Textile materials and textile design are a part of countless products in our surroundings, as well as diverse design fields and industries, each of which has very different material traditions and working methods. The aim of this thesis is to add to our understanding of the relationship between textiles and products in the design process, and to explore how textiles enter and influence product design processes and how products function in textile design processes. A further aim is to examine the effect of new textile technology, such as smart textiles and 3D printed textiles, on this dynamic.

This thesis is the result of an interplay between theoretical work, experimental practice-based projects, and observation of design practice, and it presents two types of results: Firstly, descriptions of how the relationship can manifest itself in the design process, which give a broad picture of the relationship between textile and product and in so doing add to our understanding of textiles as design materials and highlight some of the additional complexities and possibilities for the design process that come with new forms of textiles. Secondly, this thesis presents ways of describing the dynamics between textiles and products in the design process, with the intention of opening up for reflection on how we design, and can design, with textiles. Here, the main outcome is a theoretical framework which examines the relationship from both a product design and a textile design perspective, and includes methods and questions that can be used to explore and define how textiles and products meet in the design process.
TEXTILE INFLUENCE: EXPLORING THE RELATIONSHIP BETWEEN TEXTILES AND PRODUCTS IN THE DESIGN PROCESS

LINNÉA NILSSON
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This thesis explores and describes the relationship between textiles and products in the design process. It considers both how textiles become part of and influence the product design process, and how the requirements, considerations, etc. that come with designing textiles for products become part of and affect the textile design process. The thesis also explores how new textile technology, such as smart textiles and 3D printed textiles, can influence the textile-product relationship, and how these new textile qualities can come to impact how we design textile products, and textiles for products. Taken as a whole, the thesis aims to open up for reflection on how we design with both conventional and new forms of textiles.

The character of a design process and the products and designs that are its result are strongly connected to one another (Kroes, 2002). A similar connection exists between products and materials, in that textiles, wood, glass, etc. are used to realise the designed object, but also influence the design and the design process through their properties and expressions. Knowledge and experience of what materials can do, as well as how to work with them in a design process is, as such, very important when designing, and a lack of understanding regarding this can limit both designs and design practice: “Materials are the core of the built environment: everything we touch and smell, and most of what we see and hear, is based on material of some kind. Design is the practice of making those materials into products and environments that, hopefully, meet the needs and desires of the consumer. If a practitioner is creating designs based on a limited knowledge of materials, the designs themselves will in turn be constrained. We all use tools to accomplish our work: some might use a computer while others use a pencil; many use both. It is in the understanding of what each of those tools brings to a task that is ultimately important. Knowing what materials are available is knowing what tools are available.” (Beylerian & Dent, 2007, p. 17)

Textile materials and textile design are a part of countless products, and can be found in everything from home furnishings and sports equipment to car interiors. Thus, they are present in contrasting design fields and industries with very different material traditions and working methods. Textiles are in these diverse processes a material, but also a design form and a flexible, transformable sketching medium. Thus, textile materials and textile design decisions, when designing products, can enter the process as anything from a complete, constant material to something which is designed in great detail, as well as a tool to help develop the overall design. The following fictional cases illustrate four examples of the different ways textiles and products meet in a design process to form textile products:
INTRODUCTION

Imagine the fabric of the sofa at the Bellemont Hotel, Nottingham, England. The fabric’s texture, colour, and pattern give the otherwise plain sofa a luxurious expression. The fabric brings out the sofa’s shape, but hides some elements in the design and fortunately some of the stains which clumsy guests have left on the seat. The sofa was designed by a furniture designer, commissioned by a furniture company. There was not a specific surface material in the design, and instead this choice was left to whoever bought the design. The fabric on this particular sofa was designed by a textile designer, who works at a Swedish textile company which produces upholstery fabrics and other interior fabrics for the contract market. The textile designer doesn’t know how or where the fabric will be used, and therefore designs a woven fabric with a good, stable quality, which could be used as an upholstery fabric on many types of furniture. The fabric finds its way from the textile company, through a fabric fair, to a supplier in England. It is here that the interior designer who designed this hotel finds it. The interior designer sees a sample hanging on a rack, and decides to use it. She orders 30 sofas with this fabric, and hopes that it will work with the shape and the rest of the decor she has specified.

Imagine a car seat for a baby, placed in the back of a car. The car seat has a grey woven polyester fabric with a printed geometric pattern, and a light grey soft quilted fabric, giving the product a detailed but quite neutral expression, which works quite well in most car interiors. The car seat has been on the market for a couple of years; first in a plain red fabric with black details, then a light green fabric with a floral pattern, and now in this new fabric, which has been designed to update the product one more time before a completely new version is designed. The fabric was not a focus when the car seat was first designed by the in-house design team, and was not taken into account when defining the form and where to place the seams, etc. Instead, the design of the fabric was performed based on the rest of the product; first, selecting a woven quality that could withstand a high degree of wear and tear, and then designing a pattern that could be cut and placed freely on the seat.

Imagine a pillow sitting in a boutique which sells hand-made products, made by local designers and artists. The pillow has a unique and detailed surface, making it stand out among the other objects in the room. The pillow was hand-made by a designer who found an old piece of fabric in a thrift shop; she was inspired by its simple but expressive design, and decided to do something with it. The original fabric had a graphical pattern, probably designed in the ’50s or ’60s. The designer liked the original design, but wanted to do something different with it, so she started to pleat and embroider sections of the fabric, transforming the original design into something completely different, changing the pattern and adding texture and colour. Based on the size and shape of the finished piece, the designer decides to turn it into a pillow-case and, adding her logo, brings it to the small boutique.
Imagine a textile space divider in the entrance hall of a library. When you first draw near to the fabric it changes colour, revealing a pattern on the surface - when you move back, the fabric goes back to its original, plain expression. When you return the following week, another part of the design is revealed to you. The year after, a poetry event is held at the library and, as more and more people enter the room, more and more of the surface is transformed into a colourful pattern. The textile space-divider is the product of a group of designers who were asked to create an interactive textile piece for the library so as to draw people into its newly built area. The designers were asked to do something that would react and change in relation to the different things that would and could take place in the space; people reading quietly, small book group discussions, and large gatherings. The design was developed based on the possibilities of the textile techniques they used, but also the requirements of the specific space they were designing for. They created a programmable textile system that would react to the sounds in the room, and would reveal more or less of its hidden design, and they also made it possible for the people working at the library to change the design in terms of both how the fabric would transform and what it would react to. This meant that there were many options for how to use it, but also that exactly how it would work and look in the space was not known to either the designers or the people who commissioned the design; instead, it would develop as the people in the library used it.

Textile materials and the textile industry have undergone many changes during recent decades in terms of how and where textiles are produced, and what textiles can be and do. For example, textiles which have the ability to change their expression in relation to stimuli, be programmed, sense the environment, etc., are expanding the borders of what a textile is, what it can be used for, and the expressions it opens up for (Schwarz et al., 2010). The industries and product design practices that textiles as materials are involved in are, at the same time, also transforming, through e.g. increasing digitalisation of the design process and improved 3D CAD programs (van Bezooyen, 2014). Thus, changes in both the textile and product design fields influence what and how we can design with textiles and how we design textiles for products. Moreover, the production of both textile materials and textile products continues to be problematic from an ethical and sustainability point of view, e.g. with regard to the use of hazardous chemicals and unsustainable raw materials when producing fibres, yarns, and fabrics, and poor working conditions when using these textiles in production processes. As a result, many new and conventional textile products continue to be problematic in one or several stages of their life-cycle, including production, use, and/or final disposal (van der Velden et al., 2015). Moreover, in current practice, textile materials are often designed and produced wholly divorced from considerations of their future use in products. This means that there is a risk that many materials are never employed in a use to which they are especially suited, which in turn means the production of essentially wasted materials, or textile products in which the textile material in the design is not suitable for its use, affecting the quality and, potentially, the life-span of the product. However, more and better options are appearing – in raw materials, production techniques, sustainable design strategies, etc. – which could enable designers to make better choices (Fletcher, 2014). However, if we do not reflect on the design of the textiles that we use, their production, and how we design with them, we risk continuing to use the old working traditions which can lead to poor decision-making. Thus, as textile materials, techniques, and industries change, it is important to focus not only on developing new products, but also on re-examining and developing design practice so as to fully realise – rather than waste – the potential of both traditional and new textiles.

What had previously been minor details in the design process took centre stage when turning from the product design to the textile design area. During my product design education, I was taught to focus on users and develop functional and aesthetical products, thinking primarily of materials as a consequence of other design decisions. Within the textile design education, however, the quality and aesthetics of the material was in focus and, instead of designing the whole product, I began working with only the textile part of it, in much greater detail, which required new methods and skills. The clash between traditions and working methods in the two design areas gave rise to an interest in the point at which these two fields meet. What was most fascinating was the openness of textiles in relation to the products that they could or would become part of; e.g. the textile designer does not always know in what product or context the design will appear, and the same textile design could be used as part of a chair, a piece of luggage, or an interior design, as some of the previous examples illustrate. My interest in the subject was increased when I started to design textiles in products; for example, when working with colour and material at a car company, it became apparent how textiles in products could be designed for that specific use and context, e.g. a specific car model, and have a strong impact on the function and aesthetics of the design, but at the same time be given low priority in the design process. These experiences created questions which became the start of the research undertaken for this thesis; how does textile design enter into and relate to other design processes today, how can this be developed, and what does the fact that the same textile can be a part of many different products say about the qualities of textiles as a design material?
These questions are of intrinsic interest for the development of textile design methods in a landscape in which there exist new materials, new techniques, and new programmes for product design, but also in a more general sense, in relation to positioning textiles as design materials that function within complex systems of product development. These issues are important for the development and identity of a modern textile design, as well as for the development and identity of textiles as design materials in the context of a modern product development.

The research theme / programme

In order to develop the practice of designing products with textiles and textiles for products in a direction that can take advantage of the potential of both traditional and new forms of textiles, it is important to reflect on and develop the relationship between textile design and product design. To this end, we need to better understand and find ways to look at the relationship within the design process. Here, design theory, conceptual frameworks, design methods, observations of design practice, and design experiments, which explore and define how we design, can contribute in many ways (Friedman, 2003). The extensive research undertaken with regard to materials and design in general can take us part of the way, but, to gain a better understanding of how the design of textiles and the specific considerations that come with designing with this type of material can come into and influence the product design process, and how the design of products and the specific considerations that come with this type of application can come into and influence the textile design process – we need to closely examine this specific relationship. Here, it is interesting to consider traditional textiles, but also new forms of textiles, e.g. smart textiles and 3D printed textiles, as these textiles, through their new properties and considerations, both can come to challenge current practices and have the potential to open up for new ways of designing.

At present, there exist several notable examples of research in this field; e.g. Bang’s thesis, ‘Emotional value of applied textiles - dialogue-oriented and participatory approaches to textile design’ (Bang, 2010), the research performed by Heimdal (Heimdal et al., 2012; Heimdal & Lenau, 2010; Heimdal & Rosenqvist, 2012), as well as related examples in fashion design, which look at textile and print design in relation to garment design (Townsend & Goulding, 2011). However, explorations of this subject, which examine and describe the ways in which textile design and product design relate to each other, and development of methods for looking at the relationship, also have the potential to contribute with new knowledge in this field.

The research theme is built around these ideas and is formulated as follows:

This research project explores the role which textile design plays and can play when designing products, and the role the application/product plays and can play when designing textiles for products. The aim of the work is to gain a better understanding of the relationship, develop theory, e.g. in the form of frameworks, for discussing the subject, and explore how the new types of functionality, expressiveness and increased complexity that come with new textile technologies, can influence the dynamic between textile design and product design. What the various relationships of today have in common is that textile materials/textile design meet the product during some form of design process. For this reason, the focus of the research is on what takes place in the design process.
On materials and the design process

Designers’ perspectives on materials, and the role of materials in the design process
this perspective opens up for, are diverse, and have evolved in relation to changes in
design practice and developments of materials and production techniques. Artefacts
were, before the industrial revolution, made by craftsmen who, with their skills, tools,
etc., created objects using the materials that were available. This involved working
closely with the materials; relating their design to each specific piece, adapting to its
limitations, and taking advantage of its unique qualities (Manzini, 1989). The industrial
revolution introduced new and more effective methods of design and production;
the person who defined the design of the object no longer produced it, and instead
this was performed by a number of different people, each possessing their own set of
specific skills. This development of practice created a divide between the designer and
the material, which continues throughout much of design practice of today (Manzini,
1989). The increasing digitalisation of the design process and the development of CAD
tools have opened up for further separation between the material and the designer in
the process (Ahlquist & Menges, 2011; Moles, 1995; van Bezooyen, 2014). Exceptions
exist but, in many 3D modelling CAD programs, materials are worked with as ’skins’,
i.e. patterns which can be added to a surface of the model without incorporating the
specific properties of the material or considering how this may influence the form,
function, etc. of the design. This type of program has influenced how products are
designed and how practice is taught in design education (van Bezooyen, 2014); on the
one hand, this has opened up for more effective design processes and more complex
forms, but on the other has led to an increased focus on geometry and a decreased
focus on the meeting between the abstract and concrete aspects of the design (Ahlquist
& Menges, 2011).

