 30°C</th>
<th>Washing 40°C</th>
<th>Washing 60°C</th>
<th>Steaming</th>
<th>Ironing</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVA 60°C</td>
<td>yes, shrinks and melts</td>
<td>yes, shrinks</td>
<td>yes, melts completely</td>
<td>yes, shrinks</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Grilon LT</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes, breaks slightly</td>
<td>yes, breaks slightly</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: The reactivity of the dynamic materials.

The final fabrics in the collection included (see Fig. 55 for details):

The paper weave with even texture

A paper yarn and cotton double weave, with a PVA binding weft floating on the reverse (Figs. 56, 58-63). A material that can, as a result of the application of water and heat in the form of e.g. spraying, dipping, machine washing, or steaming, change from flat to various textures, and from thin to thick. In its textured state, the material can be manipulated by hand to break the floats in specific places. The material can also be divided into two separate layers.

The yellow weave

A triple-layered cotton weave with a Grilon binding weft between the first and the second layers and a PVA binding weft between the second and the third layers (Figs. 56, 64-67). A semi-thick, flat material that can, as a result of the application of heat, water, or both in the form of e.g. machine washing, steaming, or ironing, become textured and divide into two or three fabrics with a different colour and texture.

The paper weave with uneven texture

A paper yarn and cotton double weave with a PVA binding weft floating on one side (Figs. 57, 68-69). A material that can, as a result of the application of water and heat in the form of e.g. spraying, dipping, machine washing, or steaming, change from flat to various uneven textured surfaces and from thin to thick. The material can be manipulated by hand to break the floats in specific places after shrinking. The material can also be divided into two separate fabrics as the last step.
The paper terry cloth

A paper yarn and cotton double weave with a PVA binding weft between the layers (Figs. 57, 70-72). The flat fabric can be shrunk into a thicker, rough terry cloth surface using water via e.g. steaming, spraying, or machine washing. Its texture can, after shrinking, be manipulated by hand by break the PVA in specific places. The material can be divided into two separate fabrics.

Comments

Swatches of the fabrics were tested by subjecting them to ironing, steaming, and machine washing at 30, 40, and 60°C. Combinations of different treatments were also tested, for example steaming then washing at 30°C, and washing at 30°C then steaming. The fabrics were used in further experiments regarding form and use, which are presented in the next part of this chapter (Sections 4.2.1.1. and 4.2.2.2.).

Three of the fabrics – the even- and uneven-textured paper and the paper terry cloth – had the same raw materials but different structures. They were woven on a Jacquard loom and consisted of cotton in the warp, paper yarn as the main weft, and PVA as the main ingredient that caused the changes in expression and structure. All three played with variations on a double weave with a binding weft between the layers (Fig. 55). Slight modifications in the placement of the binding points between the two layers produced three different textured surfaces when the fabrics shrank (Figs. 61, 69, 71). This suggests that relatively small adjustments in material choice and composition may lead to noticeable differences in the resulting expression and function of the textile.

The outcomes of this experiment thus far show that textiles can go through several stages in which their form is altered, and suggest that it is possible to embed these stages in a textile's structure. Depending on the material and structure, and how and in which order the textile is treated, the expressions or stages take different paths as regards their development. The possibility of e.g. one part of the textile reacting to heat and another to water while leaving the rest unchanged could be explored further.

Fig. 55: Details of the four woven fabrics in the collection.
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Fig. 56: The paper weave with even texture: (a) Non-treated fabric, (b) steam and ironed, (c) ironed and machine washed at 30°C, (d) steam and machine washed at 30°C, (e) machine washed at 30°C, and steamed and manipulated by hand. The yellow weave: (a) Non-treated fabric, (b) steam and ironed, (c) machine washed at 30°C, (d) machine washed at 40°C and steamed.

Fig. 57: The paper weave with uneven texture: (a) Non-treated fabric, (b) machine washed at 30°C. The paper terry cloth: (a) Non-treated fabric, (b) machine washed at 30°C, (c) machine washed at 60°C.
Fig. 58: The paper weave with even texture: no treatment.
Fig. 59: The paper weave with even texture: steaming and ironing.
Fig. 60: The paper weave with even texture: ironed and machine washed at 30°C.
Fig. 61. The paper weave with even texture; steamed and machine washed at 30°C.
Fig. 62: The paper weave with even texture: machine washed at 60°C.
Fig. 63: The paper weave with even texture: machine washed at 30°C, steamed and manipulated by hand.
Fig. 64: The yellow weave: no treatment.
Fig. 65: The yellow weave: ironing and steam ing.
Fig. 66: The yellow weave: machine washed at 40°C and steam heated.
Fig. 67: The yellow weave: machine washed at 30°C.
Fig. 68: The paper weave with uneven texture: no treatment.
Fig. 69: The paper weave with uneven texture: machine washed at 30°C.
Fig. 70: The paper terry cloth: no treatment.
Fig. 71: The paper terry cloth: machine washed at 30°C.
Fig. 72: The paper terry cloth: machine washed at 40°C.
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4.2 Utilising changeability in textiles

In this part, some of the textiles presented in the previous parts are explored from three different perspectives: creating form in garments, usage, and teaching changeability to design students. Textiles are often placed in a context – they are a raw material for something, and this context directs and influences which conditions and types of wear and tear the textile will experience, and the types of changes that are likely to occur as a consequence. Garments, interiors, and textile products are common applications of textiles. In these contexts, a textile will generally experience stimuli such as water – in the form of washing, steaming, spillages, and rain – UV light from the sun, heat from ironing and steaming, and wear in the form of rubbing and stretching when being worn, slept in, and sat on. Textiles are also used in teaching in textile and fashion design, where they form a central part of the practice.

4.2.1. Changeable materials from the perspective of form

Textiles whose structure and tactile and physical properties can change from soft, loose-fitting, and drapeable to hard, close-fitting, and stiff through shrinkage, texturising, or hardening can open up for various forming possibilities. Textiles can be formed around objects, or their ability to hold their form after finishing treatments can be used to create volume and form. Garments are one common application area for textiles, where form is explored in relation to the body. Two examples of explorations of changeable qualities in textiles as a means of creating form in the context of garments are presented in the following sections.
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4.2.1.1 Surface and form in garments

The first experiment, which was carried out in collaboration with Karin Peterson, explored the expressional possibilities of woven textiles with inherent form-giving qualities in conjunction with moulds for the simultaneous creation of surface and form in garment making (see Publication III). Three varieties of woven fabrics, which combined water-reactive PVA as a binding weft and a paper yarn and cotton double weave, were used in the experiments. The fabrics used in the exploration are presented in greater detail in the previous section (see pages 150-185).

The fabrics, which were all flat and smooth in their initial states, developed different textured surfaces. One had an even, striped texture when shrinking, one had an uneven, textured surface when shrinking, and one had an even, thick terry cloth surface when it had shrunk. The qualities of the fabrics could be manipulated with water, which shrank and stretched the textile and divided the layers into channels, pockets, or two fabrics. By changing the texture and thickness of the materials, they could be formed either in specific places on the material or as whole surfaces.

T-shirts and dresses were experimented with using these materials and two full-size moulds: one of a regular t-shirt/torso shape, and one with a free, irregular dress shape (Fig. 73). The fabrics were sewn together at the edges to form rough bag-shaped forms, which were placed on the moulds and then sprayed with water to explore the forms and surfaces that were created through the combination of the fabric’s qualities and the shape of the mould. The shrinking behaviour of the fabrics was tested beforehand in order to adjust the size of the bag-shaped forms to the size of the mould, such that an optimal fit could be acquired in order to transfer the shape of the mould to the garment. As the fabric shrank in the weft direction, both horizontal and diagonal placements of the fabric were explored to investigate how they affected the form, fit, and drape of the moulded garment.

In total, six garment prototypes were made: one t-shirt and one dress made of the fabric with an even texture and horizontal placement, formed on the t-shirt mould; two dresses made of the fabric with an uneven texture, one with horizontal placement and one with diagonal, formed on the dress mould; one dress made of the terry cloth, formed on the dress mould; and two t-shirts in knitted double-thread (PVA and stainless steel) fleece, formed on the t-shirt mould, one with vertical and one with horizontal placement of the fabric.
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Forming with the double-layered paper weave with an even texture:
One t-shirt and one dress on the t-shirt mould

The shape of the mould, direction of placement of the fabric on the mould, and texture of the fabric all influenced the shape of the garment. The even-textured, stripy fabric enhanced the directions and shape of the form when it shrank around the contours of the mould in thinner places, such as the waist, and spread out in wider ones, such as the shoulders (Figs. 74-80). The clear direction and dense surface of the texture also helped to support the form when the garment was removed from the mould.

Fig. 74: The even-textured paper weave, shaped on the t-shirt mould.
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Fig. 75: The even-textured paper weave, shaped on the t-shirt mould (video still).
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Fig. 76: The even-textured paper weave, shaped on the t-shirt mould (video still).
Fig. 77: The even-textured paper weave, shaped on the t-shirt mould (video still).
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Fig. 78: Removing the even-textured paper weave from the t-shirt mould.
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Fig. 79: Detail of a form experiment - the even-textured paper weave, shaped on the t-shirt mould.

Fig. 80: Form experiment - the even-textured paper weave, shaped on the t-shirt mould.
Forming with the two-thread (PVA and stainless steel) fleece: Two t-shirts on the t-shirt mould

In order to explore whether it was possible for a garment to hold its shape better, two experiments were performed with the water-reactive, knitted two-thread (PVA and stainless steel) fleece fabric; one with the fabric placed vertically, and the other with the fabric placed horizontally (Figs. 81-83). The vertical placement gave no form from the mould as its shrinkage was in terms of height rather than width. The horizontal placement resulted in a t-shirt which, due to the metal and the stiffening of the PVA in its melted state, was able to retain its form after removal from the mould, although the surface expression and form were not very interesting. Another form than that of a t-shirt may have been better suited to this fabric. It was felt that the material dominated the form rather than collaborating with it, and so this line of experimentation was not pursued further.
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Fig. 82: Form experiment with the two-thread fleece – vertical placement of the fabric, shaped on the t-shirt mould.

Fig. 83: Form experiment with the two-thread fleece – horizontal placement of the fabric, shaped on the t-shirt mould.
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Forming with the double-layered paper weave with uneven texture: Two dresses on the dress mould

Two full-length dresses were made of the fabric with an uneven texture (Fig. 84). The fabric of the first was placed horizontally on the dress mould, with the front side of the fabric outwards (Figs. 85-87). For the second, the raw fabric bag was slightly smaller in order to produce a closer fit to the form of the thinner parts of the mould, and the fabric was placed on the mould diagonally in order to enhance the form and directions of the mould (Figs. 88-90). The reverse side of the fabric was faced outwards in order to explore how its slightly different texture affected the garment.

Although the airy texture of the fabric resulted in a form that had a relatively large volume, it dominated the surface details of the mould. The full length of the dress and the weight of the double-layered fabric also influenced the form somewhat when it was removed from the mould. The direction of the resulting form was influenced by how the fabric was laid and shrunken on the mould, which may be of interest with regard to further explorations involving other materials which possess even clearer directions in terms of texture (Figs. 91-92). When the dress was placed on the body it was felt that the combination of the material and the mould created a promising shape and direction for further exploration. Some of the volume and form of the mould were lost in the meeting, as were some of the surface details of the form, but the resulting form of the dress suggested the placement of armholes and a neckline based on the underlying form (Fig. 91). Using the full width of the fabric with a horizontal placement resulted in a better balance between the properties of the form and the fabric than the pre-fitted diagonal form, with the drape of the fabric influencing the form and movement of the dress. This suggests that the qualities of both the form and the fabric have an impact on the resulting form, and their relationship with each other should be considered when forming.
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Fig. 85: The first experiment with the uneven-textured paper weave, shaped on the dress mould – horizontal placement of fabric.
Fig. 8.6: The first experiment with the uneven-textured paper weave, shaped on the dress mould – horizontal placement of fabric.
Fig. 87. The first experiment with the uneven-textured paper weave, shaped on the dress mould – horizontal placement of fabric.
Fig. 88: The second experiment with the uneven-textured paper weave, shaped on the dress mould – diagonal placement of fabric.
Fig. 89: The second experiment with the uneven-textured paper weave, shaped on the dress mould – diagonal placement of fabric.
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Fig. 90: The second experiment with the uneven-textured paper weave, shaped on the dress mould – diagonal placement of fabric.
Fig. 91: Uneven-textured paper-weave dress – horizontal placement of the fabric on the mould, full width of fabric, front side of the fabric outwards. Fitting the first dress on a body.

Fig. 92: Uneven-textured paper-weave dress – diagonal placement of fabric on the mould, slightly fitted raw fabric, reverse side of the fabric outwards. Fitting the second dress on a body.
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Forming with the paper-yarn terry cloth: One dress on the dress mould

One of the dresses which was moulded on the dress form was made of the terry cloth (Figs. 93-95). The fabric formed a smooth, furry surface when it had shrunk on the mould. Due to its thickness, the material also supported the contours of the form relatively well, and its subtle texture did not draw too much attention away from the shape of the mould. The finer surface details of the mould were lost to the thickness of the fabric in its textured state, but there were very subtle directions and volume in the form of the garment that suggested the placement of an armhole or neckline (Fig. 93). The terry-cloth experiment was conducted with a slightly more fitted bag, which led to the dress holding its form better than the unevenly structured dresses and a clear contrast in width between the upper and lower parts of the dress.
Fig. 94: Form experiment – paper terry cloth, shaped on the dress mould.
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Fig. 95: Form experiment – paper terry cloth, shaped on the dress mould.
4. EXPERIMENTS

Comments

These initial experiments suggest that textiles with changeable qualities could be used to create form, but further development is needed to find a better balance between form-giving qualities, the surface texture of the fabric, and the shape of the mould. Non-water-soluble shrinking yarns such as heat-reactive ones may be more suited for providing permanent form as they are unaffected by moisture, and thus wear, without compromising the structure. Another direction for further development may be to work with the spaces between layers in double-woven textiles, exploring how and where the layers are attached or separated, what materials they consist of, and how they are worn or otherwise shaped to create a form. Some tentative experiments using a Jacquard loom were conducted to explore the possibility of adding stops and seams directly to the fabric to create a raw shape and openings for the garment on the loom, eliminating the need for sewing. Further experiments with both bindings and the placement of stops and seams, eventually on a full-body scale, would be needed, and may offer an interesting direction for further development.

4.2.1.2 Student work on form

Several of the works created by fashion students during workshops explored changeable qualities in textiles as a means of creating form in garments. The students worked on an assignment to recreate a garment that they had previously made during their studies using materials with changeable qualities.

One student created volume and form in a dress by shrinking parts of the water-reactive knitted two-thread (PVA and stainless steel) fleece fabric, creating both a three-dimensional surface texture and the shape of the garment (Fig. 96). The student’s treatment of the material ensured that it retained its flexibility and softness, and the direction of the stripes – which were painted with water vertically to maximise shrinkage – influenced the texture, form, and movement of the garment. The same material was used by the author to create a top that combined a soft, white, opaque bottom part and a hard, translucent, stiff upper part, formed around a tailor’s dummy to create rigid shapes with a flat surface texture that was able to retain its form (Fig. 97). The student ensured that the material retained its form during drying by pinning the treated, texturised fabric to a dummy, treating one part of the dress at a time. The author, on the other hand, created a flat surface by painting small sections of the fabric at a time, using vertical strokes and letting the material dry between brush strokes to prevent the entire surface from splitting due to the pressure of the shrinkage.

Another student created volume and form in a poncho by stretching certain parts of the fabric pieces he had cut out and leaving others untreated, before sewing the pieces together. This contrasted with the more traditional method of creating volume in the pattern of a garment, before the pattern pieces are cut (Fig. 98). His layering of fabrics, the weight of the fabric, and the metal content enhanced the voluminous effect and affected the movement of the layers when the garment was worn.
Fig. 96: Volume, form, and texture created through shrinkage. A dress by Sofie Larsson.
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Fig. 97: Two ways of forming the two-thread (PVA and stainless steel) fleece: (a) Three-dimensional texture by Sofie Larsson and (b) flat rigid surface by the author.
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Fig. 98: Volume and form through stretching certain parts of the fabric. A poncho by Lui Iarochewski.
Comments

The preliminary outcomes of the garment form experiments, along with the student works, suggest that changeable qualities in textiles could be used as an alternative method of creating form in garments in different ways – by moulding a form, or by using a fabric’s ability to be shaped and to retain its form after it has been formed – and that during such processes multiple surface textures can be created simultaneously. Due to the nature of changeable materials, treating a textile to create form usually involves changing the surface texture and tactile qualities due to changes in structure. The way this occurs depends on the materials and how and in what type of textile structure, such as knitted or woven, they are combined.