However, other developments in the design field open up for a stronger emphasis on
materials. One example is the increasing focus on ethics and sustainability. Material
selection and material design has a significant impact on the sustainability of products
(Ljungberg, 2007) and, as a result, material issues can come more into focus when
designing sustainable products. Another related example is the increasing interest
in craft-inspired small-scale production, where designers control more aspects of
the realisation of the product, bringing all issues, including materials, closer to the
designer—see e.g. Berlinord (n.d.), Vík Prjónsdóttir (n.d.), and Periphere (n.d.) who,
in their ways of working, resemble the artisanal approach to craft production which
still is common in many countries around the world. The increasing availability of
techniques such as 3D printing also opens up for this way of working, as well as new ways of relating to materials and material design, blurring the line between the digital and the physical in the design process (Ratto & Ree, 2012; Quinn, 2011). This may be achieved by, for example, designing form and material structure in one (Oxman, 2007; Freedom Of Creation, 2014), or by using the qualities of digital programs and three-dimensional printing to reinterpret traditional materials, e.g. three-dimensionally printed knitted structures (Desbiens, 2013).

Along with developments in design practice, developments in terms of materials themselves have also influenced how we design, as the available options have changed, from a small number of clearly defined material groups that practitioners can become familiar with, e.g. wood and stone, to the larger number of standardised and homogenous materials that came with industrial production, to the increasingly complex material spectrum of today (Manzini, 1989). Designers’ material options now also include made-to-order materials; those which, through their properties, expression, etc., can be designed with a specific product or usage in mind. This opens up for a design process which includes material design, rather than just material selection. More recent developments make it possible to go one step further; e.g., by designing form, structure, and material in one by combining 3D modelling programs with 3D printing (Oxman, 2010b), by programming the behaviour and expression of a material in relation to a specific design or context, or by designing changes in the material expression or properties over time through digital (i.e. ‘smart’) materials (Bergström et al., 2010). However, these new material developments create an interesting dilemma for designers, in that, on the one hand, materials can be designed in great detail and freely manipulated so as to create, at least in theory, an almost infinite number of possibilities for their designs, whereas, on the other, material decisions are strongly influenced by what is feasible, accessible, affordable, etc., and where the increasingly complex material spectrum makes it challenging for designers to gain experience of and to communicate about materials (Manzini, 1989).

In today’s complex material world and diverse design practice, there exists a wide range of views on materials in the design process, each of which opens up for ways of thinking about and working with materials in the design process, as well as allowing for different agendas when researching materials in relation to design. One of the most common perspectives on materials in the design process relates to viewing them simply as a minor detail, defined late in the process, and as a result of other, more important, aspects of the design. This way of approaching materials when designing is sometimes referred to as “shape over matter” (Oxman, 2010a, p. 73), and is described by van Bezooyen as follows: “In the traditional design process, materials selection is a process that takes place at the later ‘develop’ stage where the materials selection criteria are defined by context of manufacturing and costs to realize an already mature product concept” (van Bezooyen, 2014, p. 281). The design process for the chair seat in the introduction is an example of this approach to materials, as the textile’s properties and expression are adapted to the requirements of the rest of the product. How to select (and in some cases design) materials that enable the realisation of the near-complete design is an important part of designing with materials using this perspective. As such, material selection has been an area of interest, particularly within the field of industrial design, and has been explored with regard to e.g. developing and testing methods and strategies for selecting appropriate materials in the design process (Ashby & Johnson, 2010), investigating designers’ information needs when selecting materials (Karana et al., 2008), and examining the influence of stakeholders (clients, manufacturers, users, etc.) over material selection (Pedgley, 2009).

However, materials can also be seen as the foundation or core of a design. Thus, a design process does not necessarily begin with a specific problem, function, or conceptual idea – materials can be the starting point and basis for a design. This perspective on materials is referred to as “material first” (Oxman, 2010b, p. 81), “material driven approach” (van Bezooyen, 2014, p. 282), or “microscope perspective” (Manzini, 1989, p. 58). The design process for the cushion in the introduction is an example of this approach to materials, as the textile was the origin and core of that design, from which the rest was created. This way of working with materials is sometimes described as a path to product innovation (Fischmeister, 1989), and research that relates to this perspective deals with this by e.g. exploring ways for designers and materials experts to collaborate so as to create new uses for existing materials (Ashby & Johnson, 2010). This perspective can also be related to material-based design research, which explores the potential of existing or new materials or techniques; for example, Worbin’s (2010) thesis that explores dynamic patterns in textile design, and Nimkulrat’s research that explores paper string as an expressive material in textile art (Nimkulrat, 2009).

A third perspective sees materials as an important and influential part of the design, and one which cannot be separated from the product when designing. From this perspective, materials are something that can be designed, adapted, etc. in relation to a design, as well as elements that introduce certain functional and aesthetic possibilities, which in turn influence what can be designed with them (Manzini, 1989). As such, materials are a part of the design problem (Dooridan, 2003), and designing becomes a form of collaboration with the materials (Mazé, 2007). This can be related
to Schön’s description of the design process as a “reflective conversation with the materials of the situation”, where the elements that are part of the design process (i.e. materials) interact with one another and influence the development of the design (Schön, 1992, p. 3). The design process which led to the creation of the interactive wall described in the introduction is an example of this way of working, in that the textile and its requirements influenced the design of the wall and the design of the textile was affected by the development of the overall design. This perspective relates to several design areas, e.g. the material thinking as related to art practice described by Bolt (2007), where materials should be considered as active and equal actors in the creative process, and Oxman’s experiments in product design and architecture, in which material design and structure play important roles in defining form and function (Oxman, 2010b).

Materials can also be seen as important tools and media when designing. This perspective on materials in the design process focuses on how materials and materiality can be used in the design process, rather than in relation to the final product. This includes different forms of objects, materials, and techniques that can be used to develop and visualise ideas and designs, from raw materials to digital design tools (Mazé, 2007). The role and potential of materials in the design process is an area of growing interest, and research in the fields of architecture, industrial design, interaction design, etc., explore materials in the design process with this perspective in mind. Research has been performed which e.g. explores how materials in prototypes, visualisations, etc. give rich descriptions of design ideas and open up for communicating ideas by engaging our senses, how alternating between different types of materials in representations/prototypes can help expand and re-direct ideas (Jacucci & Wagner, 2007), and how materials can be used in ideation as creative stimuli so as to trigger ideas (Ashby & Johnson, 2010). Hybrid materials, which combine digital and physical materiality, are also explored as new sketching materials and tools at e.g. the MIT Media Lab, where physical sketching materials such as clay and cardboard are merged with the flexibility and programmability of digital tools (Hiroshi et al., 2012).

The last two perspectives highlight the importance of materials and their properties and expression in relation to the design process, rather than simply as a material in the design of the final product—how each material brings its specific aesthetic and functional possibilities to the table when designing, and in turn is influenced by the specific context in which it is used (Manzini, 1989). Nordby & Morrison’s term “design affordances” in its original usage refers to the technology in RFID-tags, it also adds a useful model with which to consider also physical forms of materiality in relation to the design process: “A design affordance may be defined as what the technology offers the designer in the activity of designing” (Nordby & Morrison, 2010, p. 82). Their definition e.g. builds on Norman’s description of affordances; “…the perceived and actual properties of a thing, primarily those fundamental properties that determine just how the thing could possibly be used” (Norman, 1998, p. 9). The design affordances that a material introduces would then be the design activities that the material allows for; the possibilities and activities that the material opens up for in relation to the design to be, and what it brings to the process of making it.

The perspectives on materials in the design process described above illustrate some of the dynamics in the relationship between the designer and the materials that they work with. This relationship can be considered from two perspectives: Firstly, that of the designer; how they view, approach, and work with materials and material decisions when designing. Secondly, that of the material; how materials, through their properties, expression, etc., influence which designs can be created, along with the design process itself. Both directions are important when examining the relationship and the role of the materials in the process, and as such are at the centre of this thesis.

On textiles and the design process

Each material brings its own unique design affordances to the design process; introducing certain aesthetic and functional possibilities for the design, and possibilities for actions such as opening up for ways of sketching and working with the material (Nordby & Morrison, 2010; Manzini, 1989). Clay is characterised by its soft and freely formable properties in the design process, and its hard and stable properties in produced objects, whereas textiles are generally known for being soft, flexible, and adaptable in relation to both the final product and the process. The specific design affordances of a textile are dependent on a large number of interrelated textile design variables; structural decisions, e.g. construction technique, yarn quality, type of binding, and decisions that influence the appearance and touch, e.g. prints, coating, dyeing (Wilson, 2011).

Textiles in products can, from a product design perspective, be a ‘material’, a finished element that is selected and incorporated into the product as it is. Textiles can also be part of the “design problem” (Doordan, 2003), as an element that is defined as a part of the product. The design of the textile material in a textile product can in other words take place either inside or outside of the product design process, i.e. either defined by
the designers creating the product or designed by someone else, in a separate process. From a textile perspective, variation exists with regard to how connected textiles are to the products they are eventually used in. On one end of the spectrum, there are textiles designed specifically for a product, e.g. textiles in car interiors, which are designed with the specific brand and car model in mind (Powell, 2008), and textiles that are an integral part of the product and cannot be separated from it, e.g. the textiles in Nike free knit running shoes, where the form-knitted textile creates both shape and surface (Nike Inc, 2012). Conversely, some textiles are designed entirely separately from the product, and sold by the metre as piece goods. Here, the same textile has the potential to become part of numerous contexts and products. Designing this type of textile without a specific product in mind has been common practice in the textile industry. However, the design of these fabrics is often done with a specific type of application in mind, e.g. upholstery fabric for the contract market. With this type of textile, it is up to the customer to apply the fabric in a product, a piece of furniture, or interior design (Bang, 2010).

This separation from the design of products can be related to a disconnect between material and design, that came with industrial production, but it can also be attributed to the way textile materials have been produced, e.g. are long production runs of the same print design required to make a design profitable with roller printing, which means that it can be costly to develop textiles specifically for a product or other context using this type of textile production technique (Wilson, 2001). However, there are a number of techniques and possibilities in current textile production that open up for customised textiles or altered sold-by-the-metre textiles; e.g. digital printing, laser-cutting, and embossing (Creation Baumann, n.d.; Fralix, 2010). Moreover, it is now common for textile suppliers to offer custom solutions or designs, opening up for a more integrated process. Bang (2010) uses the term “applied textiles” to describe textile components or product solutions designed in this way for a specific use or context. Her research explores ways of creating a stronger link between textile suppliers, their customers, and the product’s end-users; she has e.g. developed co-design strategies and methods for Danish textile supplier Gabriel in order to enable a move away from piece goods and towards context- or product-specific textiles; for example, to include upholstery textile design decisions in the furniture design process of clients, and to include context- and user-specific input in the textile design process (Bang, 2010).

Textiles that are designed within a product design process can be defined in varying degrees of detail. It is possible to design the make-up of the fibres, yarns, etc. which fabricate the textile, thereby defining the fundamental properties of the material. It is also possible to construct the textile structure by defining how the materials should be woven, knitted, etc., thus defining much of the expression and properties of the fabric. Moreover, the surface properties and expression of the textile can also be defined through surface treatments, prints, etc., and the adding or removal of material, e.g. by embroidery, laser-cutting, etc. (Wilson, 2011).

The textile component of the product can also be given more or less influence in the process by the designer and, can play very different roles when designing; it may be a material which is e.g. selected or designed based on what can create a design, or it may have a strong impact on the design and be a driving force in the process. Textiles that are worked with as a detail, i.e. in a way which embraces the ‘form over matter’ approach, can be found e.g. in textiles in the automotive industry, where textile material design is part of the process, but does not have a strong influence over the product. For example, the shape of the seat is not often changed to accommodate a specific fabric, and instead fabrics are altered or changed to accommodate the shape and function of the seat (Powell, 2008). Textiles that have a strong impact on the design and which are allowed to influence the form or construction of the product are e.g. found at the furniture company Paula Lenti, where the textile is defined in the beginning of the process, and it is based on the properties and expression of the textile that the pieces of furniture are created; “…the approach starts from the material that I propose to the designer, asking them to design something that would fit this particular material.” (Beylerian & Dent, 2007, p. 128). The fact that textiles can also be designed in the process opens up for a broad spectrum of roles between these two examples, e.g. processes which relate to designing with materials as a conversation view (as described in the material section above), where the design of the textile in the product and the product itself influence one another, and together build the design.

Fashion is a design area and industry that is most often connected to textiles, and it is a practice where textiles are worked with in diverse ways. Townsend and Goulding have divided the fashion design process into three categories, distinguishing how textiles, and specifically print design, become involved; firstly, the garment-led process, where textiles are a relatively minor detail; secondly, 2D led processes, where the garment is designed around the fabric; finally, the mixed process, where the garment’s design is influenced by, but not designed around, the material (Townsend & Goulding, 2011). The fashion design field differs from many others due to its strong connection to textiles, in that how to design with soft, elastic materials is an important skill which
is taught in fashion design education (Gale & Kaur, 2004; Udale, 2008). The fashion design field can therefore be an interesting source of inspiration for other design areas that work with textile products, both in terms of how textiles are used in designs and how they take part in the design process.