The water-reactive PVA yarn stiffened when it shrank and melted, which contributed considerably to the form-retaining properties of the fabrics that contained a large amount of it, particularly when they were reinforced with stainless steel wire, as with the t-shirt on the mould. However, the size of the treated area of a textile also had an effect, as could be seen when comparing the softness, flexibility, and movement of the student’s textured dress (described in Section 4.2.1.2) with that of the top created by the author, in that these features were more or less eradicated and a relatively self-supporting shape was created instead. In the case of the paper weaves and the wool roll pattern, the amount of PVA in the fabric was considerably smaller, and its effect was limited to changing the texture of the fabric without erasing the traditional textile properties. In these examples, the properties and weight of the other materials influenced the garment’s drape, shape, and movement to a greater degree.

In addition, how the textile is treated to create form affects the resulting shape, as the experiments that created different surfaces and forms on the same knitted water-reactive two-thread fleece suggest. How the textile, forming, and form relate to one another depends on the qualities of the textile, as well as how and which parts of it are formed. With regard to the development of the form experiments, other shrinking materials, such as heat-sensitive Pemotex, retain their softness even in their shrunken state, and could be one alternative for further exploration. They also do not react to the natural moisture of the body or the environment, which can affect a garment’s shape unexpectedly. However, allowing this to occur and form the garment directly on the body is another possible avenue of exploration.

4.2.2 Changeable textiles from the perspective of use

Two perspectives on textiles which possess the quality of changeability in relation to use are discussed in this section. As the focus of this thesis is on exploring the possibilities of textile materials with changeable qualities, ‘use’ is defined here quite broadly, including in general the type of handling or uses a textile may encounter. Textiles are often used as raw materials for products in public and private interiors, and for various purposes. This subjects them to different conditions and interactions with people. Being continuously subjected to e.g. sunlight, wind, moisture, abrasion, stretching, handling, and washing leads to different types of wear and tear. This is an unintentional, passive change which leads to changes in colour, texture and form in materials, often over longer periods of time.

A complementary approach to this ever-present passage of time could be to consciously build the potential for change into textile products through structure and material choices. This would mean that the textile or product could be actively changed at will, for example by changing its structure when so desired or when it starts to show certain signs of wear and tear, such that its expression, function, and/or purpose can be changed. In a subtler sense, it may mean setting certain directions for how the textile’s expression may develop during non-intentional use, while leaving open the exact way in which it changes.

4.2.2.1 Use: Experiment I

The first experiment explored the potential of non-intentional changes through wear and tear that occur as a result of use, in the context of prototypes of everyday textile products. To explore how colours and patterns are accumulated by textiles through use, prototypes were made using plain and Jacquard-patterned woven textiles which combined paper yarn, wool, polyester, and cotton (see Publication IV, and pages 74-149 of this thesis for more detailed information regarding the materials).

Products in everyday use situations, consisting of upholstery for two chairs in different public spaces – a foyer and a conference room – pocket details on lab coats in a textile printing lab, a fabric bag, and an apron for private use, were chosen for the prototypes. They were then subsequently used for two months. After this period
of use, most of the prototypes had undergone some changes in terms of expression, which varied depending on what they had been exposed to and resulted in several different expressions stemming from one starting point (Figs. 99-103). Washing tests with laundry of three different colours – black, blue, and yellow – were conducted using the triangle-patterned and the circle-patterned woven fabrics, consisting of cotton, wool, paper yarn, linen and polyester. Different materials were dyed during the tests; during machine washing with black laundry, paper yarn was dyed the most, making it stand out from the pattern, while with yellow laundry, all of the materials except for polyester were dyed evenly, making the polyester the most visible part of the pattern (Figs. 104-106).

Comments

The outcomes of the experiment show that a textile can be designed in such a way that its expression may evolve in several different directions, depending on what it is exposed to. The material and the structure of the textile define the general guidelines for these changes; paper yarn picks up certain pigments while others fasten better to wool, and paper yarn draws in dirt more easily while wool felts relatively easily during machine washing (Figs. 99, 104, 106). However, the experiments also suggest that how a textile or object is changed or used has as much effect on the resulting changes as the material and structure.

Some of the changes in colour of the prototypes were clearly visible, as with the bag, the upholstery of the chairs, and the materials dyed during the washing tests, while other prototypes, such as the apron or the lab coats, did not show significant signs of change. The coats used in the printing lab were washed at 60°C as they regularly are, which removed most of the pigment stains, changed the texture of the pockets, and subtly shrunk the fabric, changing the coat’s fit (Fig. 103). The white bag became grey in the places where it had come into contact with hands, a coat, or had been laid on the floor or folded (Fig. 100). The chair placed in the foyer acquired a large coffee stain, while the chair placed in the conference room had a generally worn-out appearance, with the upholstery material having turned greyish, particularly at the front of the cushion (Figs. 101-102). The washing tests suggest a use of another kind altogether, wherein the usually unwanted side effect of garments bleeding colour during washing could be used to dye patterns either intentionally or unintentionally. The experiments further suggest that the accumulation of signs of wear and tear requires time and repetition to occur, and that materials produce different changes in expression under different conditions and timespans. Whether all of the changes are permanent and remain wholly present, particularly with regard to the washed textiles, is perhaps not highly relevant, as repeated washes will add layers on top of the previous ones.
Fig. 100: Bag, sewn using the triangle fabric: (a) Before and (b) after two months of everyday use.
Fig. 101: Coffee stains on the seat cushion of the foyer chair after two months of use.
Fig. 102: Dirt marks on the seat cushion of the conference chair after two months of use.
Fig. 103: Pocket detail of the lab coat: (a) before and (b) after two months of use and machine washing at 60°C.
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Fig. 104: Machine washed at 40°C with black laundry. Triangle pattern, and circle pattern in three different material combinations.
Fig. 105: Machine washed at 40°C with blue laundry. Triangle pattern, and circle pattern in two different material combinations.
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Fig. 106: Machine washed at 40°C with yellow laundry. Triangle pattern, and circle pattern in two different material combinations.
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4.2.2.2 Use: Experiment II

The second experiment focused on exploring the possible uses and functions that textiles which possess the possibility for structural changes could be put to with regard to changes in length and thickness, texturising, and dividing materials into pockets, channels, or layers. Fabrics whose structure and expression can be altered in different stages through changes in their materials were woven by the metre. These included: a fabric that was possible to alter the form of, from flat and thin to various thicker, textured surfaces, and eventually be divided into two flat layers through steaming, spraying water, or machine washing; and a flat fabric that could be formed into a textured surface and divided into two or three fabrics, each with different colours and textures, through the application of heat, water, or both in the form of machine washing, steaming, or ironing (see pages 150-185 for more details regarding the materials).

A series of preliminary prototypes was developed to test the uses and functions a fabric’s qualities can suggest. The prototypes explored changes in structure and texture through shrinkage. These included fitting a textile around a lampshade, creating both texture and fit through shrinkage (caused by spraying water), changing the size and texture of a bedspread through shrinkage (caused by machine washing), and creating three pillows of different sizes and textures using steaming and machine washing (Figs. 107-108).

Some of the prototypes were intended to use textile qualities to change the product’s properties during the production phase, such as the lampshade and the bedspread (Fig. 107). The bedspread prototype was pre-shrunk using machine washing before trim was added to shrink it to the desired size and create a textured surface, but the basic idea could be developed further to include the possibility of altering the size of the finished product, e.g. changing from a smooth, double-bed-sized bedspread to a more roughly textured single. This would mean that the structure and materials of the entire textile product would need to be considered from the perspective of the planned change, including the shrinkage of the edges and seams along with the trim and the sewing thread. If a division of layers is desired in order to, for example, turn a bedspread into one tablecloth and one blanket, the structure and choice of sewing thread would need to allow for the product to divide in the necessary places and remain together in others. This suggests that embedding changeable steps in textiles may open up for alternative uses or functions in textile products, but that further development work is required in order to match a material’s qualities to a product’s.

The role of the prototypes in the experimentation thus far is relatively tentative; they have been used to explore the possible uses of changeable qualities in existing products, rather than directly proposing new products. Some of the scenarios, such as being able to easily change and re-size textiles according to specific needs by washing, watering, steaming, or ironing them to change lengths or create channels, openings, or pockets in different contexts, may offer an interesting direction for further development. Ideas such as form-fitting textiles for different purposes could perhaps be applied to existing processes in the industry as an alternative method for fastening or creating textures in forms, or be used as hands-on methods for repairing, renewing, or customising products that textiles are part of, without the need for advanced skills or specialised equipment.

The materials were also used in discussions with product developers from various departments of IKEA of Sweden to further explore ideas regarding how textiles’ qualities can be applied in a product context to suggest alternative uses or roles for textiles. These included using shrinkage and changes in the texture and thickness of a material to fit upholstery fabrics around furniture, and creating custom storage spaces by ironing pockets into the fabric. The most promising outcomes of these discussions related to the use of changeable qualities as part of the production processes of products with traditional, static expressions. These could be used to create novel expressions or use less material or avoid chemical- and work-intense processes, such as creating textured surfaces through shrinking parts of the textile’s structure rather than using the traditional, time-consuming quilting method of sewing. Embedding changeable qualities in the textiles or textile products sold to customers was seen as a less obvious alternative, primarily due to the difficulty of communicating the existence and relevance of such properties to customers, as well as because product developers and the personnel responsible for material acquisition are not aware of the existence of such textiles, and thus do not know to ask for them during design processes.
The outcomes of the experiment thus far suggest that a textile and the context in which it is placed influence each other to varying extents. This suggests that both the textile and its possible use need to be considered during the design process, at least to some degree. The context of use that the textile is placed in influences the conditions that it experiences and changes in expression, structure, and even function that occur.

A textile’s qualities may suggest certain uses or treatments, opening up for changes in expression or function. For example, a fabric with the ability to gather and shrink in one direction could suggest an alternative method for shortening a pair of curtains, by shrinking as much of the fabric as is needed to attain a suitable length. The same curtains could later be washed to regain some of the length if needed. Turning the idea around, curtains could be easily hung without sewing in channels for the curtain rod, and so a textile in which channels can simply be opened by ironing may be useful. Easy assembly and customisation using everyday methods may be a relatively easy way of introducing alternative types of textiles to the public. This would, however, require the learning of other skills than sewing, such as how to handle and modify textiles in order to produce the desired outcome and avoid unwanted changes.

Embedding structural changes in textiles through material and structure could open up for alternative uses and ways of thinking about e.g. circularity; when a textile no longer needs to remain flat but can become smaller, larger, textured, or divided, and perhaps even change its purpose or shed worn-out parts. Textiles could be better adapted to certain uses or needs in textile products or processes, but how this can actually be achieved may prove to be a complex task due to the quantity of variables that have to be considered and the lack of information as regards both material qualities and how these can be used in more diverse ways.

The discussions with the textile product developers highlighted the fact that they often start with a need, and may have difficulty seeing the need for materials that they do not know exist. One challenge in designing inherent changeable qualities in textiles may be how to communicate such qualities in a meaningful way to a range of different audiences – the public, companies, legislators, product developers, designers, and marketing personnel – who are unaccustomed to viewing textiles as objects that can, or should, change.
Fig. 107: Prototype for a pillow whose size can be adjusted in increments by steaming or washing: (a) non-treated, (b) steamed, and (c) machine washed at 30°C.

Fig. 108: Two prototypes made using the yellow triple-layered weave. The material’s shrinking behaviour was used to create texture in a bedspread through machine washing, and to fit the material around a lampshade.
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4.2.3 Changeable materials from the perspective of teaching

In order to explore changeability as a basic property in textiles from the perspective of teaching, learning, and developing design skills, a series of workshops was arranged for fashion and textile design students. The main aim of the workshops was to introduce the students to new materials and alternative design methods using changeable materials. Two workshops, one with second-year Bachelor’s students in fashion design and another with second-year Bachelor’s students in fashion and textile design, were held, and are discussed in this section (and in more detail in Publications I and II).

Materials from the Smart Textiles Sample Collection were used in the workshops. The materials in the collection were originally developed within various research projects at the Smart Textiles Design Lab at the Swedish School of Textiles in Borås, Sweden. They include knitted and woven fabrics spanning a range of dynamic qualities, from structural changes such as breaking, shrinking, melting, and textural changes to different types of smart colour, such as heat and UV-reactive colour-changing pigments, printed on textiles. The materials can be activated either by direct manipulation using e.g. heat or water or through programmable sensors and actuators, which enable the materials to react to stimuli such as touch or proximity.

The materials in the sample collection were produced by the metre, and have been used in teaching and workshops with various participants (for further detail regarding the collection and the materials included in it, see e.g. Dumitrescu, Nilsson, Persson & Worbin 2014; Worbin 2010; Dumitrescu 2013; Persson 2013; Nilsson 2015; Kooroshnia 2017; Talman 2015). In addition to fabrics, yarns and pigments with these properties were available for the students to use in developing their own textiles and prints. The dynamic qualities of the materials responded to everyday stimuli such as heat and moisture. Together, they offered a varied range of easily accessible, hands-on, dynamic qualities to explore, covering both reversible changes, such as colour changes, and irreversible ones, such as melting and shrinking.

The task set for the fashion design students was to recreate a garment that they had previously made using the dynamic materials (see Publication I). They were asked to identify interesting or characteristic elements of their original garments and explore these using the alternative materials. The assignment for the textile and fashion design students, who worked in pairs or groups of three, with members from both disciplines, was to explore how materials with the property of changeability can be used in the design of textile expressions (see Publication II). The students were asked to bring one example of their previous work that they wanted to use as a starting point, and formed groups based on common interests found through these examples. The groups were able to choose a specific context to work towards, such as garments, interaction, spatiality, or textile materials.

During both workshops, the students were initially encouraged to freely experiment with all of the materials in order to better acquaint themselves with their properties; after this, they were asked to select one or more properties to explore further. Most students began experimenting quite randomly, using the information that they received regarding the materials as a starting point to gather experience of how the materials functioned. This involved e.g. dripping water, oil, or water-based liquids such as red wine or gouache colours onto fabrics containing PVA in order to see how the materials reacted, heating shrinking Pemotex fabrics in different patterns or to shape them around various forms, heating thermochromic prints with a hair dryer, and placing them in a freezer to test the changes in colour (Figs. 109-111).

After a period of free experimentation, the students began to understand how the materials respond to different stimuli, and how their properties relating to e.g. shrinking, dissolving, and formability, or changes in texture or colour, could be used. Based on the observations and discoveries made during the initial tests, the students then developed more systematic methods of forming the fabrics, such as trying different ways of creating patterns by painting lines or dots on a fabric with water or heat, forming specific parts of a fabric on a body or dummy using water or heat, or mixing thermochromic colours with regular pigments to create patterns that can change colour. They created irreversible changes in expression by painting with water, shrinking and forming using steaming, printing water-based pigments on water-reactive fabrics to change both colour and texture, and sculpting and moulding layers with water or heat. Reversible, temporary changes were also achieved by painting with warm water on thermochromic prints to create temporary patterns, using a hair dryer and body heat to leave thermal traces and create temporary colour changes, and using differences in the temperature outdoors and indoors to create changes in printed patterns.

Two approaches to changeability can be discerned in the students’ experiments:
using changeable qualities as a method for creating a static expression, and creating textiles, patterns, surfaces, forms, and garments wherein changeability was part of the expression or, in some cases, a means to alter the expression or structure of the garment. Both categories included examples that focused on both textile expressions and garments. An example of the first category was created by a pair consisting of a textile design student and a fashion design student, who developed a method of creating surface expressions on knitted, heat-reactive Pemotex by tensioning the fabric on a frame before heat-treating areas to create patterns. Tightening the fabric helped to control the shrinkage in the material, leading to a relatively flat surface with a pattern of opaque and transparent areas, contrasting with Pemotex's generally pronounced shrinking and texture-building behaviour. The students complemented the pattern of the fabric by placing a printed pattern on top, creating a layered effect in which the transparency of the material beneath influenced the appearance of the colours of the print (Fig. 112).

Another example of combining a material’s properties with print was a pair consisting of one textile design student and one fashion design student, who explored water-based printing paste to both add colour and change the form or texture of a knitted fabric consisting of copper and PVA. The students printed patterns on the water-reactive fabric with water-based pigments to create both a visual pattern and a surface texture (Fig. 112). A third example from this category is a fashion design student who created the shape and surface texture of a dress by painting lines in water on a water-reactive, knitted fabric consisting of PVA and stainless steel. She developed a method for preventing the fabric from splitting when water was applied and enhancing its tendency to shrink to fit a form by holding up the fabric when she was painting, then pinning it down to dry in order to retain the texture (Fig. 112).

The second category includes examples of both reversible colour changes and irreversible changes in a material’s structure. An example of the former was created by a pair consisting of one textile design student and one fashion design student, who explored cold- and heat-reactive thermochromic prints in order to develop temperature-reactive patterns, that were changed by e.g. using a hair-dryer or placing the fabric outdoors (Fig. 113).

A fashion design student created a multifunctional garment that could be transformed from a white pleated top into a long, white-and-pink striped dress using warm and cold water. The structure of the garment used PVA as a sewing thread to stitch the dress as a top, and regular polyester sewing thread was used in the seams of the full-length dress. A thermochromic print, which was transparent at ambient temperature and coloured in response to cold, was added to the dress to reflect the pleated structure of the top’s colour (Fig. 113). A group consisting of two fashion design students and one textile design student developed a loose, oversized, white t-shirt that could be formed and fitted directly on a wearer’s body by the wearer themselves. The pair used knitted, heat-sensitive shrinking Pemotex yarn, with thicker layers of material to influence the form of the resulting garment in its shrunken state. They also added a heat-activated thermochromic print to enhance the changes that would occur (Fig. 113).
Fig. 109: Miriam Julin, Camilla Arnbert and Tove Ulfsåker’s experiments using the PIA single jersey.
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Fig. 110: Student experiments using the IPVA and stainless steel two-thread fleece. Far right Emilia Elvek’s layering experiment.
Fig. 111: Lisa Viola Zetterberg’s experiments using the wool, stainless steel, and PVA slipstitch pattern.
Fig. 112: Student work – static expressions created using changeable materials:
(a) Sofie Larsson: Painting with water to create texture, (b) Cecilia Björck and Julia
Ragnarsson: printing with water-based pigment to create texture and pattern, and (c)
Ida Linde and Karen Huang: creating a surface by controlling shrinkage.
Fig. 113: Student work – changeable expressions created using changeable materials:
(a) Vika (Tori) Im, Lotta Sorvo and Maja Freiman: Using shrinkage to form garments on
the body, (b) John-Daniel Isacsson: changing the length of a garment using water, and
(c) Julia Falkhorn and Marie Stark: creating dynamic printed patterns using heat.
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The works created by the students during the workshops exemplify the idea that changeability can be taught by focusing on material properties through hands-on exploration. First-hand experience of the materials and how they react to different treatments, gained through free experimentation focusing on the properties of materials, seemed to be crucial for the students to learn the logic of the materials’ behaviour, and how these properties could be further used as design materials. The outcomes of the workshops further suggest that the inherent property of changeability in materials can be used to both develop more traditional, static expressions in textiles and garments and embed changeability in the expression, form, and/or function of a garment or textile in several contexts. The examples created by the students during the workshops used irreversible changes in material properties to both create static expressions and embed changeability in final outcomes. Materials capable of reversible changes were used to embed changeability in the final expressions of the produced objects due to the materials’ ability to repeatedly move between different stages or expressions.

During the workshops, the students primarily worked with existing fabrics from the Smart Textiles Sample Collection, although some created their own thermochromic prints or used PVA as a sewing thread. Working with existing fabrics meant that the combination of material and structure afforded the textiles certain qualities and types of changes, offering some possibilities but also setting certain limitations. Some fabrics were perhaps more open than others to being manipulated in various ways. For example, the two-thread (PVA and stainless steel) fleece could be formed into three-dimensional textured forms or flat surfaces (see Fig. 97). The possible incremental stages of change in the woollen slipstitch pattern were more fixed; it could be stretched in the desired places to change its dimensions, texture, and opacity. This limitation in the possible changes directed how the materials could be worked with, making the students rethink their own methods of making garments. Taking the poncho as an example, the student reconsidered the method for creating volume and form, altering the size and form of the pattern pieces after they were cut from the roll of fabric rather than before (see Fig. 98).

The materials in the Smart Textiles Sample Collection can be used to introduce students to new materials and alternative design methods, and the materials serve as an easy-to-approach, hands-on way of experiencing and experimenting with the quality of changeability in textiles. The workshops attempted to provide a basic understanding of different types of dynamic materials and design methods, which the students can, if they wish, explore further by developing their own textiles, garments, or products using the dynamic materials in yarn or pigment form, instead of readymade fabrics.

On a broader level, the workshops could be used as an introduction to changeability in textile materials and their applications, even for audiences other than textile and fashion design students. The workshop participants have thus far primarily been students in these fields, but other groups who use textiles, such as product designers, interior architects, and even people who use and encounter textiles in their everyday lives, could benefit from such a hands-on introduction.
The experiments presented in this licentiate thesis explore change as a quality in textiles from the perspective of the textile material, and examine changes in textiles from three different perspectives: form, use, and teaching about changeability. These changes range from visual, for example changes in colour, pattern, or texture, to tangible: changes in texture and tactile qualities, in the dimensions of textiles as regards e.g. length and thickness, and in opacity and the division of layers. Some of the examples include several types of change, occurring over different timespans. What connects them is that they are all irreversible; the textile’s expression builds up over time based on its potential for changeability, which is defined by its material and structure and in relation to how it is treated or handled.

5.1 Designing the quality of changeability in textiles

The tendency to wear out and change is inherent in most materials, but – aside from a few exceptions, such as the patina of leather – has been considered to be undesirable by both the industry and consumers. The work presented in this licentiate thesis suggests that, due to change in some form being an inherent property of textiles, it may be viable to look for alternative ways of designing and perceiving textiles that accept it as one of their qualities. There are two aspects to this, which are connected and relate to materials.

From a textile designer’s perspective, accepting changeability as yet another quality of textiles opens up for alternative possibilities as regards creating expressions, wherein time and change are design variables alongside more traditional qualities such as colour, pattern, texture, tactile qualities, material, and structure. Decisions regarding materials and their placement in textile structures should then be reflected upon from the perspective of changeability – what inherent potential for changeability materials possess, and how a textile’s structure allows these properties to manifest themselves. This suggests that designing with changeability as a quality in textiles, materials, and structures should have a central position in the design process, requiring experience and knowledge of both on the part of the designer.

Almost all materials possess an inherent property of changeability, but how they change and to what extent, along with the type of stimuli that the material reacts...
to, varies. Some materials, such as polyester, are less reactive and so underwent no changes in colour or physical properties during the experiments. Cotton, meanwhile, evinced moderate colour changes and degradation. There were no colour changes in stainless steel, but the material could be bent permanently. Uncoated copper could likewise be bent, and a patina appeared in response to contact with air over time.

Wool dyed readily under certain conditions, such as when buried underground or immersed in water containing iron powder, but not under others, for example machine washing with black garments. Wool can become denser through felting, or immersed in water containing iron powder. It became soft when wet and started to degrade relatively quickly in humid conditions. Wool and paper yarn, as protein- and cellulose-based materials, respectively, seemed to react in contrasting ways. During the experiment in which paper samples were dyed most, wool often reacted relatively moderately; the reverse was also true, suggesting that these materials could be used together to create changes in colour and pattern wherein some changes are triggered by certain conditions and other changes by other conditions.

When designing static textile expressions, the choice of material should generally be based on the qualities that the finished textile should possess. Designing with change in mind is no exception. PVA, which could be said to be the most reactive or explicit of the materials used in the experiments due to its dissolving completely in warm water, reacted to water and steam by shrinking, melting, hardening, and dissolving, radically altering its physical properties. Both PVA and Grilon can be almost entirely removed from textile structures, enabling the separation of layers, but while PVA shrinks, Grilon does not. The properties required of the textile, then, should influence whether a water-reactive material that is relatively easy to dissolve and which shrinks at least somewhat should be chosen over a heat-reactive material that is not sensitive to washing or humidity from the body or environment, and either does not shrink or shrinks very little. All of the materials except polyester and stainless steel seemed to react to water or humidity to at least some degree, and these conditions generally exacerbated or accelerated processes of change when in combination with heat. This may open up interesting directions for further research, as most textiles regularly come into contact with water or moisture when being washed or worn, and heat in the form of ironing or washing at a high temperature.

The experiments suggest that changes in textiles can occur gradually – over long periods of time – or instantly and explicitly. The timespan needed for changes to occur is in some cases tied to the method chosen for changing them. In the experiments, purely visual changes, such as changes in colour or pattern, were generally gradual, as with the samples which were dyed during use as prototypes, buried, or submerged in the Baltic Sea. Marks of use were often visual and relatively unintentional. The machine-washing tests dyed the samples near-instantaneously, but an intentional action of placing the samples in the machine with certain coloured laundry was involved. Placement of the textiles in a specific environment, such as burying them underground, was certainly also intentional, but the changes that occurred in those scenarios were less easy to predict.

More tangible changes in expression and structure ranged from subtle to explicit. The explicit changes, wherein the material’s property of changeability substantially changed the qualities of the textile, were usually the result of deliberate forming of the textile’s properties for various purposes. For example, stretching, shrinking, or shaping all or part of a textile, dividing layers or creating pockets, and changing tactile qualities such as texture and softness were used consciously in creating form and surface in garments, or in scenarios relating to possible usage.

Some of the textiles that were developed during the experiments possessed the potential to both change gradually over time and be shaped by conscious acts of forming, such as the white, double-layered woven paper textile. Its thickness, length, texture, shape, and layers could be deliberately formed by manipulating the PVA floats using water or steam. In addition to these more obvious changes, the paper yarn, with its sensitivity to colour changes and dirt, offers the potential for subtle and unintended changes in colour or pattern, should the textile be used for a prolonged period in its textured state. Exploring such changes in pattern or colour, in the manner of woven shibori, could be an interesting direction for further exploration.

Materials possess certain reactivities, but the structure of a textile defines how it reacts to stimuli. For example, the structure of the white single-jersey all-PVA fabric did not limit influence the material’s properties. The fabric could melt, dissolve, or deform completely, either horizontally or vertically, due the knitted structure. The steel wires of the two-thread (PVA and stainless steel) fleece set the directions in
which the structure shrunk or broke when the PVA reacted. In the case of the two t-shirts, the fabric placed on the mould in the horizontal direction shrunk in terms of length but not fit, while the vertically placed fabric produced a close fit to the mould. The knitted wool roll pattern, could only be manipulated by stretching all or part of the material with the assistance of water, which changed its dimensions and visual and tactile qualities. A small amount of PVA was used in the structure in order to avoid shrinking and hardening; this was placed a row connecting the ridges, meaning that the textile was possible to stretch out when the PVA dissolved.

The woven Jacquard patterns were relatively open to different types of colour change; depending on the stimuli that the fabric was exposed to, blues, greens, yellows, oranges, and browns were achieved. The structure of the fabric, however, defined how the materials in the pattern were placed, limiting in which places the colours and the pattern could change. The double-layered woven paper fabric was possible to form in several ways – as flat or shaped-around objects, by dividing the layers, or by creating pockets either in specific places or as overall surfaces – but its possible changes were limited to six versions: flat, a slight texture, a slightly flattened texture, a wavy texture, a looser wavy texture, and two layers. This was due to the double-layered structure, in which PVA was used as floats to bind together the layers. The direction of the PVA, which was only used in the weft, and the distance between the floats and the binding points caused the fabric to shrink horizontally, creating an even, striped texture.

Together, the experiments suggest that the combination of material and structure defines how textiles change when exposed to various stimuli. A material's property of changeability defines what the textile will react to and how, while the structure of the textile influences how the textile can change through the amount and placement of materials. In addition to these two factors, time and use – or the handling that the textile experiences – shape the exact changes that take place. The changes that occurred in most of the materials during the experiments varied depending on how the materials were treated. The woven Jacquard patterns could be coloured either through use or deliberate exposure to pigments or other dyeing agents. The fabrics that contained water-reactive PVA could be formed intentionally by steam and water, but this did not remove their reactivity to water unless the PVA was completely dissolved; as a result, the materials remained open to any further intended or unintended changes as a result of contact with water. This suggests that textiles can be open to different types of change, both intended and unintended, depending on their material and structure.

One aspect of changeability that has not been explored in the experiments described in this thesis is what happens to textiles and their materials at the end of a product’s lifespan. The use of mixed-fibre yarns and blends of several materials in textile structures within the textile industry poses a challenge with regard to the end-of-life separation, reuse, and recycling of fibres, often leading to materials being downgraded in the process or burned for energy instead of being recycled. Exploring end-of-life scenarios and material separation may be an interesting direction for further exploration, in terms of both separating materials when the lifespan of a textile has come to an end and, more interestingly, separating materials in order to change the expression and/or function of a textile when the lifespan of a textile or one of its materials has come to an end. Some of the experiments, including those involving water-soluble PVA yarn, touch upon the topic in terms of separating PVA from the rest of the materials through dissolving and separating layers of materials from one another. The latter concept may be preferable so as to avoid large amounts of PVA being washed down the drain. Embedding several lifespans into one textile through the ability of materials to degrade or otherwise disintegrate at different rates could open up for cradle-to-cradle thinking on the level of textile structures without downgrading materials. However, with such explorations care would need to be taken with regard to the importance of appropriate lifespans for a specific material in its intended use, and what becomes of materials when they disintegrate.

5.2 Utilising changeability in textiles

Embedding the possibility for changes directly in textiles could also open up for alternative ways of designing with textiles as raw materials. Properties of changeability suggest different types of changes and applications. For example, materials which are easily dyed and stable within a structure could suggest applications in which patterns and colours gradually evolve over time and during use, while materials that react instantly to water or heat by changing their physical properties could suggest applications in which conscious actions are taken to form textiles. These properties could also be used as a method for creating more static expressions, such as using the sensitivity of materials to different types of dye to create patterns when utilising multiple fibre types, using the shrinking properties of materials to form, texturise,
5. DISCUSSION

Introducing textile design students to dynamic materials and alternative design methods that incorporate changeability, in either the resulting textiles or the process of creating them, is one way of introducing changeability as a quality of textiles within education. Providing the students with first-hand, hands-on experience of such materials through workshops was a good way to make them aware of the existence of various dynamic materials and their possibilities in design work. The availability of shrinking and dissolving yarns and colour-changing pigments at design departments for student projects, and discussing their potential during supervision and seminars when they may fit a student’s projects, has been another way to encourage students to further explore changeable qualities within their own work. Discussing the consequences of changeable properties for the qualities of the resulting textiles, in addition to the more obvious design variables of colour, pattern, and texture, could encourage students to become more aware of their material choices. The quality of changeability could also be brought up within education from the perspective of sustainability – what happens to textiles or their materials in the long term, at the end of their lifespan, and how do material choices and the structure of a textile affect aspects such as use, longevity, recyclability, and trend-sensitivity? Positioning change as one quality of a textile from multiple perspectives, alongside their other qualities, could encourage students to develop a more diverse view on what textile materials or products can be.

The experiments presented in this thesis touch on various contexts, such as use, products, and garments, and all are approached through the lens of textile design. This highlights certain aspects, such as the role of the material, structure, composition, and tactility, but does not address others, such as in-depth analysis of user-friendliness, user experience and interaction, and aesthetics and conventions within the field of fashion. Various prototypes were created during the projects, the primary goal of which was to explore the quality of changeability in textiles in a specific context, for example real-life use, rather than to design new textile products per se. Alongside the individual projects, collaborations with researchers from other fields – such as workshops with people who work with smart textiles and electronic interfaces in garments – observing students’ work during workshops, and working alongside a fashion designer have been helpful in bringing in other perspectives on this work.

From the perspective of a product designer or a fashion designer, the experiments presented in this thesis may well be simply a starting point. The openness of textiles as materials for use in different contexts allows for shifts in perspective to take place (Hallnäs 2018). Several of the materials developed over the course of this research have been used in contexts ranging from textile design to fashion design, interaction design, and product prototyping. These contexts explore the possibilities that such materials open up for, but are not limited to this line of inquiry. The inherent openness of textiles as materials often places the final application beyond the control of the designer, who may speculate on but not completely influence how materials are used. Nor is this control necessary, for the qualities of textiles in themselves suggest certain uses or applications, and in some cases also alternative uses.

How textiles are handled has an effect on the ways in which the changes afforded by the material and structure are realised. Depending on the treatment, the same textile may acquire different expressions (such as colour schemes), structures, or functions. This suggests that it may be viable to consider possible contexts of use as early as during the design of a textile material. It also suggests that an increased level of sensitivity on the part of users is required with regard to knowing what materials textiles are made of and understanding how they can, or should be, taken care of in order to retain or change their expression. On the other hand, a textile’s qualities may also suggest areas of application, or different uses may be possible, and so the relationship between the textile and its handling is not straightforward.

Considering how textiles may change and in what context they may be placed when making choices relating to materials and structures may help to create a better balance between the lifespans of a textile (object) and the material(s) that it is made of by reconnecting textiles with the inherent qualities that materials possess. Further research into the relationship between time and use may thus be fruitful, particularly as regards whether the changes that occur in textiles are passive, gradual, non-intentional, and unfold over long periods of time or active, intentional acts in which textiles...
are changed or formed for various purposes. Some of the experiments touch on, and even begin to compare, the various stimuli and ways of handling that textiles may be subjected to through placement in different contexts of use. Based on the experiments, particularly those presented in Publication I, the relationship between time and use seems to be a complex one, with several factors – social, material, aesthetic, intentional, and unintentional – affecting how a textile changes or is formed.