The soft, flexible, and adaptable properties of textiles influence how textile products are produced, and how designers can sketch and work with the material during the design process. The designer Stephen Burk describes working with textiles in the following way: “[textiles are] a material that seems to have infinite possibilities because of its ability to conform to shape, be joined, folded or overlapped” (Beylerian & Dent, 2007, p. 63). The production of textile products often involves flexible techniques, such as sewing, cutting, and pressing the material, and does not necessarily require expensive tools or advanced machinery (Tyler, 2008). For hard materials such as plastics, steel, etc., the methods, materials, and techniques used during sketching can differ from those used during production of the product; e.g. using 3D modelling programs to define the design, and injection moulding to produce the product. The difference between sketching techniques and production techniques, as well as the nature of the materials, can, when designing products in hard materials, often mean that sketches and prototypes are not realised using the materials which the final product will be made of (Feirer, 2002). The transformable character of textiles, however, means that they are not simply materials to be applied in a specific design, but also an interesting sketching and prototyping material when designing. This is partly related to the fact that their soft and flexible properties make it easy to form and sketch with them, but also that the techniques used for sketching and making prototypes resemble the methods used to produce textile products, which open up for textiles being used throughout the process - from fast sketches to full-scale prototypes that illustrate the final product, including using the same textile in both the process and the product.

The softness of the material opens up for exploring and testing numerous design solutions regarding form, function, etc. in the material itself. This can be seen, for example, in the paper of Heimdal et. al (2012), which describes how textiles were used as prototype materials in three-dimensional model-making in architecture workshops to materialise, illustrate, and develop design concepts. The properties of textiles also open up for exploring, testing, and developing the expression and behaviour of textiles in and with the materials themselves. Textiles which are part of the sketching process can, as such, be altered and transformed in relation to the design of the product in numerous ways; e.g. by cutting, folding, embroidering, and printing on the material. Wolff (1996) illustrates this potential, by describing how a single piece of material can be changed in expression and behaviour using only a needle and thread: “The ideas are techniques that change the look and feel of a piece of cloth with the assistance of a threaded needle. They texturize, embellish, inflate, and support. They create puckers, folds, waves, pufff, projections, and openings. With stitching by hand or machine, they resurface, reshape, restructure, and reconstruct a flat, supple piece of cloth into cloth with an entirely different disposition” (Wolff, 1996, p. vii).

However, the soft, elastic properties of textiles can clash with the current, digitalised product design practice. The use of materials as skins or patterns on the surface of a digital model (van Bezooyen, 2014) does not incorporate material behaviour, e.g. how textiles drape, stretch, etc., which can be misleading in the design process. The influence of a textile on the form, construction, etc. of the product is not included in the model, and the renderings which are produced in the program will therefore not necessarily give a relevant representation of the final expression of the product. There are, however, some methods and/or tools which enable textile behaviour in 3D CAD models and which are intended for use in relation to clothing design, e.g. to create continuous or particle-systems of textile materials and incorporating these in the computer software Lectra Modaris 3D-fit (Lectra, 2013). Unfortunately, it is generally a complicated and computer-intensive process, and is challenged by the diversity of the material group, as each new material requires the testing and development of a unique modelling system in order to provide a reliable result (Aileni et al., 2011). The complications and uncertainty that accompany textile behaviour in CAD models should therefore influence how a designer views models that are created with these tools. Alquist and Menges (2011) suggest that modelled textile behaviour should be seen as providing basic, and not specific, material feedback. It should, as such, not be the only solution for linking CAD models with the physical environment, and should be used in combination with physical models (Alquist & Menges, 2011).

Textile properties can differ significantly, depending on the exact design of the material and how it is used in a design. The importance of what may seem to be minor details when designing with textiles becomes most evident when the textile is not simply a surface, but instead part of the construction or function of the product, where its properties have greater consequences. The importance of details is partly related to the fact that these materials behave differently depending on their size; e.g. working with small samples when designing may not provide the designer with the full picture of what the material will do in the final, larger design. The importance of details is also related to the fact that the character and properties of a textile are determined by a combination of a large number of interdependent variables; thus,
changing one variable changes the combination, and therefore possibly the behaviour of the textile as a whole (Wilson, 2011). Changing the textile in a textile product can, as such, have large effects on both function and expression, as illustrated by Landahl’s (2013) silhouette project, in which the same basic garment designs (flat pattern constructions) were combined with different textiles. The result was distinctly different silhouettes, created with the same original ‘design’, thus highlighting how a design based on textiles is not complete until the abstract form and material meet.

On new textile technologies and the design process

The development of new textile technologies has altered and expanded what textile materials can be and do. As a result, they open up for new textile products, but also influence how we design textiles and how we design with textiles. The following text introduces two important developments; smart textiles, and 3D printed textiles, both of which have been explored in this thesis. They were selected because they constitute significant developments within the textile field, and because both researchers and practicing designers have used them in their practice.

Smart textiles

Smart textiles are textiles with dynamic properties, which can be designed to sense and/or react to user interaction or changes in the surrounding environment. The term ‘smart’, refer to a large number of properties with more or less advanced functions; what they have in common is the combination of traditional textile fabrication and advanced materials and/or digital technology (Addington & Schodek, 2005; Ritter & Peat, 2007; Schwarz et al., 2010). These may e.g. take the form of textiles printed with thermochromic inks that, in relation to external stimuli, in the form of temperature, reversibly or irreversibly change their microstructure, which in turn change their optical properties, creating a visible change in colour (Ferrara & Bengisu, 2014). Alternatively, there exist textile structures in which conductive threads and electronics are incorporated so as to create soft sensors that can detect if the fabric is stretched or touched (Schwarz et al., 2010).

Smart textiles have the potential to be used in many different types of textile product areas; e.g. healthcare, protective clothing, communication, entertainment, sportswear, interior textiles, automotive textiles (Schwarz et al., 2010). In commercial use, smart textiles have primarily been used in fashion and sportswear (Berglin, 2013), e.g. MOON Berlin (n.d.) and Numetrex (n.d.), but there also exist examples of smart textile solutions in other fields; e.g. the solar-powered light source, ‘Portable Light’, designed by KVA MATx (Portable Light, 2012), and Luminous Textiles, a programmable textile and light wall made by Philips in collaboration with the textile company Kvadrat (Philips, n.d.). Healthcare, workwear, and other technical applications have been the focus for many funded projects, and are believed to be the areas where smart textiles could have the greatest potential for the future. Smart textiles are, however, not as yet considered to be an established material (Berglin, 2013). There are several possible explanations for this, including problems with technological solutions, e.g. how to incorporate electronics and power sources, standardisation and safety, and the combination of low production rates and high costs (Schwarz et al., 2010). Thus, smart textiles, while they introduce new possibilities, also come with associated challenges for producing and designing products.

How to utilise the potential of smart textiles in creating interactive or transformable products and environments has been the subject in numerous research projects within both industry and academia, and the prototypes that have been created have helped to illustrate the potential of these materials in a broad spectrum of design areas. Smart textiles as design materials have also been explored from a number of perspectives, and research has been conducted which has explored the expressive potential and developed methods and techniques in relation to specific smart materials; e.g. thermochromic inks (Worbin, 2010; Kooroshnia, 2013), fibre optics (Jansen, 2013), liquid crystals (Sara Robertson et al., 2011). Research into smart textiles as a material in relation to other areas of design has also been carried out; e.g. the IT + Textiles project (Redström et al., 2005), which examined the relationship between textile design and digital technologies as a means of integrating textiles into our daily lives; research on smart textiles in relation to interactive architecture (Dumitrescu, 2013; Ramsgard Thomsen & Bech, 2013); and smart textiles as design materials for interaction design (Persson, 2013). Research that takes a step back from the material and examines the interdisciplinary and inter-industrial collaborations that are involved in developing and producing smart textile products has also been carried out; e.g. research in smart textile product service systems at TU/e (Wensveen et al., 2014). There are also projects that aim to disseminate the potential of these materials by spreading information and knowledge in the hope that designers and students will be able to begin using these materials in prototypes, products, etc. These include Robakant’s workshops and online
DIY-descriptions of how to work with electronics and textiles (Satomi & Perner-Wilson, n.d.), the Smart Textile sample collection (Nilsson et al., 2011b), in which different types of smart textiles are designed and produced for use in workshops, prototypes etc., and work carried out by Heimdal and Lenau (2010), in which smart textile samples that are developed to differing degrees are used in workshops and studied in relation to what type of applications and design solution they facilitate.

**3D printed textiles**

3D printed textiles are modelled in CAD software and printed using additive manufacturing. This new form of textile goes by several different names, e.g. laser-sintered textiles and Rapid Manufactured/Fabricated textiles. These structures can be constructed in a wide range of ways which vary as to their resemblance to conventional textiles, and what constitutes a 3D printed textile is therefore not wholly self-evident. One potential definition comes from Bingham et al., who state that “In order for the RM [Rapid Manufactured] textile to be deemed a textile, it must incorporate free movement and drape characteristics” (2007, p.103). This type of textile material is currently constructed primarily using stiff materials with jointed structures, e.g. acrylic plastic, which are either 3D printed versions of existing textile constructions, e.g. knitted structures (Desbiens, 2013), or those that in their expression or properties resemble or are inspired by textiles (see e.g. Bingham et. al, 2007; Nervous System, 2014). 3D printed textiles can be produced using one of the two main additive manufacturing techniques: Selective deposit printing, in which layers of raw materials are deposited to build an object, and selective binder printing, in which powdered raw material is bound together using a laser or an adhesive. The range of raw materials that can be used to print these textiles is constantly expanding, and now includes soft rubber-like materials, metals, and conductive plastics (Lipson & Kurman, 2013).

3D printed textiles have the potential to be used in different types of products, but they are yet not an established material, as compared to conventional textiles. The cost of production, what with the expensive raw materials and machinery involved, and problems with CAD software currently limit development: It can e.g. be problematic to model and print large surfaces with complex textile structures, and to predict how their properties will affect the shape of a product (Lipson & Kurman, 2013; Bingham & Hague, 2013). Currently, this technique is used primarily in small products, such as bags and jewellery, with Freedom Of Creation (2014) being one notable example of a manufacturer. There are also several interesting examples in fashion design, e.g. haute couture garments by Iris van Herpen (2015), ready-to-wear knitwear designs that incorporate 3D printed sections by Pringle of Scotland (Beckett, 2014), and swimwear produced entirely using 3D printing by Continuum (n.d.).

The ability to adapt and customise a material's properties and expression to a specific product's design, or to the requirements of different parts of the same product, is currently being explored in relation to the additive manufacturing of many types of materials, including 3D printed textiles. As compared to conventional textiles, the way the structure is constructed is less tied to a specific technique with 3D printed textiles (Bingham et al., 2007). Different sections of the material can, as such, be designed to differ significantly from one another, and can include several raw materials with vastly differing physical properties. Combining the possibilities of 3D printed textiles with the design of products has been explored by several researchers and designers: Bingham et al. investigate how to work with and predict the meeting between the structure's design and the product's form using 3D CAD software (2013), while Oxman, together with fashion designer Iris van Herpen, has developed pieces of clothing that combine soft and hard raw materials, with the design of materials differing within garments (Materialise, 2013). Another notable example is the Kinematics Dress project of Nervous System (2014), which has a structure of triangular plates in stiff acrylic plastic, with connecting joints which facilitate drapability and movement in the material. The exact construction of the 3D printed material is here customised for each person who orders the dress; the combination and size of the components is achieved using an algorithm which utilises a body scan of the person who will wear the garment.

New technologies, such as smart textiles and 3D printed textiles, are still quite new within the textile field, and their characters as design materials often differ from conventional textiles. To develop the practice of designing with this type of textile therefore requires further exploration of what this type of textile can be, what they can add to products, and how they can influence textile and product design processes.
Design theory can help us to question and reflect on our practice, and introduce perspectives or methods with which to develop it (Löwgren & Stolterman, 1999; Hallnäs, 2010; Persson, 2013). Design theory and methodology is defined by Cross as “...the study of principles, practices, and procedures of design” (1993, p.21), and the resulting theories and models can be a bridge between what we know about designing and what we do when designing (Friedman, 2003). Design research can, when utilising this perspective, be seen as a dialogue, in which researchers suggest and discuss ideas about how and what to design (Zimmerman & Forlizzi, 2008). However, it can also be about increasing our understanding of current practice, and so an important contribution in design research is exploration of the fundamental elements of design, and the development of new perspectives and theories with which to view and consider different aspects of design and the design process (Friedman, 2003). This research project is a combination of the two perspectives, and aims to open up a new design space, exploring and defining ways to examine and understand the diverse and developing relationship between textile design and the product design process; in so doing, it is intended to open up for new directions in which practice could develop.

With respect to research methodology, this thesis is based on the interaction between experimental and theoretical work. Similar to the programme-based design research process described by e.g. Binder and Redström (2006) and Bang and Eriksen (2014), the work presented here was developed by shifting focus between defining and exploring – between formulating the research programme, developing theory, and working with experiments/examples. The theoretical aspect consisted primarily of developing theory for describing the relationship between textile and product (which is concluded in the framework presented in Paper VI), and the design experiments were performed through the study of and participation in design processes, i.e. practice-based design projects, and the qualitative study of other designers’ practices. With regard to this type of research process, it is through working with practice-based design examples and projects that design theory grows and is developed; initial theory is based on early examples, which is then tested and developed through others, moving from specific descriptions to general definitions (Zimmerman & Forlizzi, 2008). Later, different projects play different roles in the research process; some are selected or created because they may contribute to the understanding of the subject or add to the theoretical foundation, whereas others are built on theory, and used to explore details of and definitions within the theory (Landin, 2009). Here, the research process initially focused on finding ways to think about, describe, and discuss the relationship between product and textile. An observation of Master’s students designing textile products,
presented in ‘Designing with textiles’ (Paper III), was particularly significant, as it was through examining and analysing the students’ widely differing ways of working with textiles that the foundation of the theoretical work was developed. The ideas and ways of looking at the design process that resulted from that work formed the starting point and basis for other explorations, where some projects dealt with what takes place when designing textile products, and others focused more on the relationship that arises when designing textiles for products. During the course of the PhD work the projects gradually developed, from exploring the subject in order to provide a basic, broad understanding of what the dynamic between textile and product can look like (Papers I-III), to working more in detail in exploring specific parts of the relationship. For example, the ‘Smart textiles as raw materials for design’ project was conducted in order to explore (smart) textiles as tools in the process (Paper IV), while ‘Open Structures project’ was intended to explore the open character of textiles in other design processes, and how textile designers can approach this aspect of the relationship (Paper V).

Some experiments were undertaken as practice-based design projects. This type of method can e.g. be described as research through design (Frayling, 1993) or constructive design research (Koskinen et. al, 2011); here, knowledge of the subject is generated through constructing something, e.g. objects, services, or spaces, and then analysing and describing the outcome. It is “research that imagines and builds new things and describes and explains these constructions” (Koskinen et. al, 2011, p. 5). For this thesis, this took the form of designing with textiles and designing textiles for products, and analysing and describing the design processes. Working in a hands-on manner with design, e.g. by dealing with real materials and circumstances, provides challenges and experiences that can facilitate the obtaining of knowledge of practice that can be difficult to achieve through other research methods (Vallgårda & Bendixen, 2009). The practices of designing textiles and designing with textiles are at the centre of this thesis; thus, working with textile materials was also a central element of the research process.

Observations of design processes have also been an important part of the research process. This method was mainly used in relation to Paper III, which describes the study of Master’s students who designed textile products, although observation of workshop participants was also a small part of the project presented in Paper IV. Qualitative methods, such as observation, generally involve looking at phenomena in the world and trying to improve our understanding of them by describing and/or interpreting them. Outcomes differ in nature, and are related to e.g. what type of subjects are selected for study and which methods are used, as well as the role that the researcher plays in the observation (Creswell, 2007). The researcher can be present to differing degrees in the setting that is being observed, from complete non-participation, i.e. observing the activity from a wholly separate location, to complete participation, in which the researcher takes part in the activity alongside the group that is being observed (Baker, 2006). The form of observation that was used can here be described as “observer-as-participant” (Baker, 2006, p.175) or “participant observation” (Jorgensen, 1996, p.13). It is generally used for in-depth studies of specific phenomena in real-life situations and during the early stages of inquiry, and was here selected to provide an initial understanding of what the experience of designing with textiles can be like, as it allows one to explore phenomena without a specific result in mind. In this type of observation, the researcher does not construct the setting, but instead is present in and observes an existing situation, and has some contact with the participants (Jorgensen, 1996; Baker, 2006). In this case, it mainly took the form of observing, documenting occurrences, and asking clarifying questions.

To analyse the data that resulted from the observation, the phenomenographic method was used. The basis for phenomenography is an interest in describing the phenomena of the world, revealing and describing how they can be seen or experienced. The aim of the analysis is here to reveal variation in relation to the phenomenon in question, and to then create descriptions of this variation: “Phenomenography is focused on the ways of experiencing different phenomena, ways of seeing them, knowing about them, and having skills related to them. The aim is, however, not to find the singular essence but the variation and the architecture of this variation in terms of the different aspects that define the phenomena” (Marton & Booth, 1997, p. 117). This type of analysis was originally used in an educational context, with students learning and gaining greater understanding of a subject, but is now used in many other research fields (Marton & Booth, 1997). The analysis is an iterative process which entails searching for all possible experiences of a phenomena, comparing them, and then expressing them in clear categories; e.g. different ways of designing with textiles. The focus is not on each individual’s way of designing with textiles, but on the different approaches represented within the group of individuals (Åkerlind, 2005). The result of a phenomenographic analysis is detailed descriptions of the different ways in which phenomena can be experienced, and how these are related (Gibbings, 2008).
This thesis includes six appended papers. Taken together, these introduce the research theme, provide a picture of the exploration of the relationship between textile and product that has been part of the research process, and present the main research results. The results can be divided into two categories: Firstly, descriptions of how the relationship can manifest itself in textile product design processes and textile design processes for products. These examples give a broad picture of the relationship between textile and product and, in so doing, add to our understanding of textiles as design materials and what it means to design them. The papers contain two types of description; examples of how practice works today, i.e. the results of qualitative methods (Paper III), and descriptions of the considerations, added complexities, and new ways of working that come with designing with new textile technologies, specifically smart textiles and 3D printed textiles (Papers II, IV, V). Secondly, the appended papers present ways to describe and consider the dynamics between textile and product in the design process that can be used to reflect on how we design, and can design, with textiles. Here, the main outcome is a theoretical framework that examines the relationship from both product design and textile design perspectives, and includes methods and questions that can be used to explore and define this dynamic, which is presented in Paper VI.

Papers I, II, and IV, along with the practice-based design projects that these papers build on, were undertaken in collaboration with other authors: in Paper I contributed to the framing of the research programme, specifically the section that deals with how to design with smart textiles, I also took part in the Recurring Patterns project and the Smart Textile Sample Collection project, which are presented at the end of the paper. For Paper II, I designed and worked with the Recurring Patterns prototypes, analysed the design process, and wrote the paper together with the other authors. For Paper IV, I worked with the design of some of the samples that were used, organised the workshops, analysed the outcomes, and wrote the paper together with the other authors. However, the work presented in Papers III, V, and VI, along with the writing of those papers, was conducted independently.
This paper was written to frame a new research direction for the Smart Textiles Design Lab, and suggested a move away from exploring smart textile materials themselves, and towards considering the materials in a larger context of design. The research presented in this thesis is connected to one of the themes that is presented in this paper - specifically how we design with smart textiles, focusing not on what we design, but how we design. This paper introduces some important questions and considerations: how can smart textiles enter existing design practices? Can this type of textile, as design materials come to influence current design practices, force, suggest, or open up for new ways of working? The paper also describes two types of challenges in relation to developing a textile product design practice that encompasses smart textiles: the first is concerned with how to deal with a lack of access to these materials and how to disseminate their potential, and the second with the complexity that comes with designing and designing with these materials. In the paper, we discuss two research projects which explore these challenges: 'Recurring Patterns' (which is the basis for Paper II), and the Smart Textiles Sample Collection, a practice-based design project in which smart textile materials are designed and produced with the aim of making these materials and techniques more accessible for students, designers, and researchers.

This paper is based on the practice-based project 'Recurring Patterns', in which some of the possibilities and challenges that come with designing state-changing smart textile materials were explored. The basis for this exploration was the development and design of a ‘textile system’ (woven fabric with conductive threads, thermo chromic print, electronics, microprocessors, and a graphic interface), and the incorporation of this system into two pieces of furniture. The project resulted in prototypes with a re-designable dynamic textile surface that, depending on the context, could be programmed to change over time or in relation to people interacting with it. The paper focuses on how the new properties and design considerations that accompany these state-changing materials influence the textile design process and, in doing so, add to previous explorations of smart textiles as a design material. The paper describes the complexities that come with the temporal character of these materials, i.e. how the slow transformations that are created through this specific combination of materials transform traditional textile design variables such as colour and form, and make them more complex in their expression and in relation to the design process. The paper also describes how the interdependencies that come with the composite nature of these materials add complexities and new challenges to the design process; on the one hand making them more flexible through their programmable expression, and on the other making changes in design more difficult, as each variable is strongly related to the others. The paper also introduces strategies and tools that can be used to handle some of these complexities in the design process.

This paper is based on an observational study of a master’s course in design, where design students designed textile products. It presents eight different types of experience of designing with textiles, and in doing so highlights the diversity in the roles that textile materials and textile design can play, and the different types of influence which textiles as design materials can have over both what can be designed and the design process. The first examples describe four textile design affordances; properties and expressions, as well as opportunities and challenges that come with designing with textiles, all of which can influence both the design process and the development of the design:

- Scale: How the sensitivity of textiles to context and scale can influence the design process.
- CAD: How the meeting between soft and adaptable textile materials and 3D CAD programs can influence the design process.
- Material research: How the sensitivity of textiles to details in relation to material research can influence the design process.
- Physical interaction with the material: How incorporating more hands-on sketches and prototypes with textile materials can create a stronger link between textiles and the rest of the product, thereby influencing the design process.
The other examples describe four different ways in which textile materials and textile decisions can be approached in the design process, and the impact that this choice of approach has on the type of influence the textile materials and decisions can have over the development of the design.

- **Detail**: A type of process in which textiles are involved in the end of the design process as a detail, selected or designed based on what best enables more important design decisions.
- **Starting point**: A type of process where textiles are the starting point and inspiration, where the design is based on a textile material or design possibility.
- **Dialogue**: A type of process where textiles are designed and developed together with the product. Textile decisions influence other design decisions, and other decisions influence the design of the textile.
- **Tool**: A type of process where textile design and textile materials are used as a medium/tool in the design process, where textiles are part of the process and can influence the design, but are not necessarily part of the final design.

This paper also introduces some key ideas for looking at the relationship between textiles in the product design process through the perspectives and methods used to analyse the students’ design processes, e.g. that the influence that textile design decisions have over the development of the design is related to the phase of the design process in which they are involved. These methods and ideas were developed further and became part of the framework presented in Paper VI.

**PAPER IV**


This paper and the practice-based project on which it is based explore smart textiles as design materials. It specifically deals with what the extended transformability of these materials can add to the product design process as e.g. sketching materials, and what considerations come with designing with this type of textile as regards the textile design process. The paper introduces and explores the concept of smart textiles as raw materials for design, i.e. textiles with an unfinished design, where the expression and/or properties can be developed, enhanced, or used as tools in another design process. The paper is based on a collection of various types of smart/transformable textiles, as well as the experience of developing and working with these transformable textiles and a series of workshops in which other designers and students used these textiles as sketching tools. The paper presents four examples of smart textiles that, in different ways, can be used as sketching media. It also introduces a framework that can be used to analyse and discuss smart textiles as raw materials for design, including the interaction with the material that they open up for. The main framework presented in paper VI consists of ways of looking at and describing the interaction that takes place between textile and product in the design process, and several of these ideas are initially explored in this paper. These include how textile design decisions define the textile’s appearance, feel, etc., along with what the material as e.g. a design tool can do in another design process – which activities and ways of sketching it opens up for. Moreover, the paper provides examples of how the relationship between product and textile can be influenced by the extended transformability of new types of textiles, e.g. that these textiles have the potential to open up for new ways of interacting with the textile design when designing textile products.

**PAPER V**


This paper, and the Open Structures project that it is based on, explore the possibilities of 3D printed textiles as design materials, focusing specifically on what it means to design alterable 3D printed textile structures. The paper provides two examples of what this kind of changeable structure can be like; however, the bulk of the paper describes and discusses the considerations and decisions that arise when designing transformable textiles, and proposes ways to understand and describe what is taking place in the design process. Thus, two different types of textile design decision are described, which together frame the aspects of the textile’s design that are closed in relation to further development, and which are open for others to develop. The paper focuses primarily on 3D printed textiles, but the ideas relating to the alterability of a textile design are also relevant to other forms of textiles, and are also included in the main framework presented in Paper VI. The paper also contains an example of what a textile design process can be like when the focus is on the product design process, rather than the requirements of the future product.