5.3 Material objects and immaterial products

Embracing the inherent changeability of textiles during their design would not imply travelling back in time and only using materials that have traditionally been seen to age with grace, such as solid wood and leather, but rather open up for embracing the possibilities inherent in all types of materials (Chapman 2005: 130). On the one hand, this may involve textiles that are capable of changing their form or visual expression; on the other, learning to take good care of objects that quickly show unwanted signs of ageing. For example, ensuring that furniture made out of particleboard retains its neat surface, but also accepting the eventual changes in its surface as part of the material’s expression.

The production processes of materials and products are complicated, and few outside the industry actually know what they, or the raw materials and additives used to create these goods, look like. Albers (2000) argues that this lessens people’s connection with the material world, while Borgmann (2000: 420) refers to a similar phenomenon in noting that, with technology and devices becoming increasingly complicated, what an object is and how it can be repaired is no longer evident from the object itself. Technology has opened up for many new possibilities and made many tasks easier and faster to perform, but has also abstracted some of the functions of, for example, communication (Ibid.). In the context of textiles and garments, this may mean understanding how and from which raw materials viscose, a common material in t-shirts and dresses, is made, or how a dress shirt is constructed.

An appreciation for objects and materials retaining their appearance for as long as possible may have its roots in a time when materials were generally very expensive, and only available to a few. This is certainly no longer the case; materials are cheap, and so there is an abundance. In some ways, materials seem to have lost their value, and are discarded in favour of new things; consuming has become a way of living and building identity. Yet it seems that materials still matter, as the continuous acquisition of physical objects shows. Immaterial values and aspirations may be expressed in a cycle of acquisition and discarding, somehow rendering invisible the physical ingredients – the materials – that objects are made of. Borgmann (2000: 420) argues that this “paradigmatic consumption” – “enjoyment without effort” – lessens people’s engagement with physical reality. What is missing, he argues, is the intimacy with materials that comes from interacting with, maintaining, and learning to understand them (Ibid.: 419).

The requirement for uniformity and repeatability as a sign of quality was perhaps brought about by the need to streamline production and evaluate its outcomes, and has led to standardisation: being able to have the same experience of consumption anywhere, for example, or producing a printed fabric whose colours will not fade. At the same time, the forms, shapes, patterns, and colours of garments and textiles are updated in increasingly rapid cycles and produced using a few materials, leaving, as Edelkoort (2015) argues, no time for fashion, only clothes and styles without further knowledge of materials and structure (see also Borgmann 1999: 195). McDonough and Braungart (2002: 28-29, 33, 118-119) describe this phenomenon as “de-evolution – simplification on a mass scale”, which lessens diversity and has led to objects being distanced from the very ingredients they are supposed to embody.

One can argue, then, that the paradigm in our current relationship with materials then, is that even if objects such as textiles or garments become signifiers of something else, the physical reality of their existence does not change. Today, perfection is often associated with newness, with that immaculate surface of white laminate or the white of a new t-shirt. But when that surface acquires stains, or scratches, or the t-shirt acquires a red wine stain, they lose their charm (Chapman 2005: 131). Yet, materials are not as transient as the ideas that they represent, and will not simply disappear when they become aesthetically outdated or their meaning changes; instead, they will linger in closets or landfills, or be burned for energy. Nor do these materials come from a source of raw materials that is as unlimited as the possible identities that can be built or expressed with them.

If the meanings of some textiles and garments today are transient, perhaps their materials should be as well, and these changeable qualities should be appreciated for what they are. Accepting that textiles are changeable may also encourage an
increased understanding of the fact that both textile products and their raw materials have different lifespans, which vary from short to long. Fletcher (2014: 192-193, 201-202) and Goldsworthy (2017: S1961-S1963) propose a diversity of lifespans for garments that better matches the lifespans of garments to their purposes. Garments acquired for the purposes of novelty could be made of short-lived and recyclable materials or borrowed for short-term use, while other garments which age gracefully and become more personal through use could be made of durable materials that gain a patina (Ibid.). Alternatively, as McDonough and Braungart (2002: 139) suggest, the range of possible uses and users a product may encounter during its lifespan should also be considered during the design process in order to provide diversity. This could encourage the separation of growth from resource usage, but would require a re-evaluation, or rather rediscovery, of our relationship with materials – after all, it was not so long ago that materials were scarce, valuable, and to be kept and taken care of.

This approach may not, however, be directly applicable to industrial production, as it introduces change, diversity, and uncertainty as variables in a process that is based around predictability, stability, and repeatability in order to ensure maximum effectiveness. Perhaps, however, there is a middle way that takes advantage of the effectiveness of mass production, while still leaving its outputs open to change, ageing, and further manipulation. For example, textile bases alone could be produced featuring different properties related to change – an open toolkit, ready to be formed further by designers, seamstresses, and consumers. Alongside these there may need to exist other types of textiles and garments with more ‘ready’ expressions and functions, some small-scale or local, others ‘luxurious’. These could be acquired, bought, rented, borrowed, or donated, complementing the more open base materials but offering different properties relating to change, such as explicit patina-building (Fletcher 2014: 206-214; Goldsworthy 2017: S1961-S1963). Allowing for and encouraging imperfections and even mistakes in industrial processes (see McCallum 2018: 3) may also relieve some of the pressure involved in striving for static, unchanging durability as a sign of good quality, and allow for diverse types of products to emerge, as well as individual variation among seemingly identical products.

5. DISCUSSION

5.4 A diverse view on materials

During the workshops on changeable (melting and dissolving) fabrics, some students asked me why such materials were needed in the first place; would it not be more sustainable to only use very durable natural materials? The usual reply was that all materials change in some way, and a t-shirt that is made of durable materials such as cotton, and polyester, and assembled carefully with skilful cutting and sewing, may still be cast aside for something that is less durable if the garment is felt to be aesthetically outdated. The material’s lifespan should match the object’s in terms of material durability, aesthetic durability, and, more bluntly, the time it can be used for. Should a cover for a mobile phone be made of thick leather that ages beautifully in concert with human touch, when the next phone model will likely be too large to fit in the case, rendering the use period of the object as years instead of decades? Or would recyclable and quickly biodegradable paper, which also softens and gains a patina when handled, be a more appropriate choice?

Perceiving textiles as objects that will change over time or that can be changed at will or when needed would mean accepting change and wear and tear as part of a textile’s expression. This may mean that an alternative method for evaluating quality based on the aesthetics of change instead of durability could be viable, wherein the notion of permanence as a sign of quality in textiles is questioned. It may even mean broadening expectations regarding how long things should last; should all things last equally long, and what does it mean for something to last? Does the object need to remain unchanged? Here, an entirely new set of questions emerges, concerning how quality should be defined, regulated, and controlled to prevent possibly hazardous shortcuts being taken during production.

It may also mean becoming more sensitive to the changes that occur in textiles with age and through use, and how different materials could be handled to influence, prevent, or encourage these changes – in short, becoming aware of and understanding the materials that things are made of. Albers (2000), Borgmann (1999; 2000), and Edelkoort (2018), among others, claim that this connection has been lost due to the rapid changes brought about, first by industrialisation and later a culture of consumption and digitalisation.

Over the years, industrial manufacturing has in many senses managed to perfect its processes, today being capable of producing perfectly identical, symmetrical, smooth
coffee cups with high-resolution patterns in colours that will last forever. Or polyester blouses with a material that lasts and colours that never fade, but that may become aesthetically outdated relatively quickly due to shoddy workmanship during the production of the garment – which is still generally a labour-intensive process – collecting odours from the body, or simply changing trends.

Including changeability in the definition of good quality, or perfection, would not be excluding the existence of or need for the new. On the contrary, it may encourage broader approaches to creating newness that are less bound to the production chain and more connected to self-expression and communication between people. Technology offers possibilities for exploring alternative ways of experiencing and owning, but many of these are ultimately still used to buy and sell physical things. Possible alternatives can be found in the way that social media, blogs, YouTube, and dating apps are used for curated self-expression. What materials might be needed to reconstruct these images could be as fleeting as the images themselves – found, borrowed, tuned, recycled, random, or not materials at all.

Engaging with and learning to understand the surrounding world through making could be another form of discovery that, because – and indeed in spite of the fact that – it takes place in the physical world, precipitates an experience of newness at a slower rate. There are many forms that this might take, including DIY approaches, clothes hacktivism, clothing libraries, and cherishing inherited or otherwise personally important garments or textiles. Appreciating mending is by no means new; it has been a treasured skill for generations in Japan in forms such as kintsugi and boro, and is gaining popularity in Western countries through social media and sewing circles.

Accepting change as another quality of textiles could encourage alternative applications and appreciations of textiles in which they are allowed to and, if needed, consciously pushed to change their form and expression, opening up for a diverse array of possible roles, expressions, and functions. Rather than arriving as static, finished products and gradually deteriorating, textiles could evolve with time and during use Chapman (2012). Textiles could go through several stages, occurring over different timespans, during their lifespans. Longer, more stable periods of use and maintenance, slowly building the changes in expression and/or structure, could alternate with more intentional acts of changing and forming of a material’s expression or structure. The wear and tear and changes that occur in the structure and expression of a textile are embraced, taken advantage of, or at least made more explicit (Chapman 2005: 130).

Gradual colour changes and even the wearing out of parts of materials could build patterns over time, simultaneously making a textile more personal (Chapman 2005: 116; Niinimäki 2011: 84) and retaining its aesthetic appeal rather than seeing it as having ‘deteriorated’. Consciously dyeing a material could be a means of changing or upgrading a textile’s expression, and dyeing treatments that affect materials in different ways or blend colours could be added on top of one another over time to further build on a textile’s pattern and expression. Changes in a textile’s structure could be used to alter width, length, thickness, texture, and form, divide a textile into several layers or pockets, or adapt textiles to changing purposes, bodies, and spaces. This could encourage the adaptation of existing textiles to changing needs, prolonging the lifespans of these materials and thus negating the need to produce new ones.

Understanding and accepting that the colours of a pattern may change, only to fade and be re-dyed again – that curtains may be form-fitted on the spot and a placemat can be transformed into a fabric bag when washed at a high temperature – could encourage an interest in the materials that textiles are made of and how they can be taken care of or changed at will. A knitted fabric that melts and shrinks entirely when water is poured on it demands attention; its materiality cannot easily be ignored. In a similar manner, a pair of curtains that shrink if water is spilled on them when watering the flowers demands that its presence be acknowledged. A white laminate table demands careful handling and maintenance to retain its perfect surface. In a subtler manner, an emerging change in colour in places that are often touched makes visible how various materials age in different ways and in interaction with users. The measure of durability may become not how long a thing lasts unchanged, but how it changes.
REFERENCES


REFERENCES


6. REFERENCES


6. REFERENCES


7. Appended publications

7.1 Publication I


7.2 Publication II


7.3 Publication III


7.4 Publication IV

7.1 Publication I

Exploring the relationship between material and textile structure in creating changing textile expressions

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Abstract

This paper explores the relationship between potentially dynamic materials and textile structures for designing textiles with inherent changing qualities. Textiles are usually designed to retain their appearance for as long as possible. Yet all textiles wear out and change over time, both physically and aesthetically. This means the life spans of textile object and the material it is made from will not necessarily be equal. The dynamic changeable qualities in textiles could instead be enhanced by using the potentially dynamic, changing qualities inherent to materials and combining them with textile structures. Through contextualisation and design examples, this paper discusses the possibilities of embedding these qualities into textiles, and presents a series of woven and knitted designs that combine these materials into different textile structures. Two materials with differing dynamic qualities were chosen for the experiments. These are polyvinyl alcohol (PVA) yarn—a material that melts in water and uncoated copper wire—which creates a patina when it reacts with air. These materials are combined into woven and knitted structures and then exposed to two types of stimuli to explore how different stimuli affect the way in which the materials change: passive exposure to weather, and an active workshop with fashion design students. The results are initial explorations into the basic principles of combining potentially dynamic materials into textile structures to create textiles that take advantage of how different materials change over their life span, and how this might look. Through embedding different time spans into textiles instead of designing static expressions, the life span of materials and textile objects could be better matched, enabling the designer to tailor a more appropriate life span for textiles.

Keywords

textile design; material; structure; weaving; dynamic

In traditional textile design, form, colour, and texture are expressed by combining different materials and treatments with textile structures. When designing textiles that have dynamic qualities – those with the ability to undergo changes in expression or structure in response to different stimuli, - time, must also be considered as a design variable. The textile can thus be designed according to a time span under which it changes. In this paper, “expression” refers not only to the artistic qualities given to a textile by its designer, but also to a material’s inherent visual and tactile characteristics.

Material and choice of technique are often the major variables in textile design. Choice of material gives a textile qualities making it suitable for certain applications and after treatments. Construction of the textile, such as being knitted or woven, and after treatments like printing, dyeing, or coating further shape the textile’s qualities. Materials have inherent qualities i.e. they exist in the material itself. In some materials these qualities could be seen as potentially dynamic possibilities to change, such as wool’s tendency to felt. Having knowledge about materials is thus of great importance to a textile designer, yet this knowledge is often non-verbal. Technical information about materials is available, but designers often use their intuitive knowledge when making decisions during a design process. This knowledge can be in part experiential, i.e. gathered by the designer by experience, requiring physical interaction with the materials.

Along with material, the yarn and textile structures form the other basic elements of a fabric. As early as 1927, Nisbet (1927, p. 3) described the role of structure in woven fabrics by stating that: “...it is equally if not more important that a textile designer should be conversant with the principles of fabric structure, as that he should be an artist and expert draughtsman.” The tangible knowledge in the construction textiles is thus for a textile designer a fundamental variable in forming the expression of a textile. Also Nuno’s founder Reiko Sudo works with materials’ inherent qualities and combines them with woven structures. Sudo’s textiles often have a strong tangible presence and she has said that the first thing she considers when designing a textile is how it would feel to touch it (Milner, 2005). In this way she lifts the tangible experience of touching as a central quality in a textile.

Incorporating dynamic qualities in textiles can be divided into reversible and irreversible. A reversible pattern can go back and forth between one or several states. An irreversible pattern does not return to its original state. Instead its expression is built up over time (Worbín, 2010). Linda Worbín (2010) describes this as an inherent continual expression the textile gradually undergoes. These changes are thus inherently embedded in the textile due to its material and construction. This paper will focus on irreversible changes, since it addresses textile time spans. There is research on textiles with irreversible dynamic qualities that approaches them with various perspectives, such as interaction design (Landin, 2009; Persson, 2013; Worbín, 2010) and in relation to space design (Dumitrescu, 2013).

Several examples of this research embed change in potentially dynamic materials by using electronics and programming. Changes can be programmed to occur in response to certain stimuli, such as a textile that can for example break or shrink when it is touched (Dumitrescu, 2013; Persson, 2013). However, less information about irreversible changes is available about materials’ inherent qualities when used with textiles. When used with woven textiles, for example Dixon’s Ecoware presents one example of this type of change; tableware made out of biodegradable plastic that gradually wears out from use. Dixon argues that this character in fact makes the tableware more interesting and unique to the user who moulds them over time (Fairs, 2009). Hussein Chalayan has worked with aging and wearing out garments in two collections, ‘The Tangent Flows’ and ‘Cartesia’. He sprinkled iron filings on the garments and subsequently buried them for several weeks. For Chalayan treating garments by burying them was a method for storytelling, although he has stated that processes are for the designer and the result, the actual garments, is what is most important for the people (Golbin, 2011).

There seems to be an imbalance between material’s and object’s life spans. For example cotton is in itself a durable material, but it might be processed into a t-shirt that is made of thin single jersey that breaks easily, constructed with low quality sewing work. The life span of the object and the material it is made of do not meet. Research regarding textile life spans and the effect of material and aesthetic durability exists, for example Kate Fletcher (2008) proposes that garments could, depending on their use, have various life spans ranging from fast to slow. Defining these rhythms relates to recognising for which purposes garments are acquired. Fashionable clothes that are used for a short time could be made out of short-lived or recyclable materials. Less trend sensitive garments such as winter jackets could last for a long time and age beautifully becoming more personalised with use (Fletcher, 2008). This has been researched also by Jonathan Chapman (2013), who suggests that textiles and garments could be designed to improve with age, such as a pair of jeans that the user moulds their own through continuous use. Attaching personal memories to garments could be seen as a factor preventing early disposal of garments (Niinimäki, 2011; Chapman, 2005). Embedding fast or slow life spans directly into textiles could help to create a better balance between the material and the textile object’s life span, where life spans for both could be considered already during the design process. How such textiles could actually be constructed has so far seen little research.
In this project, textile samples are designed and produced to explore the possibilities of combining potentially dynamic materials with textile structures as a method for creating textiles with inherent capabilities for irreversible change. Two materials with differing dynamic properties are experimented with. These materials react to different everyday stimuli by changing and together they offer a range of qualities. The materials are combined with both woven and knitted structures. The fabric samples are then exposed to the passive stimuli, nature as well as active stimuli, use in a workshop for fashion students.

**Experiments**

**Method**

The starting point for the experiments was an interest in how irreversible dynamic qualities could be embedded into textiles during the design process, and to what extent it is possible for the designer to control these changes and how they might look like.

Two materials that change under everyday conditions were chosen. The first was uncoated copper wire, which forms a patina from exposure to oxygen and carbon dioxide (i.e. air). The second was polyvinyl alcohol (PVA), which dissolves when in contact with water over 20ºC. The materials were chosen because of their ability to produce visible changes from different stimuli over various time-spans. Patina can form on uncoated copper slowly or quickly depending on the circumstances. PVA reacts to water instantly by shrinking and melting, but the process stops temporarily if the material is left to dry, turning hard and translucent.

Textiles were designed to explore the synergy of these materials and textile structures. Experiments A and B explored the role of material and structure in woven textiles exposed to passive changes by setting them outdoors. Experiment C compared active and passive methods of inflicting changes on a three layered woven fabric. Experiment D focused on exploring in what way the textile’s expression change and how these dynamic qualities affected the way they are manipulated. A set of knitted fabrics with a range of dynamic qualities was developed and an active method of causing changes in them was used - fashion design students worked with the fabrics in a workshop.

*The role of material and textile structure in creating dynamic changes in textiles*

The initial experiment A was conducted on knitted single jersey in uncoated copper. A piece of the material was buried in earth for one year. Other pieces underwent active changes, exposed to vinegar both by soaking and through evaporation by being left closed in a jar with the material for various lengths of time ranging from one day up to a year. Afterwards the pieces were compared and analysed (fig.1 top row).

Experiment B explored the relationship between inherently dynamic material qualities and woven textile structures by creating changes in its expression over different periods of time. All samples were woven to an unbleached cotton warp on an industrial Jacquard machine. In experiment B1 two woven pieces of same size and materials, but with different bindings were placed outdoors for one month to observe if the choice of binding affected the way the textiles changed (fig.1 second row from the top). Both fabrics combined a white cotton warp with uncoated copper weft of the same density. One piece was of a rep weave and the other a satin binding. Two more woven samples made on the same warp with differing weft materials were hung outdoors in experiment B2 (fig.1 third row from the top). One sample combined PVA with a copper weft in a rep weave, the other used sample had only PVA as weft in a satin binding. In this experiment nature was chosen as a passive stimuli to cause changes in the fabrics. The outdoors, with its unpredictable rain, wind, sun and temperature was judged to be suitable to help create changes that could be observed occurring in the materials. All samples were exposed to weather under similar conditions and time, freely hanging outside, attached to a support from the top. The experiment lasted for one month.

**Exploring possibilities in how textiles could change**

Experiment C compared active and passive methods. A woven material consisting of several layers was developed. The sample combined an outermost layer of PVA with a black cotton background and a hidden middle layer of stainless steel. For comparison a variation of the same construction was woven out in a variant where the PVA was replaced by non-dynamic casein-yarn. The fabric was then subjected to different treatments. One sample was placed outdoors for one month, one sample was sprayed with water and one sample was machine washed at 40ºC. Afterward the samples were compared and analysed (fig.1 bottom row).

In experiment D knitted fabrics were developed with the aim of leaving their dynamic qualities open for other designers to work further with. Three fabrics with qualities ranging from subtle to explicit in expression were designed and produced on industrial circular knitting machines, combining PVA with more stable materials such as stainless steel and wool (fig.2). As this experiment explored how other people could further work with the textiles, PVA was used because it causes more instant changes in the textiles, making it more accessible to work with. The fabrics were used during a one week workshop ‘Crafting Wearables’ with BA fashion design students that was held at the Swedish School of Textiles on 28th October – 1st November 2013. The aim was to see how other designers could actively work with the dynamic qualities. At the beginning of the workshop, students were presented with the materials. After initial free experimenting the students could choose the materials they wanted to work with further. Their task for the workshop was to re-create an existing garment of theirs using the dynamic materials.
Results and analysis

In experiment A subtle changes occurred in the buried copper knit, which developed a surface of brownish and greenish shades (fig. 1 top row, centre left). Compared to the B samples that were hanging outdoors, the colours were deeper. In the sample exposed to vinegar changes in the material occurred after one day (fig. 1 top row, middle). Bright turquoise powdery patina formed on them. When left in the vinegar for a longer time the copper knit began to dissolve. After two months most of the knit had dissolved into crumbles (fig. 1 top row, centre right). After one year, the crumbles had transformed into rectangular crystals. In some places the structure of the original knit was still visible, even though the material had transformed into something different (fig. 1 top row, right).

When comparing B1 samples it could be seen that the sample with rep weave had changed colour from reddish to greyish, while remaining quite flat in structure (fig. 1 second row from the top, centre right). Colour of the satin sample had turned from an even reddish to different hues ranging from brown to grey. The fabric had developed a wavy three dimensional structure (fig. 1 second row from the top, right) due to the loose satin binding, with its irregular binding points, that allowed threads to bend in response to wind and rain. The more strictly organised rep weave was more stable, resulting in a flatter surface. The choice of binding combined with the material was thus an important design variable defining how the fabric will change.

In experiment B2 both weaves shrank over the duration of the experiment, and developed a matte, dense surface structure that felt like dry paper to the touch. Structure of the weave containing only PVA in weft was completely dissolved (fig. 1 third row from top, right). The dried out weave could be torn in direction of the warp. The piece containing both PVA and uncoated copper in the weft held its shape better. The sample shrank also, but the copper wefts held the overall structure of the weave in place resulting in flatter structure (fig. 1 third row from top, centre right). The shrinkage of PVA caused the copper wefts to form loops on top of the weave creating a new visual and tactile surface texture. Here it was the choice of material, combined with the binding that was the relevant variable defining the outcome.

At the beginning of experiment C all the samples had a similar, flat, neutral expression (fig. 1 bottom row left). After one month the sample placed outdoors developed a different visual and tactile surface expression as the PVA top layer had repeatedly melted and dried (fig. 1 bottom row, centre left). The surface was a combination of hard areas with dried, transparent PVA coating and soft areas where PVA had completely washed away. The middle layer of stainless steel had been revealed thus changing the light, neutral and sleek surface to dark and textured. Spraying with water caused more local changes revealing the stainless steel layer in specific places and causing the surrounding areas to shrink evenly (fig. 1 bottom row centre, right). Washing removed the top PVA layer completely creating a soft, dark surface (fig. 1 bottom row, right). No changes occurred in the sample containing casein-yarn instead of PVA. In this experiment the choice of material and binding in combination with how the textile was treated were the determining variables.

In experiment D working with a range of qualities from completely breaking down to stretching out enabled the creation of textiles that reacted in complementary ways. The fabrics developed included a single jersey in PVA that completely dissolves when in contact with water, a two-thread fleece combining PVA and stainless steel that changes its visual and tactile expression through partial breakdown of its structure, and finally a slipstitch pattern in wool, stainless steel, and PVA, which changes its visual and tactile expression by stretching without breaking apart (fig. 2). During the workshop the students worked with a variety of different topics. They took the materials’ dynamic qualities as part of their design
process and developed a range of methods for working with them. These methods included among others painting with water, steaming, fusing, sculpting and moulding layers with water, painting with teabags, heating, spraying with water and stretching and sewing with PVA thread.

The students effectively used and formed the fabrics’ qualities, such as dissolving, shrinking, stretching, stiffness, and formability and transition from white to transparent and soft to hard to create a variety of forms. Some worked more with the dynamic qualities as a tool for expression, others wanted to enhance the textiles’ expressive possibilities, and some used them as a functional part in their design. Students reported that in some cases the fabrics changed their way of working during the process. In one case a student redesigned a poncho. Instead of relying on creating volume in the poncho by adding fabric in the pattern, he cut out and sewed together pieces of the grey slipstitch fabric (fig.2 right). He then added volume to the garment through forming and stretching out the fabric in certain areas and leaving others untreated (fig.3). Another student created a dress combining three-dimensional structure and flat surface in the same fabric by shrinking parts of the two-thread fleece (fig.2 middle) with water (fig.4). Another created a white pleated top that could be transformed into a striped dress by using PVA as sewing thread and combining it with thermochromic print, creating a multifunctional garment with the help of dynamic materials (fig.5). In this experiment it was the combination of material and knitted structure that created a framework around how the textiles could change, but it was the action of forming them, which defined how the expression would change.

Fig. 2 Range of knits with dynamic qualities from experiment D used in the workshop. From left: a completely melting fabric that can turn from soft and white to hard and transparent, a fabric changing visual and tactile expression, and a fabric that can be stretched out without breaking.

Fig. 3 A poncho by Lui Iarocheski, where volume and form were created by stretching out certain parts of the fabric.

Fig. 4 A dress by Sofie Larsson combining three-dimensional structured surface with sleek flat surfaces in same fabric.

Fig. 5 A multifunctional garment by John-Daniel Isacsson, which can be transformed from a white pleated top to a striped long dress with the help of warm and cold water.

Discussion

The first experiments, A and B, focused mainly on material qualities, their combination into textile structures, and observing how the structure of the textile contributed to how the material changed when subjected to the elements (fig.6). In experiment B2 copper darkened in contact with air, and humidity seemed to speed up the process. Samples kept indoors retained their original colour. How tightly the copper was woven with other materials affected the result. The copper could also be shaped for example by crumbling or folding, but the resulting expression will differ from sample B1’s wavy surface which was formed by wind. Shaping PVA manually offers perhaps broader possibilities for creating different forms and surfaces, as was seen in the workshop with the fashion design students. This would suggest that materials and structures, as well as different stimuli, afford the textile certain qualities that suggest different uses. They also reveal evidence of the textiles experiencing different conditions.
The results of experiments C and D (fig.6) indicate that the way in which the textile is formed and changed is at least as important as its material and structure. In experiment C the sample exposed to weather showed the greatest potential for creating different expressions. In this case the overall effect of the weather created a change in the expression that proved difficult to achieve with other, more conscious methods. In experiment D the material and structure afforded certain types of changes, like shrinking, hardening, and breaking in the knitted fabrics, but how exactly the textiles were formed was decided by the fashion design students. This led to a variety of expressions in the resulting garments. The samples in fig.2 present one example of how the textiles could be formed, but exactly how they change depends on how they are formed and for what purpose. For example the two thread fleece in the middle of fig.2 is manipulated into a flat surface. The dress in fig.4 is made from the same material, but the student has formed a three-dimensional surface structure with the material.

Textiles are often experienced simultaneously with more than one sense. This is why their tactile qualities could perhaps be considered more in the design process. The experiments made during the project indicate that to be able to work with dynamic qualities in textiles, a textile designer needs extensive tangible knowledge about both materials and textile structures in order to be able to predict how the textiles will change. For example some of the experiments made during the project showed considerable change in their tactile qualities. Left out in the weather, PVA developed a dry paper like surface, while the same material sprayed with water turned hard and smooth. Such understanding is gained through physical interaction with material and technique—Nisbet (1927) describes this interaction as a conversation. Also for Reiko Sudo a textile’s tactile qualities are as at least as important as its visual expression (Miller, 2005), and her textiles often visually convey a sense of how it would feel to touch them. The students working with the knitted materials in the workshop reported that having the material melt against their skin felt repulsive and that the steel and PVA fabric changed from smooth to prickly when it half melted. The physical experience of interacting with the materials that dynamically and tangibly reacted to manipulation became quite central for the students. They needed to adjust the way they usually manipulated materials, which resulted in them developing new working methods.

In the project different types of changes were embedded into textiles depending on the planned method of testing. The samples tested in nature consisted of loose structures enabling them to be moulded by the weather. Subtle changes in texture and colouring occurred over longer periods of time through repeated exposure. This type of change could be described as passive. The knitted fabrics developed and used in the workshop for fashion design students had qualities that enabled them to be actively formed in different ways that would perhaps not translate as clearly when exposed to nature. Further research is needed to compare different types of change on similar textiles to acquire more comparable information about the effect of the type of stimuli and how textiles could change.

In traditional design processes with static textiles, chance is usually sought to be eliminated so the textile can retain its expression for as long as possible. Yet faded colours and worn out materials will always occur in textiles over time and use. Instead of aiming to remove all signs of ageing, wear could be taken as yet another quality of a textile. Kate Fletcher (2008) proposes that garments could have life spans ranging from fast to slow, and that one way to make this possible would be to make textiles from materials with different life spans. A pair of jeans often requires repetitive use over time to fit its wearer perfectly. This quality cannot be added to the garment at production state, but it requires the jeans to be made out of a material that wears out in a good way. Instead commitment from the user is needed, which also contributes to creating a meaningful relationship with the object (Niinimäki, 2011) and could encourage people to look after their garments for longer (Chapman, 2013).

Still the textile designer most likely cannot entirely control the exact changes the textiles might undergo. The changes will occur in interaction with other people or the environment and their precise nature is difficult to predict. There remains an element of chance in the nature of such textiles. Further research could explore what types of uses and contexts textiles with different types of dynamic qualities or life spans could afford or suggest. In the case of Tom Dixon’s EcoWare it was the combination of the material and the form of the object that determined its intended use. This exposed it to certain stimuli, in this case water and detergent that become the variables defining the product’s life span. In Delia Dumitrescu and Anna Persson’s (2013) Knitted Heat project the textile’s tangible response to touch by shrinking or breaking afforded or encouraged interaction with it and the space. The passive changes in the burying and weathering experiments were subtler. They could perhaps offer proof of the textiles’ life span, in the same way that jewellery can be refined through patina, or Hussein Chalayan’s buried dresses tell of not only his story behind the collection, but also what the actual garments have been through. Perhaps changeable qualities in textiles could invite users for more tangible interaction with their textiles, or even empower them through offering possibilities for engagement in changing the textiles.

### Conclusion

The textiles developed during the project are initial explorations into how materials with potential for dynamic changes could be embedded into textiles by the designer. The results of the project suggest that the choice of material and textile structure both have effects on how the textile will change. Depending on the combination of materials, different life spans could be embedded into textiles. The inherent qualities of a material can give indications of how they might change. Wool’s tendency to felt in contact with moisture and abrasion could for example indicate the ability to shrink and become denser in the wash. Likewise, polyvinyl alcohol’s ability to dissolve in water could be used to create textiles that are able to break or change their structure when they come into contact with water—garments could thus change their form when washed at a high temperature. Depending on how the potentially dynamic material is combined with a textile construction, different expressions can be created.

However, the experiments reveal that the way in which the textiles are formed or changed is at least as important as their structure. This would suggest that already at the stage of making choices about material and construction the designer should consider the context in which the textile will be used. Embedding life spans ranging from fast to slow into textiles could help create a better balance between textile and object, when appropriate life spans could be considered already during the design process. The textile designer does not just estimate how long a life span could be, but actively designs it. For example, a fast fashion garment could be given a very short life span, whereas a quality jacket meant for a long term use could be designed with qualities that make it age in a graceful way, becoming more personal to the wearer. Further research is however needed into how these textiles could look like under different stages of their life spans.

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References


Riikka Talman
The author is a PhD student in textile design at the Smart Textiles Design Lab at the University of Borås in Sweden. With a background in textile design she has an interest in how tactile qualities are experienced and how different materials can be combined with textile structures to create changeable qualities in textiles. Her research focuses on how inherent changeable qualities could be embedded into textiles to create textiles that change irreversibly over different time spans, and how these changes could look like.
7.2 Publication II

7 On Researching and Teaching Textile Design: Examples at The Swedish School of Textiles

Delia Dumitrescu, Marjan Kooroshnia, Hanna Landin, and Riikka Talman

Introduction

Artistic research in design is relatively new compared to experimental research in the natural sciences, but it has matured a great deal over the last decade. Its extensive development has brought new challenges to professional practice, and also raised questions regarding how knowledge should be imparted in academia. By examining the field of textile design, which has traditionally been taught in close synergy with professional practice, we can discern the emergence of doctoral theses that have brought not only new professional practice, we can discern the emergence of doctoral theses that have brought not only new professional practice, but also new roles to design educators as researchers in academia. One of the challenges that design education programs are facing, however, relates to creating a better connection between research and education in order to continually enrich curricula with innovations in the field, so that basic knowledge can interact with novelty. By looking closely at research at The Swedish School of Textiles (SST) and its interaction with undergraduate and postgraduate education, this chapter describes how research has informed the development of textile design education.