Videos and images of the final prototypes that were made during the project can be viewed here: https://openstructures.wordpress.com
This paper presents a theoretical framework called 'Textile/Process/Product', which suggests an approach for how to consider the relationship between textile design and product design, describes how textiles and products interact and influence each other in the design process, and includes questions and methods that can be used to compare or plan design processes. The framework has been developed as a result of the work presented in the rest of the appended papers, and can be seen as a summary of that work. The first part of the framework looks at the relationship from a product design perspective, i.e. how textiles become part of and influence the product’s design and the product design process; the second examines the relationship from a textile design perspective, i.e. how the product, and also the product design process that the textile design will be part of, influences the textile design and the process. One of the main assertions of the framework is the importance of considering not only how the designer works with and approaches the textile or product, but also how the material or use in a product talks back and influences the design and the design process. The paper is concluded with a discussion on what new textile technology can mean for the relationship between products and textiles, using the main ideas and some of the methods of the framework. It deals with how the new type of qualities that come with new techniques such as smart textiles and 3D printed textile structures can challenge common ways of designing with textiles by bringing new types of considerations to the design process, but can also open up for new ways for practice to develop, as a result of their extended transformability.
On the research theme and results

The work presented in this thesis explores the relationship between textiles and products in the design process by looking at what characterises it, as well as how it can come to change and develop when new textile techniques enter the design process. The subject matter of this thesis is quite broad as the relationship in question relates to a wide range of working methods, different types of industries, and textiles with very different qualities. To fully explore all of the facets of this subject within the span of a PhD project is thus not realistic. Research that in other ways deals with materials and design often focuses on a more narrow context, e.g. describing materials and the designs they are used in in a specific setting (e.g. Townsend & Goulding, 2011; Pedgley, 2009; Bang, 2010), or evaluating a specific working method (e.g. Jacucci & Wagner, 2007; Ashby & Johnson, 2010). In doing so, they can present quite definite conclusions, e.g. directly suggesting or evaluating specific working methods or design strategies. However, when exploring the relationship between textiles and products, it was very much the diversity of the practice, along with how the open qualities of the textiles within the design process enable this variety, that was at the core of the research. For this reason, focusing on only part of the relationship, or a specific way of working, was not felt to be a good option. The broad scope of the research has of course meant that the observations, workshops, design experiments, etc. that have been conducted only touch upon parts of the many possible ways of working that exist today, or that could exist in the future with new textile technology; for example, the experiments only dealt with two types of new textile materials. The broad scope of the research has also influenced the character of the results which, instead of directly suggesting or evaluating practice, as the forebears of this thesis do, it consist of examples of what forms the relationship can take, and which perspectives are fruitful in order to consider it, with the aim of opening up for reflection on how we design and can design textile products and textiles for products. The nature of the research results and the most central points are discussed in the following:

In textile products, the product chain – encompassing the creation of raw material and fibres up to the disposal of the used textile product – is complex, and involves numerous steps and stakeholders, including textile engineers, yarn producers, textile designers, fabric producers, product designers, furniture designers, retailers, users, and many more (Roy Choudhury, 2014). The exact combination of phases and stakeholders involved depends on the specific context in which the textile and textile product is created and used, the type of textile technique that is used, and in which design industry the design process takes place. To fully understand the background to the relationship between textiles and products in a specific design process, knowledge
of that product chain is important. However, in order to be able to compare processes, which may take place in different settings across the wide range of design processes that exist in current practice, it is important to look at what these different processes have in common – and this linking factor is the design process. For this reason, the work described in this thesis has not focused on the context of the design process, but instead deals with how designs are created through design decisions. To do this, the complex textile-product chain is reduced to two parts: the decisions that form the textile material’s design, and the decisions that define the object/product in which that material is used, along with the relationship between them.

When investigating related research at the beginning of this work, I lacked descriptions for how textiles and products actually influence each other’s design processes, as well as theory with which to approach how these two fields meet and influence each other in a wide range of design contexts. In summary, I lacked information to enable reflection on how textiles and products interact when designing. Part of this gap has been filled by the research results that are presented in the six appended papers, which do so in two different ways: Firstly, by introducing theory – descriptions of the dynamics in the relationship – mainly in the form of frameworks that suggest how it can be considered and what the essential elements of this dynamic are. And secondly, by providing detailed descriptions of what takes place when textiles and products meet in the design process, which add to our understanding of textiles as design materials and can be used as examples to compare against our own practice. The frameworks, together with the descriptions of design processes, should be seen as a foundation on which to base our reflections regarding how we design, and can design, textile products and textiles for products in general - as well as a starting point for considering which methods, approaches, etc. are suitable for different types of products, textiles, designers, and design processes. This type of reflection is often relevant when designing with textiles, but would perhaps be most useful in product design and textile design educations, as it is here that the methods and approaches that form our practice are first established, and reflection on how one works can have a significant impact. A better understanding of textile materials and how to work with them could, for example, have helped the students in the observation (Paper III) to avoid some of the complications that they experienced when their normal way of working clashed with the qualities of textiles as design materials.

One of the main points of the frameworks, as well as the examples, is the importance of considering how the textile and the product interact and influence each other within the design process. This builds on the fact that a design which deals with products and textiles is not complete until the design decisions that form the product meet the full properties of the textile material, and that changes to either can result in substantial alterations to the complete design. To fully understand and consider the aspects that affect the future design, it is as such important to look at both sides of the textile-product relationship in the design process. In relation to a product design process, this means considering both what the textile should do in the product, as well as how the textile talks back and influences what takes place. A key to achieving this in a product design process is to understand and consider the influence that the textile properties and other textile considerations have. Similarly, the fact that one is designing textiles for products influences what the textile design can be; one of the keys to designing textiles for products is therefore to understand and consider the influence of the product.

The open, alterable qualities of textiles in the product design process play an important role in creating the wide range of ways of working with textiles that exist in current product design practice. They enable very different types of interaction with the material, such as the use of textiles as prototype materials/sketching tools and the possibility to alter the textile’s properties and expressions. However, as Paper II demonstrates, the qualities and properties that come with new textile technology differ from the ‘open’ qualities of conventional textiles, and as such can bring a different type of influence to the process – they can be more complex, less flexible, and thereby more demanding to work with, which can challenge some of the most common ways of designing with textiles that exist today. Thus, one of the central points of this thesis is that, in order to be able to design products that fully take advantage of new techniques, we need to understand and consider the new types of influence that these textiles bring to the relationship. The examples presented in the papers, which describe some of the new qualities of smart textiles and 3D printed textiles as design materials, can here play an important role, along with the methods in the main framework for analysing the textile influence (Paper VI).

As previously discussed, when placing textile design in a product design context, the product’s requirements influence what the textile can become, but the nature of the product design process that the textile will become part of also has an impact, as it is often through the developments made by the product designer that the textile reaches its final form. Thus, one of the key points in this thesis, relating to the textile design process, is that the process, and the interaction with the material that ensues, can
DISCUSSION

significantly influence the character of the textile design, and is therefore something that textile designers should consider. Instead of designing static, finished materials that will be used as they are, the influence of the process means that the textile instead becomes a material that is ‘open’ for interaction – for alterations to its design, but also for use as a tool with which to develop other designs. Thus, this view expands the textile design brief, adding new considerations and challenges, and in so doing also brings new possibilities for what textile designers can create and work with. This perspective on textile design becomes particularly interesting when working with new techniques such as smart textiles and 3D printing, where the possibilities for designing the ways in which people can interact with textiles are expanded substantially.

On future work:
The framework presented in Paper VI can be seen as a summary of the work done within the PhD project, and contains multiple perspectives, questions, and methods that can be used to examine the relationship between textiles and products. However, it is quite complex in its current form, and for this reason can be difficult to grasp; thus, more work is required in order to make it into an easily accessible tool. An important part of future work will be to continue to develop its form and how it can be used, e.g. by testing its structure using real design processes that have not influenced or been involved its development.

Several of the projects conducted within the PhD thesis have involved new textile technology (Papers II, IV, and V), and have explored the qualities that they bring to the product-textile relationship. They have also described the added challenges that new textile technology bring, as well as some of the potential benefits that their extended transformability creates for the interplay between textiles and products in the design process. In future work, it would be interesting to continue to develop the ways of working that are initially explored in these projects; to explore the forms that these open textiles or textile tools could take, what would be involved in designing them, and what they could mean for the product design processes that use them – what types of interaction in the design process they could open up for, and what designs this could result in.
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ABSTRACT
No longer is it sufficient to add ‘smart’ to textiles to secure interesting research results. We have surpassed the initial stages of explorations and testing and now need to raise the bar. We have thus specified a research program in which we investigate what it means to design with smart textiles. What can we design with smart textiles? And how do we design with smart textiles? We now explore how these complex, often abstract, materials can enter traditional design practices and what role smart textile can play in the design of our environment. In this paper, we discuss the challenges we see at present, we outline our new research program and we qualify it through three examples of our ongoing projects: The smart textile sample collection, Dynamic textile patterns, and Bonad [tapestry]. The paper is as much an invitation to join forces, as it is a description of a maturing process within design research. We are over the first love, now what?

INTRODUCTION
For over a decade, we have in various constellations with other researchers experimented with smart textiles (Redström et al. 2005; Worbin 2010a). We have become familiar with the basic aspects of this composite material—its vast potential and its practical limitations. We have seen and demonstrated a wide range of possible expressions (Post et al. 2006; Bezworska and Coelho 2005; Redström et al. 2005; Braddock-Clarke and O'Mahony 2006; Seymore 2008; Worbin 2010a). Obviously, new developments happen continuously: new dyes, new fibers, new electronics, etc., but the basic principles are likely to stay the same for now. We have learned how the design of dynamic patterns bare strong relations temporal arts, like music, movie etc. (Worbin 2010a). And, we have learned to think of the textile as a layered set of expressions consisting of the construction technique (i.e., weaving or knitting) combined with the materials (i.e. the yarns), the after-treatment (i.e., printed patterns) and the textile’s dependence on its surrounding conditions (whether, and how it reacts to or even adapts to events in the environment). Seeing these layers it becomes apparent that a designer of smart textiles must handle new variables regarding the temporal and environmental context (Worbin 2010a). We are still, however, to find out how to handle these new variables in practice.
From another perspective, we have learned that smart textiles are difficult to grasp both physically and mentally—physically because they primarily exist as abstract notions of possibilities and mentally because they hold expressions that come to be in context over time (Redström et al. 2010). We have suggested overcoming these difficulties by creating low-fi large-scale prototypes as a method to play with the expression before getting entangled in technicalities. However, we need a larger repertoire of methods to suit the range purposes for designing with smart textiles. Furthermore, only few commercial products embed smart textiles and the dissemination seems to happen primarily as do-it-yourself handicraft (cf., Buechley 2006; Buechley and Hill 2010). Hence, there is a need to investigate present textile design practices as well as to develop new practices for smart textiles.

We have also changed our understanding of computers in this process (Hallnäs and Redström 2008). Where the role of the textile in the beginning was to serve as computer displays it is now back as textile material in its own right. Computers and other electronics, instead, serve as a raw material that can be combined with textiles to form composite materials with new properties (Redström 2005; Vallgårda and Redström 2007).

We have built prototypes of products out of smart textiles, and we have studied their use in context (cf. Ernervi et al. 2005; Redström et al. 2005; Hallnäs and Redström 2006). Still, however, we have little understanding of the full design potential of smart textiles. Little understanding of what we can do with these expression-changing and context dependent textiles. These are the challenges that make up the foundation of our new research program.

RESEARCH PROGRAM: DESIGNING WITH SMART TEXTILES

The two main questions coming out of the work so far are:

How do we design with smart textiles?

What can we do with smart textiles?

These questions form the frame of our new research program. What we can do with smart textiles are obviously linked to how we do it and vice versa. However, the smart textiles, defined by their material properties and behaviors, will in and by themselves usually have a stronger influence on both what we can do and how we do it. And it is exactly this influence of smart textiles we will explore within this program.

To carry out this program we primarily draw from the research traditions of textile design and interaction design.

TEXTILE DESIGN

There are two important elements from the textile tradition that will play a role in our further studies of smart textiles. One is related to the division of labor and the other to the design variable at play in the practical process of design.

Traditionally, the development and design of textile products and applications are layered enterprises with multiple roles and responsibilities. The road from the fiber to the finished application often starts with textile engineers designing fibers, yarns, and construction. The textile designer(s) designing the structure and pattern of the fabric and finally other designers such as industrial or fashion designers using that fabric in their endeavor to create products or clothes. Smart textiles, however, have proved difficult to fit into this division of labor, primarily because it is impossible to develop by the meter for designers freely to place and integrate in their designs. Indeed, it seems necessary to break up the divisions between the disciplines and find new ways to integrate the design of the textile into the design of the garments or the interior. This brings up questions of how to actually deal with smart textiles in design practice. How can smart textiles enter traditional design contexts when they are seldom accessible for purchase? How can the potential of smart textile be communicated in the context of a design practice?

The design variables traditionally at play in a textile design process such as yarn quality, structure, color, shape, and rhythm are all challenged by different types of smart textile possibilities as they are expanded with state changes and thus significantly extended in their complexity. Indeed, we need to investigate what this complexity entails in a design practice and how can we find ways to deal with it.

INTERACTION DESIGN

Smart textiles offer the possibility of having the material to respond to actions—a trait we otherwise primarily know from finished products. Interaction design is a design practice and research field that deals with the context-specific actions of use as well as the temporality embedded in any computational design (cf. Hallnäs and Redström 2006; Mazé 2007). As such, interaction design should be able to provide some understanding of what it means to design responsive environments. Furthermore, a recent trend within interaction design is to perceive the computer as a material for design which means that are starting to emerge practices around giving forms to computers in comparable ways to giving form to smart textiles (Vallgårda and Redström 2007; Robles and Wiberg 2010; Vallgårda and Sokoler 2010). Indeed, it seems like the two disciplines could have something to offer each other when it comes to developing new design practice around complex materials. With a background in interaction design we will investigate what it means to design with materials that changes in context over time. How the changing expressions can be used consciously as a design parameter. And particularly, what design spaces smart textiles can open as well as the constraints they invoke.

Generally, within this research program every investigation takes its outset in the material—whether it is the material’s role in the design process, or the materials influence on the design of products and environments. Thus, the investigations comprise material experiments and prototyping, prototypes of textile things, studies of design practices, and interventions into contexts of use. Essentially, with this program we shift the focus from the material in and by itself and begin to study it in a larger context of design.

PROJECTS WITHIN THE PROGRAM

In this section, we will outline three of our ongoing projects and show how each explores different aspects of our new research program.

SMART TEXTILE SAMPLE COLLECTION

Smart textile sample collection is project in which we develop a collection of smart textile raw materials with various qualities and properties. The collection will serve both as a dissemination platform for the potential of smart textiles but also as an opportunity for us to have a repertoire to draw on in future projects (Worbin 2010b). In a sense this project can be seen as a bridge between the previous program and the new. It will give a picture of what we can do with smart textiles at present, but it will also serve as a new starting point for future projects—a step above square one.

The collection will comprise “raw” samples of smart textiles that can be used directly as sketch or prototype material. This means, for instance, that the samples printed with thermo chromatic ink are designed as generic patterns to suit a wide variety of expressions. Currently, we have made approximately 100 meters of fabric design from five different principles. Four of which are woven cotton printed with different thermo chromatic inks, and one is another quality of woven cotton with strategically embedded conductive threads (see Figure 1 and 4). Additionally, we have a collection of conductive knitted textiles though only as test samples that we can reproduce when needed (see Figure 3).

The project also includes a series of workshops for various kinds and levels of designers. They are here given the opportunity to sketch and work directly in the material as means to gain some experience. The workshops also serve as a feedback platform for us to learn how the samples work as conveyers of the larger potential of smart textiles. This project will run along side the other projects and gradually expand in size and complexity.

SMART TEXTILE SAMPLE COLLECTION

A sample collection of smart textiles will be developed offering designers access to materials and properties that can be used in different contexts. The sample collection will be presented at workshops and seminars, and we will document the experiments and make them available for designers and researchers. This project will gradually expand in size and complexity.

SMART TEXTILE SAMPLE COLLECTION

In the project, smart textiles will be developed and used in various contexts, such as fashion, furniture, and interior design. The aim is to explore how smart textiles can be used in different contexts and to develop new design practices that integrate technology and textiles.

Figure 1 Sample of woven cotton with conductive threads on one side. The thread can serve as heating elements and thus change the color of a thermo chromatic pattern printed on the other side.

Figure 2 Sample of cotton printed with grey thermo chrome ink that turns white when heated above 27°C. Half of this sample is moreover coated with acryl to give a stronger surface for prototyping.

Figure 3 Three samples of textiles knitted with different strength of conductivity. Left: knitted copper with viscose. Center: knitted blue mohair with brass. Right: knitted tonqueu cotton with stainless steel.
complexity in the design process. For example, in the case of designing the temporal pattern of the dynamic pattern we used with success a combination of a "note sheet" and a graphical interface to gain an overview of the sequence of the changes (see Figure 4). In other cases, however, we are still at a loss for how to cope with the complexity in a useful way. For example, putting together the color palette for one of the patterns, which in itself was a collection of patterns, proved to be incomprehensible (see Figure 5). At first we thought it was a matter of merely composing the two possible color states so they all would fit a coherent expression. We soon realized, however, that the actual transition between two states also contained a range of colors resulting in combinatorial possibilities that are present is difficult if not impossible to sketch. Obviously, this experiment will lead to new experiments where we will try different strategies and hopefully be able to develop new tools.

From a textile design perspective the platform is used for developing new textile structures and patterns that can achieve interesting expressions with this kind of slow or rapid explicit rotations. How, for instance, a textile surface becomes more or less permeable, how it changes from a smooth surface to one with three dimensional features, or how pattern combinations can play together through the rotations. We expect to end up with an understanding of the potential expressions of textiles in composition with this kind of movement.

An interaction design perspective we investigate how textiles in movement can influence and be influenced by the atmosphere of a room (Landin et al. 2011). Currently, for instance, we are experimenting with different combinations of context dependent behavior for a setup in a chapel and in an elderly home. As means to get an understanding of what new roles smart textiles can play in our environment.

This paper describes a process of the maturing of a research field from the initial explorations designed to give a basic understanding of what is at play, to formulating more specific questions and designing more focused explorations. The research program proposed here is still, however, a sign of an early stage in a research field. It is a program formulated to find ways for the new materials possibilities to reach a greater audience in parallel with studying in what this could mean for the design of textile products and environments.

The reason for publishing the formulation of this research program is not only to demarcate the maturing of the research within smart textiles, but also to contribute with own experiments and investigations—even perhaps in collaboration with us.

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Understanding the Complexity of Designing Dynamic Textile Patterns

Linnéa Nilsson, Mika Satomi, Anna Vallgårda, Linda Worbin
The Swedish School of Textiles
University of Borås
501 90 Borås, Sweden
linnea.nilsson, mika.satomi, anna.vallgarda, linda.worbin@hb.se

ABSTRACT
Through a smart textile design project we have identified two sets of complex issues generally relevant for design with state changing materials. Specifically, we show how the temporal dimension of smart textiles increase the complexity of traditional textile design variables such as form and colour. We also show how the composite nature of smart textiles create a series of interdependencies that make the design of the textile expressions additionally complex. We discuss how these forms of complexity provide opportunities as well as challenges for the textile expressions, and we show how we dealt with them in practice.

Keywords
Smart textiles, textile print, thermo chromic print, dynamic patterns, material composites, complexity, design practice, design tools

INTRODUCTION
Smart textiles, and specifically the combination of electronics and textiles, can be seen as textiles that in one way or another are able to change recursively between two or more states of expressions. They thereby provide a stronger temporal dimension to the design variables (i.e., colour, form, texture) traditionally found in textile design [7]. For that reason, the design, and the process will differ. New developments always pose new challenges, but the challenges in designing with smart textiles are not just a matter of obtaining sufficient skills in the disciplines involved (e.g., weaving, printing, electronics, programming). We have through a practical design project identified two sets of complex issues specific for designing with smart textiles. One pertains to the composite nature of smart textiles and the other to their temporal dimension.

This paper looks at how the temporal dimension and interdependencies within the composite and among the design variables affects the design of smart textiles. Through a specific experiment with a woven textile printed with thermo chromic ink with state changes controlled by a computer we discuss how these forms of complexity provide challenges as well as opportunities for the textile expressions. In some cases, we also propose strategies, and tools, which we developed as means to manage the various cases of complexity.

The temporal dimension is a central and unavoidable design variable in, for instance, interaction design where the computer is the primary material or medium. That said it is not always dealt with as conscious variable in the design choices. In the “Slow Technology” project Hallnäs & Redström [2] pointed out how the computer’s transition from a solitary tabletop object into being embedded in every object and environment demanded an increased understanding of how the ongoing changes of expressions affects our environments. In another project, Bergström et al. [1] discuss how computational materials comes to be in context over time because of how their expressions changes over time quite often as a consequence of specifically contextual changes. They propose to make low-fi large-scale prototypes as a practical method to achieve an understanding of how a particular material will come into being in context over time.

In traditional textile design as well as in material science it is well established that there are interdependencies in the design of a textile or a composite material [3, 7]. Indeed, to make low-fi large-scale prototypes as a practical method to achieve an understanding of how a particular material will come into being in context over time quite often as a consequence of specifically contextual changes. They propose to make low-fi large-scale prototypes as a practical method to achieve an understanding of how a particular material will come into being in context over time.

In our current research program, we explore how and what we can design with smart textiles [4]. In this project, we had the opportunity to work with a furniture company and thus investigate some of the practical aspects of designing with smart textiles.

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The outset for the design was a weft ribbed cotton fabric, with conductive steel threads attached on the backside at every five millimeters in the weft directions using the stitching tie technique (see Figure 1).

This fabric is intended as a canvas for print with thermo chromic ink. When running current through the conductive threads they heat up and thereby cause a colour change in the print along each thread. Thus, the design task was to develop the canvas, the prints as well as the conditions for the changes, possibly with an interactive dimension.

Ire Möbel provided two footstools as well as the expertise and manpower to upholster them with the textile we produced. We designed a different print for each footstool, as a way to explore more techniques and expressions. Both prints are made from combinations of thermo chromic ink and pigment colour. One print is made from a magnified picture of a knitted textile, where one part of the knitted structure disappears in the heated state of the print (figure 2). The other is a collection of geometric patterns printed in a colour palette consisting of several dark grey nuances, which change into a variety of colours when heated. Some of the patterns in this print exhibit form changes when heated, and others change only colour (Figure 3).

A series of Arduino boards placed inside the footstools controls the current running through the conductive threads which caused them to heat and in turn change the colour of the thermo chromic ink. Two textile pressure sensors [1] placed one in each end enables some degree of interactivity. The setup can be configured to suit specific contexts. For the exhibitions at Stockholm Furniture Fair and at Salone del Mobile in Milan, for instance, the colour change in the footstools needed to be as noticeable as possible to attract attention. Thus, we made the textile on the one stool change colour in a looped pattern and on the other stool in a geometric pattern (see Figure 4).

Figure 4 Illustration of the components used in the prototypes.

DYNAMIC DESIGN VARIABLES

As argued in the introduction the recurrent change of expression in this sort of smart textiles poses a new complexity to the design task. In the Recurring Patterns project, for instance, this complexity is partly seen as a consequence of the gradual transitions between the cold and the warm state of the printed expression. The conductive threads that are used to control the colour change, take time to heat up and to cool down. This gradual temperature change creates an equally gradual colour change and thereby adds shades and even other colours to the expression. Obviously, this enables a whole new range of complex expressions but it also creates a new set of considerations to the design process. Below is an analysis of what this complexity means to the traditional textile print design variables of colour, form, and rhythm.

Colour and colour palette

For the Recurring Patterns project we used two types of colours: the thermo chromic inks, which change from opaque to transparent at 27°C, and pigment colours, which are constant and unaffected by temperature change. By mixing the two types of colours, it is possible to create a range of colour changes where part of the colour disappears, and other parts remain (i.e. going from dark grey to light blue or changing colour tone from green to yellow). Dynamic patterns based on these types of colours can therefore change between two different expressions Worbin has described this as an alternation between two states: “a reversible pattern changes from one expression into another or several others, and always changes back to its initial expression. The pattern can also be described as A → B” [7, p. 49]. When looking at the pattern and specifically the colour mixing in Recurring Patterns project it becomes apparent that this description should be expanded to also encompass the transitions between the states of A & B. Thus, the change of colour would probably better be described as: A → B → A.

A dynamic colour can be seen as a colour scale of nuances in-between its colour at an ambient temperature to its colour at a heated temperature. Diagrammatic this could be described as A → B.

The transition from A → B is not just a matter of grading. The nuances in-between the end colours can be influenced by how the thermo chronic inks are combined. By mixing several thermo chronic colours with slightly different transition temperatures, it is possible to add completely other colours to the colour scale. This possibility was used in the geometric shaped version of the Recurring Patterns design. In one example the colour changes from grey to transparent, passing through several shades of magenta. An expression achieved by adding a small amount of thermo chronic magenta to the thermo chronic grey colour.

For the Recurring Patterns project we used two types of prints: a magnified picture of a knitted textile, where one part of the knitted structure disappears in the heated state of the print (see Figure 2). The other is a collection of geometric patterns printed in a colour palette consisting of several dark grey nuances, which change into a variety of colours when heated. Some of the patterns in this print exhibit form changes when heated, and others change only colour (Figure 3).

![Figure 2 Footstool with a textile structure pattern.](image1)

![Figure 3 Footstool with a geometric pattern.](image2)

![Figure 4 Illustration of the components used in the prototypes.](image3)

![Figure 5 Colour scale that gradually changes from colour A to colour B.](image4)

![Figure 6 Left: Print sample in ambient temperature. Right: The surface was changing to be when it was cooling down. The nuances are showing two possible combinations of nuances at two different points in time.](image5)

![Figure 7 This scema describes the complexity of a three colour palette by showing two possible combinations of nuances at two points in time.](image6)
With this complex colour variation, designing the colour palette becomes rather challenging. Essentially because as soon as more than a few colours are at play it becomes difficult to grasp how each possible combination will work together. In the process of designing the Recurring Patterns sketching the colour palette by hand or on computer was therefore, almost completely, replaced by mixing colours and testing prints in the printing lab. By placing different combinations of samples together and study how they changed under the heat from a blow dryer we were able to make the selection of colours.

Form and pattern

When working with dynamic patterns it is not only colour that can be temporal, form is also a dynamic design variable: “a dynamic form could implicitly contain all sorts of conventional forms as it varies from time to time, at one moment it displays one geometric structure, later it changes into another, and so on.” [7, p. 266]

How each form element will behave when heated, affects the expression of the design and specifically its relationship to the surrounding forms in a composition. By combining forms that disappear, change colour, or stay the same, it becomes possible to design a pattern where the relationship between elements in the composition changes at different temperatures. The considerations needed when designing a static pattern are still relevant when designing dynamic patterns.