Teaching Design Rationales: Relationship between Basic and New Methods in Textile Design

A textile design education program generally develops students’ artistic skills, craftsmanship, and technological knowledge, enabling rational design choices to be made when creating a surface expression. The varied expertise that students gain through a textile design education program relates to technical precision and artistic ingenuity, which are employed in order to define a textile’s character and expression (cf. Gale & Kaur, 2002; Sinclair, 2015). Accordingly, the methodology builds on the fundamental notions of color, pattern, and construction, combining the aesthetic and functional qualities of a textile as a material of design, and yet is dependent on direct manipulation of material (Albers, 2000). The character of yarns and geometry of bindings are the two basic elements that form the core of the design process that a textile designer learns to operate the practice, and the interplay between these basic elements forms the structure that defines the material (the textile). While working with surface design implies a continuous process of refinement of, and critical reflection on the basics, e.g., motif, repetition, and organization, working with colors adds to the complexity of textile structural thinking (cf. Steed & Stevenson, 2012). Having become an established area of research, textile design has begun to articulate its own perspective on the relationship between material experimentation and theoretical knowledge through the education of future practitioners. This marks a shift from imparting tacit knowledge (Polanyi, 1966) to training design rationales (Kunz & Rittel, 1970) and, even more importantly, from teaching textile design to teaching textile design thinking. This journey will be exemplified below through the development of research in smart textiles at SST.

Smart Textiles

Throughout human history, textiles have been designed to exhibit one expression—a static state that gradually changes as a result of use and the organic passage of time. However, smart textiles have introduced a new, temporal perspective on design, and today we design smart textiles with an awareness of time. We design textiles that can change from one expression to another, challenging our established views of textiles’ character, functionality, and use. Accordingly, textile design practice has been broadened from working with pattern design, colors, structures, and finishes to programming and working with digital processes and methods, all in order to design complex surface interactions (Quinn, 2010; Kettley, 2016). The ubiquity of digital technology and the development of new materials have expanded the textile design field by offering a new paradigm of smart textiles. This has resulted in a shift in materials from static state materials to dynamic ones that are programmed to transform in response to stimuli. As a research paradigm, smart textiles have introduced a new perspective on textiles at the intersection of textile design, computational design, and materials technology. Research in smart textiles has challenged conventional views regarding textile methods and artifacts. It has expanded the textile design field with new notions such as temporality, dynamic forms, and acts of use. Research results in this field have led to an improved understanding of the expressive possibilities of these materials, as well as of the methods and basic variables to be used in design. At the same time, it has been clear that further development of appropriate models to link theory and practice is needed for teaching textile design as a new academic discipline. Just as theory and practice cannot be separated in design, the development of education programs cannot be separated from the development of research. Teaching methods are needed that deal with the foundation of textile design in relation to newly developed knowledge, where the materiality of the practice and its practical experimental perspective are central.

On Teaching Smart Textiles

At SST, which is located at the heart of Sweden’s historic textile-industry cluster, education has always been in close contact with industry. The Bauhaus model, with its focus on the relationship between art and technology, has been very close to the way the curriculum is organized and the way teaching models are applied (cf. Wingler, 1976; Itten, 1975; Albers, 1975). The smart textiles research program at SST investigates programmable materials, computational technology, and textile aesthetics, proposing new ways of approaching the foundational definitions of textile design through exploration of patterns, colors, structures, techniques, and expressions. Utilizing multidisciplinary perspectives, including interaction design, product design, and architecture, the program enables the exploration of new approaches using smart colors or light as design materials, a better use of conductivity as a material property, and new possibilities afforded by digital technology. SST focuses on ways of teaching new materials from the perspective of the aesthetics of textile interaction design, in terms of what a textile can do. The aesthetics of the interaction is determined by what can be achieved with the textile in relation to how changes of expression can be linked to user interaction (Hallnäs & Redström, 2006; 2008).

This perspective on teaching smart textiles has been articulated in relation to ongoing and completed research conducted in the Smart Textiles Design Lab that, together with the Smart Textiles Technology Lab and the Prototype Factory, constitutes the Smart Textiles Initiative, funded by Vinnova, the Swedish Agency for Innovation Systems. It has resulted in the development of methodological frameworks for working with new materials that move from a technological to an aesthetic perspective. For example, Worbin (2010) explores different textile techniques and ways of embedding new materials, enriching the foundational definition of textile design by creating smart textiles that can change expression—from A to B—through programming and/or direct interaction.
Kooroshnia (2017) develops a new system for working with smart colors for printing complex multiple patterns—her experimental work is situated at the intersection of fields other than textile design, such as graphic design and interaction design. Landin (2009) explores the notion of the aesthetics of interaction when it comes to form and expression with the possibilities enabled by dynamic materials and their programmable behavior. This research has partly resulted in methods and exercises that can be used in teaching that aims to develop better sensibility to the aesthetics of interaction in a design process. Furthermore, based on a multidisciplinary perspective, Persson (2013), Nilsson (2015), and Dumitrescu (2013) examine how basic variables and textile design thinking can affect other fields of design, such as product design and architecture. This knowledge gained from practice-based experimental work performed at the Smart Textiles Design Lab has influenced the development of new methods for teaching textiles. Accordingly, the teaching of smart textiles can focus on material exploration in relation to programming (Kobakant, n.d.) or on scenarios of using smart textiles as materials to/for design (Nilsson, 2016; Dumitrescu, Nilsson, Persson, & Worbin, 2014; Talman, 2016).

The new perspectives of dynamic qualities and interaction possibilities have influenced design education regardless of the textile materials or techniques used. Today, our knowledge of the design of smart textiles is embedded throughout education, featuring as elements in basic courses, technical courses, and independent workshops. From introductory courses in printing or textile materials to conceptual workshops on the aesthetics of dynamic and interactive forms, nuanced approaches to smart textiles have enriched the conventional format of teaching textiles.

The next sections will illustrate three new perspectives on textile design education that have been performed through different categories of workshops: material, color, and forms. These workshops demonstrate how new knowledge generated from research can be transferred to students and integrated in the textile design curriculum, thus creating a continuous synergy between ongoing research in the Lab and education through textile thinking. Subsequently, textile thinking in education to which these perspectives have contributed will be illustrated through examples of student work.

**A New Perspective on Teaching Materials: Transformable Materials**

Bringing smart materials into the world of textile and fashion education can act as a way of introducing students to new materials and methods. A one-week workshop for second-year textile and fashion design undergraduate students is discussed here to demonstrate how students are introduced to an alternative method for designing textile expressions. The main learning objective of the workshop is to introduce the students to new materials and design methods involving transformable materials.

As a result of the research projects mentioned in the previous section, the Design Lab has developed the Smart Textiles Sample Collection, featuring materials with a variety of transformable qualities that are used by the university’s programs and private sector workshops. Fabrics and yarns from the collection are used as raw material in the workshop. The collection spans a range of samples of transformable qualities that react to everyday stimuli, such as heat or moisture, including structural change (different characters of smart yarns in knitted or woven textiles) or surface change (different types of smart colors on printed textiles). The samples in the collection include, for example, knits that break and break in response to heat (Dumitrescu, et al., 2014), monochromatic and patterned fabrics that change color in response to heating or cooling (Kooroshnia, 2017), and knits that break, melt, and expand here to moisture (Talman, 2015). Both irreversible (e.g., shrinking or melting) and reversible (e.g., color changing) materials are featured in the collection to provide a broad and varied range of transformable qualities that can be further explored. What these materials have in common is their openness to possible uses and functions as well as expressions and states that make them suitable for various applications. Together, the materials provide students with an easily approachable, hands-on way of experiencing dynamic qualities in textiles.

The brief for the workshop is to create textile expressions using materials that react to water or heat in order to explore how changeable expressions and forms can be designed using materials that have transformable qualities. After an introduction to the materials, the students are encouraged to freely explore all materials before choosing one for further exploration. Usually, the students’ explorations take two distinctive approaches: (a) creating changeable expressions (Figure 7.1, left); and (b) using dynamic qualities to create a relatively static expression (Figure 7.1, top & bottom right). Most students choose the latter, probably because they are used to creating static expressions. Their choices also depend on whether the change in the material could only be triggered once, such as shrinking, or if it could go back and forth between several stages, such as color changing. Many students find it difficult to work with materials that they cannot control. For instance, the exact shrinkage of Pemotex in response to heat is difficult to control, and the effect of PVA melting and shrinking in response to water depends on how water spreads on the material and how the material absorbs water.

The less successful experiments include those where students control the material’s behaviors or go against them, instead of “listening” to the materials of a situation, or conversing “with the materials of a situation,” according to Schön (2003, p. 78). This makes it applicable to other design contexts, where knowledge and understanding of the interactions between material, construction, color, and scale are necessary to explore forms and to create new expressions. In this way, students must surrender control over knowing the result in advance and instead are encouraged to trust the materials and adopt an experimental way of working.

Figure 7.1. Examples of students’ explorations of pattern, texture, and fabric behavior through transformable materials. Photograph: Riikka Talman.
A New Perspective on Teaching Colors: Changeable Colors

In the last decades of the 20th century, thermochromic colors—which reversibly change color in response to temperature fluctuations—have been introduced to and included in the color palettes of designers, particularly textile designers. For instance, Disobedient Tablecloths (Worbink, 2006) illustrates how a thermochromic printed tablecloth reacts to the warmth of a cup of hot water. The color disappears in the area on which the hot cup is placed. There are two major types of thermochromic ink: liquid crystal and leuco dyes. The former provides a continuously changing spectrum of colors when exposed to temperature changes, while leuco dye-based thermochromic inks are colored in a non-heated state and become colorless or have a very light color in a heated state (cf. Bamfield & Hutchings, 2010). They are usually blended with other (static) pigments, allowing the mixture to change from one color to another.

In the basic printing course, a three-day workshop for first- and second-cycle students utilizes a new system to describe changeable colors employing the pedagogical tools of color swatches and thermochromic color transition sample spectra developed in Kooroshnia’s (2017) Ph.D. research (see Figures 7.2 & 7.3). Following the notion of learning by doing (Drew, 2004) and a motivational framework (Wlodkowski, 1999), the workshop helps students better understand the behavior of thermochromic inks at various temperatures. The first task of the workshop is to work with thermochromatic inks with the activation temperature of 32°C. The students are instructed to choose one warm- and one cold-color ink. They overprint one of the patterns (frame No. 1) with the chosen cold color and the other (frame No. 2) with the chosen warm color. Afterwards, they heat up their printed fabrics to above 32°C using a hair dryer or a heating pad, in order to examine and observe color changing effects. The second task is to mix the chosen inks with a static textile pigment paste. The students are then instructed to mix their chosen inks with a static textile pigment printing paste, of their choice, and overprint the pattern of the frame No. 1 with the mixture of the cold color ink and the pattern of frame No. 2 with the mixture of the warm color ink. Printed swatches made using textile pigment printing pastes and tasks that involve using them make up the core of the teaching materials. The swatches demonstrate the color transitions of thermochromic inks at different temperatures, while the tasks give students an opportunity to develop their understanding of the design potentials of thermochromic inks through experimentation and individual exploration. Some of these are structured while others are more free, assisting in the development of students’ ability to design dynamic surface patterns.

The design outcomes of the workshop are evaluated based on how they demonstrate the students’ ability to integrate their new knowledge, the behavior of thermochromic inks, with their previously gained knowledge of static pigments into the design of surface patterns. The workshop allows them to work on their ideas using their design skills, and assists in developing their ability to predict the consequences of their design decisions in terms of where and how to apply dynamic colors in relation to other design elements on dynamic surface patterns. The workshop therefore introduces complexity in pattern design, regardless of the use of dynamic materials.

A New Perspective on Teaching Forms: Dynamic and Interactive Forms

Bell’s definition of artworks as “significant forms” refers to an organized set of variables, e.g., an arrangement of shapes, colors, volumes, and textures (c.f. Carroll, 2008, p. 109). Here materials are seen from the perspective of forms. Thus, one of the central design variables introduced by smart materials—seen as forms—is time. This concept is addressed through the dynamic form workshop for the third-cycle students working on their research concerning transformable materials. The workshop aims to introduce forms and materials as fundamentals for designing time-based expressions. The workshop uses both DeLanda’s (2015) theoretical perspective on new materialities and Dumitrescu’s (2016) methods for working with time-based materials (not necessary textiles). Participants examine the possible variables and attributes of dynamic forms, including change, speed, and sequencing, through the discussion of exemplary works from the fields of graphic, product, interior, and architectural design. They directly explore the transformation stages of dynamic forms, examining the properties and capacities of transformable materials that are central to their research. By investigating actions that can result in the structure or surface of a transforming material, each participant is able to document the process, select preferred stages/frames of the material’s transformation, relate them through new time intervals, and extract quintessential
variables in order to define new dynamic forms. The doctoral students select materials that are central to their research, using the workshop as a means for closely investigating the properties and design possibilities of materials, as well as finding new methods of illustrating these possibilities both practically and methodologically. The workshop enables the participants to find the most suitable way for their research to document and analyze the dynamic character of the materials that they are designing.

It is worth mentioning two student explorations during the workshop in 2016. First, a participant explored the stages of transformation of kinetic yarns. Using photography and video recordings, she documented the material’s different states of change when an external stimulus was applied. The analysis of documentation enabled the participant to discover unexpected transformations and quintessential design variables that defined form. It also helped her to select preferred states, which can be used later to design a new transformation scenario. Second, another participant explored seeds as materials for textile design, photographing changes in textile expression due to the transformation of the materials that depends on different variables, e.g., time, water, light, and ways of embedding seeds in the structure (Figure 7.4).

Another workshop addresses interactive forms. It aims to enable reflection upon what new transformable materials, changeable colors, and dynamic forms could offer and mean to people. The workshop explores the use of writing to examine certain interaction issues (as distinct from using writing solely for documentation). Writing as a way of thinking and experimenting is introduced to doctoral students working on projects concerning future living with adaptive and responsive interior design. They are guided to try out thoughts on how the relationship between people and interiors can be designed. Writing is used as a tool for considering design possibilities and for exemplifying the differences between interaction scenarios that describe expected user experiences and interaction scenarios that build up perspectives on the relationship between people, objects, and spaces. The participants are able to explore different perspectives of what a dynamic design can add to people’s lives. Such a workshop opens up questions regarding aesthetics within interaction that can be difficult to see, explore, and exemplify in other ways.

Reflections on the Present and Recommendations for Further Development of Textile Design Education

Research in smart textiles has opened up new teaching methods about materials, colors, and forms. By aligning the knowledge taught in higher education with contemporary research paradigms in the field, it has proposed new variables and ways of designing surfaces. Modules on traditional yarns of static qualities, e.g., cotton, linen, and polyester, have been supplemented with new ones on transformable materials, e.g., conductive, heat reactive, and water-soluble. Established methods of teaching color theory have been enriched with a new system to describe dynamic colors based on the behavior of the leuco dye-based thermochromic inks. Traditional form and material workshops with a focus on static expressions have been complemented with interaction design perspectives: the exploration of time as a design variable and the role of a dynamic design in people’s lives.

Research at SST has provided a broadened view on what textile design is now and what it could be in the future, and on what basic knowledge is appropriate for students, who commit to the changing field, to be able to create its future. This perspective is more general than textile design with smart materials and independent of technical textiles. It has led to critical reflection on the basic notions of textile design, e.g., pattern, form, construction, texture, and color. Such reflection on the field has arisen from experimental research work, and from challenges and discoveries when working with unknown materials with changeable behaviors.

Examples of work by the first- and second-cycle students illustrate how the synergy between research and teaching can sustain ways in which students develop the field of textile design. For instance, works exploring how textile properties can be introduced to other materials by using certain techniques (Figures 7.5 & 7.6), or works demonstrating how new design expressions can be created using certain materials and structural manipulations of conventional textile techniques (Figures 7.7 & 7.8).

The foundation of how we perceive, read, and navigate the field has also been questioned through the engagement of the expressive possibilities of a technique (Figure 7.9) or through research into color and material interaction that generates new sustainable methods for designing textiles (Figure 7.10).
On Researching and Teaching Textile Design: Examples at The Swedish School of Textiles

Figure 7.5. It’s Now or Näver by Emma Dahlqvist explores ways of applying textile design thinking to birch bark craft, using the technique of laser cutting. Photograph: Emma Dahlqvist and Jan Berg.

Figure 7.6. Dear Dear by Hanna Bredberg looks at food consumption through textile aesthetics and proposes a way of taking care of materials which are commonly looked upon as disposals. Photograph: Jan Berg.
On Researching and Teaching Textile Design: Examples at The Swedish School of Textiles

Figure 7.7. Inspired by the Japanese wood joinery, Giving Textiles Form by Lovisa Norsell develops a coating technique for challenging the soft character of textiles. Photograph: Jan Berg.

Figure 7.8. Lily Adamsdottir’s Tension Attention! Dancing Embroidery! brings a new perspective on embroidery. The thread tension enables playfulness when interacting with the elements on the top surface. Photograph: Jan Berg.
The development of the textile field is maintained by keeping an active critical view of what textile design is. This can be done with the help of other fields, such as architecture, interaction design, product design, fine arts, and computer science. This perspective corresponds to Findeli’s (2001) revisit of the three models of design education—Bauhaus, Chicago Institute of Design, and Ulm School of Design—that recommends design education to intertwine the following fundamental aspects: art, technology, and human and social science.