Figures 9-11 are prints made in the Recurring Patterns project, which illustrate how this possibility can be used to transform the overall impression of a pattern and also to understand the temporal dimension not only the temporal dimension, but also the dynamic and contextual dimension of a pattern. The expression of a dynamic textile pattern, on the other hand, can be created and re-created through the program controlling the dynamics of the pattern or by making the dynamics dependent on contextual factors that can be sensed [1]. Indeed, the temporal dimension not only influences the design variables colour and form it also calls for the specific design of a temporal form—a rhythm. Even if the temporal form is made dependent on some kind of contextual change, the responding expression is still to be designed. Designing the temporal form becomes complex because it happens over time—we cannot in one moment see what will happen in the next, but more important because the heating and cooling does not happen in an instant the temporal expressions might overlap and thereby create new unpredictable combinations. Moreover, here we have even left out the cases of making the changes contextually dependent which adds a whole new layer of unknowns to the design process.

The heat sequence in a dynamic pattern is built up from a number of individual surface layouts (See figure 15). The composition of each individual layout is determined by the positions, sizes, and intensities of the heated areas. A new surface layout can begin even if the sections are still in unknowns to the design process.

Traditionally, textiles are given their final expression in the making (i.e. during weaving, felting, or knitting), and in after-treatments (i.e. by printing, shrinking, or dying). The expression of a dynamic textile pattern, on the other hand, can be created and re-created through the program controlling the dynamics of the pattern or by making the design dependent which adds a whole new layer of unknowns to the design process. The heat sequence in a dynamic pattern is built up from a number of individual surface layouts (See figure 15). The composition of each individual layout is determined by the positions, sizes, and intensities of the heated areas. A new surface layout can begin even if the sections are still in different degrees of cooling. The expression as seen at one point in time, is therefore, likely to be a combination of large number of different size and placement designs.

Figure 9 The first version of the same combination of forms. Left: shows the pattern in ambient temperature. Right: shows the pattern has been heated.

Figure 10 This is the second version of the composition in ambient and heated state. (The forms are the same in both prints but print colours are different, the two versions are therefore slightly dissimilar in ambient temperature.)

Figure 11 Left: Print sample in ambient temperature. Right: Heated print sample.

When one area changes that will have an influence the expression of the rest of the surface. Working with a textile that can be programmed to heat up sections independently means that at any given time is it possible for each part of the surface to be in its ambient state, in its heated state, or somewhere in-between. This type of complexity makes it possible to play with the relationship between shapes, both in the small area where the heat change takes place but also in relation to the printed surface as a whole. Examples of how this possibility can be used to transform the overall impression of a pattern can also be seen in Worbin’s project “Textile displays” [7] where the prints go from repeated to placement print by changing how the heating elements happen in the final prototypes. We therefore developed a physical sketching tool from a piece of the cotton fabric with the conductive threads, a driver able to control up to ten threads, an Arduino board, and a max/mssp graphical interface. This combination made it relatively easy to program the heating sequences on the Arduino board. This tool enabled us to print sketches on fabric and immediately see how they would work with different types of heating sequences. The size of the tool meant that it still was not possible to grasp the whole expression of a pattern, but it made it significantly easier to become familiar with the dynamic expression in the sketches.

Figure 12 Geometric pattern, showing several types of form-change occurring on the same print.

One way to reduce the complexity of the dynamic pattern is, of course, to reduce the number of combinations. By using only a few shapes and work with the same change in all areas of the surface the design tasks need not be any harder than traditional pattern design. We used this strategy in the design of the “textile structure” pattern, where the colour scales and shapes where combined in the same way all over the surface.

Figure 13 Textile structure print with one type of form change.

Sketching tool

When developing ideas for the patterns, we needed a way to quickly evaluate their transitional expression in the exact way they would happen in the final prototypes. We therefore developed a physical sketching tool from a piece of the cotton fabric with the conductive threads, a driver able to control up to ten threads, an Arduino board, and a max/mssp graphical interface. This combination made it relatively easy to program the heating sequences on the Arduino board. This tool enabled us to print sketches on fabric and immediately see how they would work with different types of heating sequences. The size of the tool meant that it still was not possible to grasp the whole expression of a pattern, but it made it significantly easier to become familiar with the dynamic expression in the sketches.

Figure 14 Left: The Sketching tool is used to evaluate printed pattern sketches directly in the printing lab. Right: Printed samples would be placed on the heat element, to see how they would change when heated.

Time & rhythm

Traditionally, textiles are given their final expression in the making (i.e. during weaving, felting, or knitting), and in after-treatments (i.e. by printing, shrinking, or dying). The expression of a dynamic textile pattern, on the other hand, can be created and re-created through the program controlling the dynamics of the pattern or by making the dynamics dependent on contextual factors that can be sensed [1]. Indeed, the temporal dimension not only influences the design variables colour and form it also calls for the specific design of a temporal form—a rhythm. Even if the temporal form is made dependent on some kind of contextual change, the responding expression is still to be designed. Designing the temporal form becomes complex because it happens over time—we cannot in one moment see what will happen in the next, but more important because the heating and cooling does not happen in an instant the temporal expressions might overlap and thereby create new unpredictable combinations. Moreover, here we have even left out the cases of making the changes contextually dependent which adds a whole new layer of unknowns to the design process.

The heat sequence in a dynamic pattern is built up from a number of individual surface layouts (See figure 15). The composition of each individual layout is determined by the positions, sizes, and intensities of the heated areas. A new surface layout can begin even if the sections are still in different degrees of cooling. The expression as seen at one point in time, is therefore, likely to be a combination of large number of different size and placement designs.
should also be dense enough to insulate the conductive threads yet permeable enough to let the heat through. Moreover, the quality of the material still has a strong influence on the durability and expression of the finished textile and thereby for which purpose it is suited. Another example is the combination of a computer and a textile. Separately they can be used in innumerable ways. In unison they restrict each other’s potential, but simultaneously enable completely new expressions. More specifically, the textile must be able to express at least two states to accommodate the temporality of the computations and the computer program must be restricted (programmed) to effectively express something specific in the textile. In Recurring Patterns the computer is programmed to control the switches on the array of mosFETs, which in turn control the flow of current through the specific lines of conductive threads. The strategy used in the Recurring Pattern project was to develop the composite starting with one material element and then gradually adding others. This strategy made it possible to understand the consequences of each new addition, and therefore to relate the new potential to the choices already made. In this case, the woven fabric with the conductive threads served as the starting point. The linear layout of the heat elements, for instance, became a strong signifier for the later design of the print layout. The downside of this strategy is that the resulting material composite could perhaps have accommodated the desired purpose better if some of the choices made in the beginning were kept open till the end.

In the Recurrent Patterns project it was possible to heat the surface in 40 individual stripes. Each stripe could be turned to full heat for a few seconds at the time and each used a couple of minutes to cool down. Again, the combinatory possibilities are staggering, but design is not necessarily mathematics and a significant number of combinations might be ruled out simply because they do not look good. Thus, before we started to sketch the temporal patterns we needed to see what the changes actually looked like. For example, we studied different intensities of changes occurring all over the surface at once as well as changes growing from one end to the other.

After gaining some familiarity with the possible expressions of the纺织 composite, we understood the importance of being able to sketch and discuss the layout of the temporal pattern. For this, we developed and used combination of a “music sheet” and a graphical interface to the programming of the pattern.

Sketch tools for the heating sequence

The sketch tool for the heating sequence became a combination of a “music sheet” where it was possible to mark the heating of specific sections and still keep track the previous and the following layouts. It was, however, not really possible to depict the intensities and thus the overlaps of expressions. So in a sense it is comparable to sheets of music; it still takes a skilled player to interpret the notes successfully. The graphical interface made it easy to transfer the sequences from the sheets to the Arduino controlling the heat and thereby to rapidly test or merely adjust the temporal form.

Another example of the forms. Another palette will simply regulate the forms to adjust the temporal forms. Figure 15 illustration of how the layout of the heating overlap in a composite with 7 individually controlled heat elements.

The sketch tool became a tool for the heating sequence. Right: the sheets used in the heating sequence design process.

INTERDEPENDENCY

Interdependencies are the other aspect that gives rise to practical as well as conceptual complexity when working with smart textiles. In the Recurring Pattern project we identified what makes sense to talk about as two areas of interdependencies even if they, to some extent, also influence each other. One is found in the composite form of the material, and the other in the combination of the dynamic design variables and their corresponding complexities. The following text describes the two areas of interdependencies further by giving examples from the project.

Designing the composite

In any composite material, the material properties are not just the sum of its component’s properties. Instead, they represent the result of a delicate negotiation between restricting some properties and enabling others [3]. Indeed, in this negotiation often enabling or enhancing one material property will directly restrict another. If the outset is seen as a tree of possibilities each choice will cut off a branch and its sub-branches. Hence, the consequences of a choice can sometimes be difficult to judge in advance. A smart textile is inevitably a composite material and thus inheres this interdependency in its design.

In this case, the main components of the composite are a woven cotton textile embedded with steel yarn, a pattern printed with thermo chromic inks and pigment colour, a microcontroller on an Arduino board, an array of mosFETs as the driver circuits, and a computer program. One example of the interdependencies that we encountered while developing this composite is the relation between the conductive thread, the cotton yarn, and the sensitivity of the thermo chrome ink (which reacts at 27 °C). The conductive thread attached to the woven cotton using the stitching tie technique should be able to produce enough heat in the fabric to reach the transition point of the thermo chrome ink. Furthermore, the material, which constitutes the primary part of the fabric, should be susceptible to the thermo chrome ink as well as being resistive to the concentrated heat produced in the threads. The material...
Some of the complexities can be turned into powerful expressions if they are mastered sufficiently. The question is how to master them. We have proposed some ad-hoc strategies and developed some sketching tools whose principles at least could be transferred to other projects.

Yet, there is a special issue which we have not yet addressed, namely, the fact that most of these smart textiles are made for a specific project and thus to a large extent will always be novel in the design process. In traditional textile design it is possible to become really skilled in certain techniques, but the same is difficult to achieve for these smart textiles, as they are rarely mass-produced. Experimenting with the properties and potential of the smart textile at hand will therefore be a significant and time-consuming part of the design process, especially if the smart textile is also open to be changed in its composition.

Nonetheless, we do believe it is possible for textile designers to achieve some level of familiarity with the dynamics of the classic design variables, when it comes to textile prints. We do believe that identifying some of the complexities can be a start to better understand the design space these materials afford. And we do believe that with some effort and after other iterations it is possible to develop more general sketching tools and strategies to aid the designer through the design process.

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DESIGNING WITH TEXTILES

Introduction

Textile materials are a part of countless products in our surroundings, and can be found in everything from home furnishings to sports equipment and car interiors. Textile materials and textile design are thus present in contrasting design fields and industries and are, to varying degrees, part of many types of design processes with very different material traditions and working methods. The flexible, stretchable, and adaptable qualities of textiles bring both opportunities and challenges when designing textile products. These properties can e.g. make it possible to cut and form material into products without requiring expensive moulds or advanced production techniques. However, the considerations that come with working with textiles can be very different from those that come with working with other materials. Designing with textiles can for this reason be challenging for designers who are accustomed to working with materials such as hard plastics, wood, or metals, or design students learning to design with textiles.

In contrast to the large number of textile products being designed at present, there are few descriptions and a limited amount of research being performed on how textile materials and textile design come into and take part in the product design process. Research on the relationship between material and design can take us part of the way but, to gain a better understanding of how the design of textiles and the specific considerations that come with designing with this type of material can come into a design process, we need to look specifically at designing with textiles. Exploring the relationship between product and textile design from different perspectives can add to our understanding of the subject, and examples and descriptions of the different ways in which textiles are approached and handled by designers today can play an important role in that exploration. Besides adding to our general understanding, these examples can be used by individual designers searching for new working methods, or be used as material for reflection when teaching the subject in design education.

The methods and approaches which a designer uses are refined during practice, but are initially formed during their education. This makes it interesting to look at not only practicing designers, but also design students, in order to improve our understanding of how textiles are approached and worked with when designing products. The foundation for this article is an observation of a course in which MA design students were given the task of designing textile products. This course was selected for observation because of its potential to inform our understanding of
designing specifically with textiles. The major part of the course was a design project which spanned several months, meaning that it was possible to get a detailed view of a number of different textile product design processes over a long period of time. The course was also selected because it had the potential to provide a wide range of experiences, a result of the diverse design backgrounds of the students participating in the course. The data collected was analysed phenomenographically, resulting in eight categories of experience of designing with textiles. These categories provide examples of how textiles influence not only the product, but also the product design process.

The article begins with a description of how the observation was conducted, and the phenomenographic method used to analyse the data. The main part of the article describes the eight categories of experience that resulted from the analysis. The categories are divided in two sections; firstly, examples of how the nature of textiles and the considerations that come with designing with textiles influence the process of designing with them; secondly, examples of how the students approached textiles when designing products. The article ends with a discussion which summarises the types of design process that are described in the categories, focusing on the challenges and opportunities that are related to designing with textiles and how these relate to the process of learning to design textile products.