Maybe a complementary element is needed in conjunction with the existing experimental material approach when teaching design, as Findeli suggests? One way is to look at textiles outside their novel materiality and design methods, and to complement them with a relational perspective—textiles as fundamental materials for living. As relational aesthetics reverse the idea of passive matter and artifacts, which has been traditionally dominant in the artistic fields, and as we reconsider our relationships with the things around us (Bourriaud, 2002; Ladyman, 2015) we need to add new perspectives on teaching textiles as well. This could be done by looking at the three perspectives of teaching textiles proposed in this chapter—transformable materials, changeable colors, and dynamic and interactive forms—from an experiential viewpoint of the everyday use of textiles. By doing so, the teaching of textile design may need to introduce a method of changing typical situations into unexpected ones, stimulating reflections on everyday living, on ways of expressing identity, and on ways of looking at materials permanence and/or consumption.

Figure 7.9. The Clothes I Live In by Maike Schultz uses weaving to capture the dynamic expressions of wearing. Photograph: Maike Schultz.

Figure 7.10. Dyeing Diversity by Emy-Rut Väikesopp explores the expressive potential of plant dyeing and proposes a method for working with biodegradable materials and weaving. Photograph: Emy-Rut Väikesopp and Jan Berg.
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7.3 Publication III

Rikka’s research explores how inherent changeable qualities can be embedded into textiles in order to create materials that change or evolve over different timespans, thus enabling the designer to tailor a more appropriate lifespan for both textiles and the artefacts made from them. The research explores how different materials can be combined with textile structures to create expressions that change over time or in use, ultimately challenging the notion of permanence as a sign of quality in textiles.

Karin’s research examines ways to mould and 3D print garments. Suggesting the use of an amalgam of analogue and digital techniques its primary focus is the exploration of expressive qualities within a design process where the development of garments strive towards a simultaneous creation of surface and form. Mimicking processes commonly found in the fields of glass and ceramic, the work challenges the predominant use of cut and sew techniques when creating and producing full scale, fully functional and reproducible garments.

Exploring the expressive possibilities of woven textiles with inherent form-giving qualities in conjunction with moulds obtained for simultaneous creation of surface and form in garment making, our venture challenges existing predominant ideas surrounding material, construction and aesthetics in the field of textile design as well as that of garment making. Further, it proposes alternative methods for design within both fields, challenging our understanding of ‘new luxury’.

Merging Formable Textile and Flexible Moulds
In search of new design methods and expressive qualities in the fields of textile and fashion

Rikka Talman & Karin Peterson
Textile & Fashion design department, Swedish School of Textiles, Boras, SE

Creative Contribution → Parallel Session #3.1: Material Agency
Friday, June 1 13.15–14.45 Muzenzaal
Short introduction of creative practice that will take place outside the parallel session

Formable wovens, 2018 → Rikka Talman
Simple T on flexible mould, 2018 → Karin Peterson
Designing for Multiple Expressions: Questioning Permanence as a Sign of Quality in Textiles

Riikka Talman

ABSTRACT Developing alternative materials and methods of production and recycling is crucial to achieving more sustainable, circular textile practices. In addition to these, a shift in how textiles are perceived may well be needed. Textile practice has long sought to create textiles that, regardless of their material or post-production treatments do not subsequently change in expression, eliminating the fading of colors and wearing out of materials. Questioning this in order to evaluate quality, durability, and aesthetics may open up for greater circularity through extending product lifetimes, and allowing change to be embraced rather than delaying the signs of aging. This paper presents work that challenges the notion of permanence as a sign of quality in textiles by shifting the focus towards creating textiles that are capable of developing different visual expressions over time. By examining the natural changes in color of materials in plain and Jacquard-patterned woven
textiles made of several materials, this paper explores the possibilities relating to designing textile patterns that can evolve in multiple different directions from one starting point. Textiles woven with a combination of different materials were used in various contexts, including outdoors, in order to explore how the materials reacted. The resulting color combinations varied depending on what conditions the material was exposed to, suggesting a more versatile view on the aesthetics of textiles. The results indicate that various colors, patterns, and structures can be achieved from one starting point, indicating that an alternative definition for quality, based on the aesthetics of change, may be viable. The natural aging of materials could be used in design processes to embed evolving patterns, colors, or structures in textiles, reconnecting textile products with the inherent, changeable qualities of materials.

KEYWORDS: Textile design, sustainability, circularity, lifespan, evolving patterns, material

Introduction
Quality in textiles

In relation to the search for sustainable alternatives in the field of textiles and fashion, there is a growing interest in circular design practices (Goldsworthy 2017; S1963; Moorhouse and Moorhouse 2017; S1949; Smith, Baille, and McHattie 2017; S1938-S1939). Finding alternative materials and methods for production and recycling is crucial to developing more circular textile practices. Initiatives that have explored biological processes such as growing building materials or textiles—such as paper yarn, hemp, bio-plastics, and recycled polyester, have broadened the range of traditional materials and production and recycling processes.

Yet, in addition to these improvements, changes in how textiles are designed and appreciated may be necessary in order to open up a more holistic perspective on circularity. Here we note an opportunity to make a change in how textiles are designed in order to move from a current focus on delaying signs of aging to embracing them, thus encouraging people to look after them for longer. This in turn would set the conditions for materials, and how they behave as they age. Consider a pair of jeans: through extensive use, the wearer molds them as their own, creating an individual pattern, and so wear and tear is something that adds to the product’s value and narrative (Chapman 2005: 133). This process is often called “quality control,” a term which hints at how quality in textiles is perceived.

The tests do not, however, take into consideration the form that the changes that occur in textiles take. A thin single-jersey t-shirt may lose its shape, while stiff leather becomes softer and acquires a better fit with use. Social norms also influence the ways in which the aging of different materials is experienced (Chapman 2005: 133; Townsend 2011: 92–93, 105). Discussing quality in terms of how objects age could open up for broader interpretations of what constitutes a finished textile or product, and question when the lifespan of an object has come to an end (Chapman 2012).

When the durability of textiles is tested, this is performed with regard to retaining the appearance for as long as possible. Testing usually aims to ascertain how much use and exposure to the elements a textile can endure before its colors and materials begin to show signs of wearing out. Textiles, yarns, and fibers are tested according to various standards; the Martindale abrasion test, for example, measures the durability of fabrics against abrasion. Here, a fabric is abraded by circular movements for a fixed amount of time, after which changes in the textile are measured (Bilisik and Yolacan 2009: 1625). The less material the fabric loses during the test the higher its test score, and a new textile with an intact surface serves as the starting point for measurement, deviations from which are considered to constitute a decrease in quality. Testing methods are developed in order to improve their accuracy and repeatability and eliminate variation (Pegram 2000: 90), i.e. to produce standardized, homogeneous textiles that can be produced as exact copies of one another. This procedure is often called “quality control,” a term which hints at how quality in textiles is perceived.

Specific types of textile product, such as aprons, sportswear and doormats, act as sacrificial layers that become stained. On other textiles and garments, however, stains are unwanted, marking the fabric and the wearer and recording the passage of time (Sorkin 2000: 77, 79).

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The tests do not, however, take into consideration the form that the changes that occur in textiles take. A thin single-jersey t-shirt may lose its shape, while stiff leather becomes softer and acquires a better fit with use. Social norms also influence the ways in which the aging of different materials is experienced (Chapman 2005: 133); some, such as thick leather, improve, while others, such as acrylic, lose value with time and use.

Chapman (2005: 133) argues that design should challenge the norm of new, intact products, and proposes an approach to designing artifacts in which retailing is seen as the starting point of a product’s life. He further argues that textiles and apparel that are designed to improve with age could create emotional value and encourage people to look after them for longer. This in turn would set several requirements for materials, and how they behave as they age. Consider a pair of jeans: through extensive use, the wearer molds them as their own, creating an individual pattern, and so wear and tear is something that adds to the product’s value and narrative (Chapman 2005: 116; Townsend 2011: 93, 98, 105). In denin, this quality has proven so popular that designers have added various treatments to the fabric to achieve similar effects during production (Townsend 2011: 92–93, 105). Discussing quality in terms of how objects age could open up for broader interpretations of what constitutes a finished textile or product, and question when the lifespan of an object has come to an end (Chapman 2012).
**Wear and tear**

Using wear and tear as a design expression is not new in the field of textiles and fashion. The most typical example of the wear-and-tear aesthetic is perhaps jeans. Even Japanese wabi-sabi, kintsugi, and boro boro, however, which originated out of necessity, praise the imperfection of things and the value of taking care of and repairing them. Chalayan explores the wear and tear of materials in his collections “The Tangent Flows” and “Cartesia,” accelerating the aging process of garments by covering them with iron filings and burying them for several weeks (Golbin 2011: 29–33). The resulting garments have a rich texture and pattern, combining rusty tones and decomposed areas. The research presented in this paper used a similar method, with time and relatively extreme outdoor conditions creating changes in the expressions of textiles. Margiela (Luna 2009: 155), Worbin (2013: 4), Landin et al. (2008: 139), Storey, Ryan, and Belford (UAL Research Online 2016), and many others have explored different aspects of degradation, wear and tear, and time in their work.

How different materials age, wear out, and respond differently to treatments, all is influencing the ways in which textiles change. In the experiments presented in this paper, wear and tear is approached as a method of exploring the design of multiple expressions from one starting point. This was undertaken using the materials’ inherent qualities, in combination with textile structures and exposure of the textiles to a range of stimuli. There is great potential in this way of thinking about textile materials; considering them to be objects that textiles have the ability to go back and forth between different states (e.g. changes in color), tactile (e.g. changes in texture), or both, and can be reversible or irreversible. Both color-changing and light-emitting textiles have the ability to go back and forth between different states (see Figure 1) (Berzowska 2005: 69–72; Worbin 2010: 37–42; Jansen 2015: 27; Kooroshnia 2015: 17–19; Taylor & Robertson 2016). Other textiles, however, exhibit more irreversible changes in color or construction in reaction to various stimuli, such as light, heat, touch, or information (see Figure 1) (Worbin 2010: 37–42, 2013: 4; Dumitrescu 2013: 5; Persson 2013: 5; Landin 2009: 147–164). In the case of irreversible changes, unlike with reversible ones, the expression does not return to its starting point, but builds up with time and use (Worbin 2010: 49).

In line with the work of Hallnäs and Redström (2002: 113), “expression” is used in this paper as a fundamental notion that refers to the ways in which texture, color, structure, shape, etc. create an overall impression. The changes in expression described in this paper are the result of various changes; in some cases what is discussed is a change in the pattern of the textile, in others it is a change in the color of a pattern wherein the pattern itself can be said to be unchanged. It should also be noted that what we refer to as a textile’s “aesthetics” do not necessarily change when the expression changes, although in some instances this is the case. This relates to the fact that “aesthetics” is a relatively broad term that differentiates between various textile styles and genres. “Expression” has therefore been chosen as a notion that refers to the sum of all of the aspects of a textile. When compared to “appearance” or “aesthetics”, ‘expression’ does not relate to surroundings, contexts, viewers, etc.; the expression is what it is, regardless of the circumstances, and is dependent solely on the inherent qualities of the textile itself.

Regardless of whether or not a project’s focus is on textiles that change between one or several states, a textile’s expression usually

![Figure 1](Image 547x94 to 805x621)

Irreversible and reversible changes in textiles. (a and b) Hanna Landin’s, Anna Persson’s and Linda Worbin’s work “the Burning Tablecloth”, a tablecloth that reacts to incoming phone calls by burn marks, explores a non-chemical burnout technique as an alternative way of presenting information (photos: Linda Worbin). (c) Marjan Kooroshnia’s work explores the design properties of heat reactive, color changing thermochromic inks to create dynamic surface patterns in textiles (photo: Jan Berg and Marjan Kooroshnia).
changes in a linear manner: one or several steps unfold from one starting point and the changes always occur in the same order. Relatively little research has been conducted regarding expressions that can develop in multiple directions from one starting point. However, Worbin (2013: 4) has explored evolving textile expressions through colors that change over time, in opposition to the traditional preconception of color as something permanent. By plant-dyeing fabrics without mordant, she explores and documents colors that gradually and irreversibly change over time (2013: 4), opening up for textiles aging in several ways depending on where they are placed.

Several other designers and scholars have used either materials that are capable of changing or changes that take place in materials over time as a method of creating evolving expressions. Whiting, in collaboration with Puma, developed a white sneaker with an emerging pattern that becomes visible as the shoe becomes dirty, exploring an “evolving narrative experience” (Chapman 2012). Wood has worked with the concept of an emerging pattern with Stain; cups with a pattern of glazed and non-glazed areas that, through use, change in color, showing the user’s individual coffee- or tea-drinking habits (University of Brighton 2013). Dixon works with the same theme albeit from a more everyday, commercial perspective with the Eco Ware tableware, which is made out of biodegradable plastic. As the dishes are used their material wears out, gradually changing from shiny to dull until they can eventually be composted (Fairs2009: 61). These examples set evolving patterns in the context of an object’s lifespan, considering the form, choice of material, and type of change in relation to the intended – or probable – use.

Fletcher (2014: 192–193, 201–202) and Goldsworthy (2017: S1961–S1963) propose that garments could have lifespans ranging from long to short depending on their purpose, challenging the notion of garments as something permanent. Creating these lifespans would mean matching the material of the garment to its intended use. Short-lived, trend-sensitive garments could be made of recyclable materials, while those that are to be used for a long time would improve with age (Fletcher 2014: 206–214; Goldsworthy 2017: S1961–S1963). Considering a textile’s expression to be something that evolves throughout its lifespan would, as Chapman (2005: 133–134) suggests, make the purchase of a new textile only the first step in its life. This could encourage a more personal relationship with textiles and garments, preventing early disposal (Chapman 2005: 116; Niinimäki 2011: 84). Whiting’s sneakers, Wood’s cups, and Dixon’s Eco Ware all turn wear and tear into something that customizes and improves a product, instead of it losing value.

Rather than designing static expressions, different lifespans could be embedded in textiles through choice of material and construction, enabling the designer to tailor lifespans to both the object and textile it is made of (Talman 2015: 351). Considering how a textile’s expression can evolve during the design process opens up the possibility of achieving many expressions from one starting point, challenging how aging and use are valued.

**Experiments**

Experiments involving different treatments were performed in order to achieve visual changes in textiles and divided into two groups: creating textile patterns through degradation (burial underground and immersion in salt water) and creating textile patterns through use (prototypes used in different contexts). The first named aimed to dye patterns through degradation and the latter to add color and/or patterns to textiles through use. The aim of all of the experiments was to explore the possibilities of creating variation in different textiles. Table 1 shows an overview of the experiments with the left hand column indicating the material (marked from A to K), and top column indicating the treatment of the material (numbered from 1 to
Table 1
An overview of the experiments with the left hand column indicating the type of weave pattern and materials used (marked from A to K), and top column indicating the treatment of the material (numbered from 1 to 14). Several of the experiments combine multiple materials in one treatment, and are referred to with one number, and several letters (e.g. an apron (5) combining plain satin in thin paper and cotton (B), and triangle patterned fabric (J) is referred to as B5–J5).

<table>
<thead>
<tr>
<th>Textile material</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: plain satin - copper, cotton</td>
<td>A1</td>
</tr>
<tr>
<td>B: plain satin - paper thin, cotton</td>
<td>B1</td>
</tr>
<tr>
<td>C: plain satin - paper thick, cotton</td>
<td>C1</td>
</tr>
<tr>
<td>D: plain satin - wool, cotton</td>
<td>D1</td>
</tr>
<tr>
<td>E: circle pattern - paper, wool, cotton</td>
<td>E1</td>
</tr>
<tr>
<td>F: circle pattern - paper, linen, cotton</td>
<td>F1</td>
</tr>
<tr>
<td>H: circle pattern - paper, wood, cotton</td>
<td>H1</td>
</tr>
<tr>
<td>I: triangle pattern - polyester, wool, cotton</td>
<td>I1</td>
</tr>
<tr>
<td>J: triangle pattern - paper, polyester, wool, copper, cotton</td>
<td>J1</td>
</tr>
<tr>
<td>K: triangle pattern - paper, polyester, wool, cotton</td>
<td>K3</td>
</tr>
</tbody>
</table>

Creating textile patterns through degradation

The first experiment explored colors and pattern variation based on how different materials degrade in nature. To this end, woven textiles were buried in approximately 20 cm of soil near the Baltic Sea. Samples A1–J1 (Table 1) were buried in soil at a depth of roughly 60 cm. In addition, three samples of the triangle-patterned samples (Figures 4, 5) were buried, with each material forming one element of the pattern with an additional weft of uncoated copper (K) or cotton (M).

To compare how different materials change, two cellulose-based yarns (paper and cotton), one protein-based (wool) yarn, and one synthetic (polyester) yarn were investigated. Wool is often used as a texturing agent due to its strong reactivity to air and moisture. All of the samples were woven using a Jacquard loom, with cotton as the warp, and a focus on the different expressions that can be achieved by changing the materials. Basic geometrical elements (triangles and circles) were chosen as the elements of the Jacquard patterns, and combined several materials in order to highlight how each material changed. The circle-patterned Samples F–I (Figure 3) each consisted of two elements—circle and its background—each of which combined two materials. The triangle-patterned Samples J–K (Figures 4, 5) consisted of two elements: circle and its background, with each material forming one element of the pattern with an additional weft of uncoated copper (K) or cotton (M).
triangle-patterned Sample K3 were placed in a bucket filled with water and iron powder for 1, 2 and 3 days, respectively. Dyeing with oxidized iron is a well-known technique that requires no additional pigments or fixing of the color, and so was explored to ascertain how the pattern was transformed when parts of it absorbed color differently.

After 2 months underground and in salt water, the samples were recovered for analysis. All had changed in appearance, with the materials reacting differently to the conditions. The buried samples generally had stronger, muted, and more even colors, whereas the salt-water samples had uneven, lighter colors (Figures 2–4). All of the samples were washed in fresh water without detergent and left to dry. The colors of all of the samples changed after this—the colors of the patterned samples in particular became stronger making the pattern stand out more clearly, likely due to the fact that the samples came into contact with air. Wool in particular took on a green shade.

Creating textile patterns through use
The second experimental series explored colors and pattern variation in relation to how different materials wear and become discolored and dirty through use. Five categories of everyday uses of textiles were chosen, and a total of eight prototypes were made using
the same fabrics as in the first experiment. The results of the first experiment suggested that patterned fabrics in particular undergo more versatile changes in expression. As a result, primarily triangle- and circle-patterned fabrics were used for the prototypes, which were subjected to everyday use for approximately 2 months.

The prototypes included textiles for use in both domestic and public spaces: a fabric bag (J4), an apron combining two materials (B5–J5), two chairs for public spaces—a foyer (K7) and a small conference room (F5–6)—and pocket details on four working coats used in printing labs, which have pockets on the front, act as towels and a protective layer between clothing and pigments and/or the body, while an apron works as a towel and protective layer when cooking or cleaning. Chairs in public locations come into contact with different kinds of clothing, as well as some staining. Lab coats used in printing labs, which have pockets on the front, act as towels and a protective layer between clothing and pigments and other chemicals used in hand printing.

In addition, three washing tests were conducted wherein white triangle- and circle-patterned fabrics were washed with yellow (F12–K12), blue (G13–K13) and black (F14–K14) garments to ascertain how the different parts of the patterns absorbed color. This was undertaken in relation to the fact that colors bleed during washing, and that this is a well-known but frequently undesirable way of dyeing textiles. Garments and textiles made of multiple materials, including cotton, viscose, silk and wool, were used in the washing tests in order to include several types of loose pigment.

Results
Following the period of use and/or exposure to an outdoor environment, all of the textiles evinced some form of wear and tear. They were colored, stained and in some cases even degraded. Each had been dyed differently based on the environment in and use to which they had been placed. The colors of the samples may well continue to change, strengthen or fade with time.

The changes in the buried and immersed samples
Samples A1–J1, A2–J2, and K3 (Table 1) changed from white to colored, and the patterned Samples F1–J1, F2–J2 and K3 developed multi-colored schemes based on their material combinations and the type of exposure (Figures 2–5). The surfaces of the circle-patterned samples became multi-colored, and the triangle-patterned samples developed various color schemes depending on the aging method. The patterned samples were dyed quite evenly, likely due to the relatively small elements of the patterns, while the plain samples acquired more random splashes of color. The main factors that influenced the resulting changes in expression were the choice of material, how the materials were combined and the conditions that the fabrics were exposed to.

As was expected, wool and paper yarn exhibited the most pronounced changes in color. More unexpected, however, was that some treatments, such as immersion in water with iron powder (K3) resulted in wool being most strongly colored, while others, such as the black laundry test (F14–K14) and burial underground (A1–J1, but not immersion in salt water), resulted in paper obtaining the strongest color (Figures 2–5). Although this may be related to the chemical compositions of the textiles and the substances that they came into contact with, just as with regular dyeing methods, the results of these experiments were relatively difficult to predict. This may open up the possibility of designing patterns or surfaces in which different parts of the pattern are highlighted or relegated to the background depending on what the textile is exposed to, creating not only new color combinations but multiple different patterns. The circle pattern is an example of this, in that the elements of the pattern were either highlighted or hidden when the paper yarn in one sample (but not the other) had been dyed brown (Figure 3).

The buried paper samples degraded considerably faster than the linen ones, for example. Burial also seemed to generally cause degradation to occur more rapidly than being submerged in salt water. The durability of various materials could be further explored with a view to creating textiles that gradually reveal new expressions, in the form of textures, colors or materials, as parts are worn out or degraded. The specific ability of paper to react in a unique manner to various stimuli could open up for further research regarding the design of textiles with expressions which develop in distinct directions depending on their handling.

The differing expressions of the triangle pattern. The raw fabric (a); after 2 months underwater (b), 2 months underground (c), 2 days in water with oxidized iron powder (d), 4 weeks in use as a bag (e), and having been washed with yellow (f), blue (g), and black laundry (h), respectively.
The triangle-patterned samples developed different color schemes based on the treatment (Figures 2, 4, 5). The samples that were submerged were colored green, yellow, or black, dependent on the composition of the material and whether mud from the sea had covered some or all of the sample. The integrated copper wire formed black lines in the fabric. The buried triangle-patterned samples acquired more even shades of green and brown, and here the copper wire created a pattern of circular shapes. The triangle-patterned samples that were placed in water containing iron powder developed a color scheme featuring various shades of reddish brown, with wool having the strongest color.

The changes in the samples in use
After 8 weeks of use, most of the prototypes had undergone some form of change in expression. The bag and the washed samples underwent the most pronounced changes.

Washing with laundry in different colors produced yellow, blue and bluish-gray patterns (Figure 5). Black garments produced the strongest color, which was a shade of bluish gray. In the machine wash with black laundry paper took on the darkest shade, while cotton warp and wool were dyed lighter shades and polyester was not dyed at all, and so this created the greatest contrast in terms of the pattern. In the yellow laundry wool and paper were dyed quite evenly, making the white polyester parts of the pattern stand out clearly. The blue laundry did not result in strong color changes; rather, the fabric took on a more neutral, white hue. The effect was reminiscent of the whiteners containing blue pigments that are sold to decrease yellowness in older white textiles.

These experiments explored the variation in patterns that can be achieved by making use of the varying ability to absorb dyeing substances of different materials in a woven pattern and different methods of dyeing materials. The results, however, suggest an alternative way of approaching the generally unintended transfer of pigments between textiles. When one does laundry, the transfer of loose pigments from one textile to another is usually avoided on the basis that it is undesirable. However, this has the potential to create new color combinations, alter the expression of existing textiles and even update textiles with stains or marks of wear and tear.

The bag underwent relatively localized changes in color: dark areas appeared where it had rubbed against clothing and at the corners, enhancing the tactile and visual elements of the pattern (Figure 2). The paper yarn and wool absorbed more color, while the polyester remained relatively white. The handles acquired a grayish tone. Some marks did not follow the logic of the pattern due to the use of the bag in practice (e.g., its being folded or put on the ground). Over a longer period of use and possibly after washing, such marks could add to the complexity of the pattern. These could perhaps be used as a way of creating more individual patterns, and so go beyond the design of the original piece.

The chairs and the apron showed similar evidence of use focused on the areas of greatest wear, although the changes were subtler. The pigments used in the lab influenced the changes in the color and pattern of the pocket details of the lab coats. The changes in the expressions of the prototypes were, however, relatively preliminary, constituting just one stage in the lifespan of a textile. These would generally evolve gradually over a long period of time, and so the prototypes will be used further in their environments in order to ascertain the changes in expression that take place over a greater timeframe.

Aging and change as a part of a textile’s lifespan
Considered from the perspective of traditional quality standards, which aim to produce standardized, predictable textiles, the samples would likely be deemed to have degraded in quality. From the perspective of aesthetics, however, the textiles could be said to have acquired alternative expressions, e.g., changing from a white pattern or fabric to one that is colored. Either of these expressions could have been designed from the beginning by weaving a colored pattern, dyeing the fabric or performing other post-production treatments. In these experiments, however, all of the expressions were achieved from one starting point and by exposing the textiles to various stimuli (Figure 5).

The results of the experiments indicate that various colors, patterns, and structures can be achieved from one starting point. The resulting color combinations, visible on the same patterns, varied depending on the treatment that the materials had been exposed to. This suggests that the natural aging and changing of materials could be consciously used in design processes to embed evolving patterns, colors, or structures into textiles. This could open up for the design of textiles that do not have one expression throughout their lifespan, but can develop several depending on what they are exposed to. This in turn challenges the notion of permanence as a sign of quality in textiles, and what is considered to be the lifespan of a textile.

This suggests a shift in how quality in textiles is defined; from the intention of producing identical, standardized textiles that do not change to embracing how they wear out and evolve over time. New methods of evaluating quality based on the aesthetics of change, rather than measuring visual or mechanical changes such as fading or pilling, are, however, needed. Defining these methods is not, unfortunately, straightforward, as they would build on the textile during various stages of its lifespan rather than be possible to measure precisely at any given point in time. A shift in attitude is also necessary in terms of accepting textiles as objects that undergo changes rather than continuing to view them as static.
This is related to expectations of what is being purchased and what happens when a white textile becomes colored, and is a subject for further research.

Discussion

Both the outdoor- and wash-dyed examples explored changing the appearance of a pattern using a material’s inherent properties, but in different ways. In the outdoor-dyed samples, shades from green to brown emerged depending on the material and placement of the sample, resulting in multi-colored patterns. The outdoor environments seemed to enhance the tendencies of materials to change color in a certain way; wool, for example, consistently turned green, and paper yarn brown. Leftover pigments in a washing machine were absorbed by some materials and repelled by others. The samples were exposed to a random mixture of substances, each of which affected the various fibers differently; man-made pigments, on the other hand, reacted to different stimuli in various shades between yellow, green, and brown, depending on the materials used in the different parts of the pattern.

The patterns were successful in that they, through the combination of several different types of fibers, evinced more variety in the resulting color schemes. Using different treatments and paper, wool, and polyester in different parts of the triangular pattern resulted in seven different color combinations from the same, white-on-white pattern. This opens up the possibility of more color combinations emerging over time than in single-colored fabrics, in which the single weft material also determines the main color of the fabric.

The circle pattern also changed from white to multi-colored, but its color palette was more limited due to the blending of the materials on a small-scale surface. The textured surfaces of the pattern elements were, surprisingly, more interesting than the overall pattern, showing subtle gradations in color. This could be further explored through the use of different textures on various materials and scales, which may relate to the color of the fabric rather than enhancing an existing pattern, and so draw attention to individual patterns of use.

Furthermore, the plain satin fabrics might be better utilized as markers for use; Blank canvases used in contexts in which the textile is worn through repeated handling or placement in specific positions. The changes in expression that occurred through use were subtle and largely took the form of localized changes in hue, but were closer to the type of stimuli a textile encounters in everyday life, than burying or immersing in salt water for longer periods of time. With regard to colors and patterns in textiles being influenced by how various materials gather dirt in use, for example, the resulting expression bears a closer connection to the use of the textile or object when the areas that are handled most frequently change more, creating individual marks and patterns of use (cf. Sorkin 2000: 77).

Different treatments dyed different areas of the triangle pattern; some triangles became lighter and some darker, and this varied based on the treatment. In the laundry-washed samples, for example, the paper yarn gained the strongest color; in the samples that were soaked in water containing iron powder, the wool was most strongly dyed (Figure 2). When applied to a pattern with greater differences between its elements in terms of size and proportion, this technique could result in various patterns from one starting point, depending on how the material is dyed. If multiple treatments are applied to the same piece of fabric, further color combinations could be created.

This approach could also be used in the design of colored textures or patterns. A yellow textile would turn greenish or brownish depending on whether it was made of wool or paper. A patterned, even, single-colored yellow textile might develop a multi-colored pattern in various shades between yellow, green, and brown, depending on the materials used in the different parts of the pattern.

Designing for multiple expressions

The basic knowledge regarding how different materials change under different circumstances that was gathered during the experiments could be used in a broader design perspective. The broad range of colors in the Jacquard patterns, which was obtained without the use of dyes, suggests that patterns could be designed and colored using only the inherent qualities of different materials and how they react to different stimuli. Further research would, however, be needed regarding the colors that can be created using different materials, what they react to, and if multiple colors could be achieved using one material and different treatments.

Changes in color were explored in these experiments, but changes in the construction of the textile are another possible track for further research. The speed and way in which different materials wear out or degrade could be used to create surface expressions and textures wherein colors, materials, and/or constructions are revealed as parts of the textile degrade, wear out, shrink, or melt. Paper, which degrades relatively fast, could be combined with more durable materials such as cotton, wool, polyester, or metal, for example. A combination of paper, cotton, and polyester might result in a textile with several different time spans embedded in it, and so the materials would degrade at different rates based on usage. Biodegradation could even be used as a means of material separation in fabrics that combine several materials.

Altering or removing parts of a textile’s construction through the enacting of changes in its materials could be used to create new functions in textiles. Shrinking, forming, or dividing could be used to change textile qualities such as texture, size, volume, number, thickness, and opacity, altering the way in which the textile can be used. Dynamic materials such as melting, shrinking, and evaporating yarns responding to heat and water could be used. Combining materials that react to different stimuli in one fabric could open up for the design of textiles that have a function and expression that can be
formed in multiple ways depending on the treatment. Using everyday stimuli such as water, washing, ironing, or steaming to trigger changes in textiles would also make the forming of the textiles more accessible and controlled, facilitating the planning of the various steps and variations.

The experiments presented in this paper are initial explorations of creating variation in textile patterns using different treatments. The chosen methods, which involved various forms of degradation and wear of textiles, indicate how different materials react to different conditions. They also hint at how the approach presented here might be used to create pattern variation through changes in color and wear and tear. However, while the prototypes were made for use, this was undertaken specifically to explore the possibilities presented by the patterns as relates to the variation of patterns, and the alternative uses of evolving patterns are a topic to be investigated by further research.

**An alternative approach to quality in textiles**

Designing textile lifespans can be seen as designing a starting point from which the textile evolves based on various influences. The woven fabrics used in these experiments are one example of a starting point, which was developed in different directions depending on what the textile was exposed to (burial underground, immersion in seawater), for how long, and the context of use. If some of these parameters – period of exposure, placement, and handling – were to be changed, the resulting expression would be different. Regardless of the textile’s lifespan, using change as a design variable requires good knowledge of materials on the part of the designer, together with an ability to foresee how the materials will evolve over time and in relation to one another.

Precisely directing the ways in which textiles will, or should, change can be difficult due to the fact that exactly what conditions they will be subjected to is not known or controlled by the designer. On the other hand, the way in which a textile is designed suggests certain uses or interactions. Whether a textile is woven, knitted, stiff, or flexible, what material it is made of, and if the changes in its expression are triggered instantly through user interaction or more gradually over time all suggest different areas of application. In the case of Dixon’s Eco Ware, the size, cupped form, and hard, water-resistant, washable material of the objects suggest that they be used as dishes.

The experiments presented in this paper are an initial exploration of designing textiles whose expression can develop in several different directions from one starting point through various influences. Several variations of the same pattern were created through degradation and washing. The results on adding color and pattern to textiles would also make the forming of the textiles more accessible and controlled, facilitating the planning of the various steps and variations.

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The experiments presented in this paper are an initial exploration of designing textiles whose expression can develop in several different directions from one starting point through various influences. Several variations of the same pattern were created through degradation and washing. The results on adding color and pattern to textiles through use were rather preliminary due to the short period of time for the experiment. A prolonged period of use is needed to assess their extent properly. The main finding of the experiments is, that it is possible to achieve various colors, patterns, and structures from one starting point, indicating that an alternative definition for quality, based on the aesthetics of change, may be viable. The experiments propose ways in which textiles could evolve, quickly or gradually, and shift the focus away from single, static expressions and towards designing textile lifespans. Through choosing materials that age in various ways and combining these with patterns or surface textures, evolving patterns or colors can be added to textiles, questioning the ideal of static aesthetics.

Thinking of materials in terms of how they change over time and what they react to could open up for designing textile lifespans that are better tailored to different uses, suggesting a more holistic approach to textile design that goes beyond the design of single, static expressions. Taking change as one quality of a textile could even encourage the development of sustainable alternatives, such as circular design practices, in the field of textiles, matching a material’s lifespan with the product’s or encouraging a sense of emotional attachment, and in so doing open up for alternative perspectives on what sustainable textiles can be. Further research should, however, be performed regarding the ways in which these can be created through a combination of material, construction, and handling.

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**References**