Observation and Analysis Methods

The objective for the observation was to help broaden our understanding of the role which textile design can play in product design processes today. The aim was not to give a complete picture of how textiles can come into a product design process, or to make general conclusions on how textiles should be incorporated. Rather, the intention was to study and describe different types of experiences that can occur when designing with textiles, and to provide examples of the ways in which product designers incorporate textile design in their design processes. The object of study and methods of observation and analysis were selected based on this objective.

Sampling

The methods and approaches which a designer uses are refined during practice, but are formed during and influenced by their design education. Thus, it is interesting and relevant to look at not only practicing designers, but also design students, in order to improve our understanding of how textiles are approached and worked with when designing products. A course in which MA design students were given the task of designing textile products was selected as the subject for the study. This specific context was selected because it had the potential to inform our understanding of designing specifically with textiles due to the focus on textiles in terms of both the main task and the overall content of the course. This method of selecting the subject of study is described by Creswell as “purposeful sampling”, and is characterised by selecting contexts and individuals which make it possible to study phenomena that are central to the subject matter, or that have the potential to offer new insights or perspectives (Creswell, 2007, p. 126). Another advantage of selecting this specific course was that it also had the potential to be an “information rich case” (Creswell, 2007, p. 126). Firstly, because the students participating in the course came from diverse design backgrounds; three different design schools, several nationalities, and various bachelor programmes were represented. Secondly, because the course incorporated a large design project that spanned several months, meaning that it was possible to gain a detailed view of a large number of different processes and likely that a wide range of different perspectives and ways of approaching textiles would present themselves.

The design course

The design course that is the foundation for this article was a collaboration between three different universities, and first year Master’s students and teachers from all three universities participated in the course. The students came from diverse design backgrounds; this was partly related to the various directions of the design programmes that were part of the course, and partly to the many different types of design education (product design, interior design, architecture, textile design, etc.) that the students had completed before they started their Master’s education. The first group of students in the course came from a Master’s programme in industrial design which had a strong engineering and problem-solving focus. The second came from a school where it was possible to specialise in several different design areas; the students that participated in the course focused primarily on product and furniture design, but some of the students worked with interior design and design for children. The third group of students came from a Master’s programme in textile design; the majority of these students had completed a Bachelor’s degree in another design area, and therefore had only one semester of experience of working with textiles before starting this course.
The aim of the course was to broaden the students’ perspective on how textile materials can be used in product design. The initial part of the course consisted of lectures, study visits to textile manufacturers, and a week-long workshop in which the students were divided into groups and given the task of designing a product based on a specific piece of textile. The rest of the course consisted of a group project in which the students were given the task of designing a product based on or using textile materials. The type of product, how the students worked with textiles in their process, and which textiles they worked with, were all decisions which were left up to the students. Most of the students participating in the course had experience with long design projects and other materials, but had little or no experience of designing with textiles, and this course was the first time they were given the task of designing a product in which textile materials were to be a central element. For the main task, the students worked in groups of between three and six, although some students left their groups and worked individually with the task; in total, nineteen students completed the course. The course ran over one semester, and the students who completed the course received 15 ECTS credits. The students and their design projects were observed evenly over the duration of the course.

**Observation method**

The course was studied through a form of participatory observation, a qualitative method whereby researchers study real-life situations which have the potential to inform their area of interest. This type of observation is suitable for exploratory studies, where the aim is to give in-depth descriptions of a phenomenon (Jorgensen, 1996), and it is therefore compatible with the objective of this study. The data collection methods used in the observation consisted of; direct observations, field notes, recording presentations and discussions, taking photographs of what was presented, and reading student reports. The role of the researcher can vary depending on the nature of the study; in this case, it can be described as “observer-as-participant” (Baker, 2006, p. 175). This observation method is focused on observing the students’ experiences in the given setting, and the researcher’s participation was therefore reduced as much as possible, so as to minimise their influence on the development of the students’ designs and design processes. The subjects, in this case the students, knew that the researcher was present. The researcher did not actively take part in the situation, but instead sat in on the events taking place during the course, and in some cases asked clarifying questions.

**Phenomenographic analysis**

The intention of the study was to describe different types of experiences that can occur when designing with textiles. This focus on providing a broad perspective suited the aim and outcome of the phenomenographic method, and this type of method was therefore used when analysing the data collected from the observation. The aim of the phenomenographic method is summarised by Marton and Booth: “Phenomenography is focused on the ways of experiencing different phenomena, ways of seeing them, knowing about them, and having skills related to them. The aim is, however, not to find the singular essence but the variation and the architecture of this variation in terms of the different aspects that define the phenomena” (Marton & Booth, 1997, p. 117). The outcome of a phenomenographic analysis is descriptions of distinctly different ways of experiencing the phenomena of interest, and these descriptions are referred to as “categories of experience”. It is important to note that these do not describe individual persons’ experiences, but rather different ways of experiencing the phenomena found in the group that has been studied (Marton & Booth, 1997).

The data collected during the observation was analysed through several steps, each with a specific focus when looking at the material (the steps used to analyse the data are an adaptation of the process used by, among others, Gibbings (2008)). The analysis of the data was conducted in the following way: First, the collected data was thoroughly examined in order to gain an overview of the content. The second step involved obtaining an understanding of the individual experiences of the participants. Studying quotations is a major part of the process of a phenomenographic analysis, and quotations from the subjects are analysed with regard to what they say about the experience. According to Marton and Booth, however, other sources may also provide important insights into the phenomenon being studied: “Experiences are reflected in statements about the world, in acts carried out, in artefacts produced” (Marton & Booth, 1997, p. 118). As the analysis presented here focused on exploring and eventually describing the students’ experiences when designing with textiles, it was important to not only understand the specific statements and individual events, but also the overall context: the students’ design processes. An important part of approaching the data collected was therefore to understand the development of the students’ designs. During the third step of the analysis, the focus shifted away from individual experiences and towards collective ones; thus, experiences were grouped together to form initial categories of experience. The character of each category was gradually defined and refined by alternating between focusing on similarities and differences
in the different types of experience (Walsh, 2000; Gibbings, 2008). The experiences found in the data were divided into two groups, reflecting two different perspectives on the experience of designing with textiles. One focused on how the nature of textiles and the considerations that come with designing with textiles influenced the design process, while the other one focused on how the students approached textile materials and textile design when designing. The categories presented in this paper are grouped in relation to these two perspectives.

The choice of subject and methods of observation and analysis have a large impact on the outcome of the study, as each choice opens up for certain insights and makes others more difficult to come to. For example, the decision to observe this specific course made it possible to study a large number of textile product design processes in great detail, and to compare a number of different experiences; however, this specific focus on textiles ruled out the possibility to compare experiences of designing with other materials, which a different course or context could have opened up for. Another aspect that influenced the outcome was the decision to observe students, which made it possible to study how students learn about designing with textiles, and look at future designers’ experiences with textiles as their design methods are being formed. Observing or interviewing experienced designers would have provided a different type of outcome which could have brought other useful insights; on the other hand, it would have been more difficult to gain access to such subjects in large numbers, which would in turn have made the comparing of experiences in the analysis stage more difficult. The method of data collection is another factor that influenced the outcome. The decision to work with participatory observation made it possible to collect a large amount of data, which formed a strong foundation for the analysis. Interviews or case studies could have provided another type of data, and could possibly have provided greater insights into the students’ own reflections on their way of working; such an approach, however, would also have offered a more restricted perspective on the details of their design processes and the roles which the material and its design played when designing. Having previous experience of the subject being studied can lead to presuppositions and bias conclusions, but being able to fully understand the phenomena that the subjects are experiencing can also benefit the work and be an asset in the analysis process (Gibbings, 2008; Denscombe, 2003). The researcher’s experience and background in both product design and textile design was in this case found to generally be an asset in the analysis process, as this made it possible to analyse both sides of the experience, as well as the meeting of the two fields.

A decision-oriented perspective on the textile product design process

The role which textile materials and textile design decisions play in a textile product design process depends on the importance the designer places on this aspect of the design, and how much influence they are given over the development of the design. To be able to analyse and describe the role that textiles had in the observed design processes, a perspective for looking at and describing the importance placed on different elements in the design was needed. The following describes the basis for this perspective:

Textiles can come into the product design process in diverse ways, and can be more or less actively designed; how and when this is done, or how and when textile decisions in any form come in, can be important clues when analysing how much influence textile issues have in the design process. For example, it is more likely that a textile material that is one of the central ideas for the product will have a stronger influence on the design than one which is selected as a minor detail at the end of the process. A focus on how these design decisions take part in the design process became the foundation for examining the relationship between textile design and the product design process. The way in which the design of the material itself is incorporated into the process, and the type of design decisions this brings with it, also says something about the approach that the designer has to the material and to what extent the material design is part of the product design process, and is therefore also important in looking at what role the textile can play when designing. This decision-oriented perspective on the textile product design process made it possible to analyse the role of the textiles and what type of influence they had over the design. By looking at similarities and differences in where and how textile decisions came into the different types of processes, it gradually became possible to define the individual character of the eight categories of experience. A model of the design process formulated by Jones (1992) was used to describe where textile choices are made, and the textile product design area was divided into four groups, making it possible to describe what form of textile design decisions are worked with in the different textile product design processes. The following is an introduction to the two models and how they relate to the textile product design process.
Jones’s three-stage design process

Jones divides the design process into three phases: divergence, transformation, and convergence. These phases represent three fundamental, logical phases of the design process, each with its own type of design decisions. Divergence is the initial phase of the design process, and is described by Jones as “breaking the problem into pieces” (Jones, 1992 p.63). In this phase, the designer takes the original brief, deconstructs it, and then expands upon it, looking at aspects that are important in the specific design situation and searching for decisions that could be used in the design. The explorations and experimentation that the designer performs during the divergence phase inform the upcoming transformation phase, giving the designer a better understanding of the boundaries and potentials of possible decisions and an improved conception of the consequences of decisions that may be made in the upcoming design work (Jones, 1992). Textile design decisions can be present in the divergence phase of a textile product design process, e.g. by being part of the original brief or by being one of several options that are explored in the design space. The outcome of the designer’s divergence exploration become the base for the rest of the process, and if textile decisions are a part of this foundation, the designer’s understanding of the material will have a chance to influence the development of the design.

Transformation is the second phase of the design process, and is described by Jones as “putting the pieces together in a new way” (Jones, 1992, p.63). Here, the designer searches for and develops ideas and basic concepts. The transformation phase is about fixing the objective for the design - in other words, defining what it is that the designer is designing, and deciding which design decisions are important and how these decisions are related. The choices made in the transformation phase create the general direction of the design, and set the scene for the upcoming, more specific design choices (Jones, 1992). Textile design decisions can be present in the transformation phase, and can become one of the essential decisions that form the direction of the design; when this is the case, these textile decisions have a strong influence over the development of the design.

Convergence is the third phase of the design process, and is described by Jones as “testing to discover the consequences of putting the new arrangement into pieces” (Jones, 1992 p.63). In this phase, the objective has been defined, and the designer gradually develops the abstract idea to a finished design; thus, decisions become more and more detailed. Each decision in this part of the design process is influenced firstly by the directional decisions made in the transformation phase, and secondly by the decisions which the designer has made previously. The order in which decisions are defined determine how much influence a specific decision can have on the design, and can provide us with a clue to the importance which the designer places on different decisions, i.e. whether a decision is considered to be a crucial element or a minor detail in the design. Textile decisions can be a part of the design process in the convergence phase; if a textile choice enters the process at this point, it will be directed and influenced by previously established decisions. The more it is considered to be a ‘detail’, the less impact it will have on the development of the design.

It is important to remember that the design process which Jones (1992) describes is not linear; it does not proceed directly from divergence, through transformation and convergence, to a finished design. Rather, it is a process with several cycles, in which the designer moves between the different phases until a finished design is completed. The designer goes back and forth between what could be part of the design (divergence), what it should be (transformation), and how it should be (convergence).

In summary, decisions made during the divergence, transformation, and convergence phases play three different roles in the design process, and therefore influence the development of the product in three different ways. Jones’s division of the design process, and the perspective on the design process this opens up for, made it possible to go into detail and look at the role which textiles played, and the impact this had on the students’ design processes. It therefore played an important role when analysing the students’ experiences and defining the categories of experience. An illustration of Jones’s division of the design process was created in the final stages of the phenomenographic analysis in order to clarify and visualise how textile decisions became part of the design process in the different categories of experience. The illustration has also been used in this article to summarise and visualise where textile design decisions comes into the divergence, transformation and convergence phase in the descriptions of the categories of experience.
Jones’s three-stage design process

The small circles in the illustration represent design decisions. These decisions float freely in the divergence phase, and, during the transformation phase, combine to form a design direction, a form of embryo, for the development of the design. This embryo then becomes the core of the convergence phase. The large circle in the convergence phase represents the design of the entire product. The placement of the small circles in the large circle represents how central they are to the design. The closer a decision is to the centre of the circle, the more important it is, and the more influence it will have on the design. The further out it is placed, the more the designer regards this decision as a minor detail, and so it will have a smaller influence on the development of the design.
Four forms of textile design decisions

Textile materials and textile design can come into the textile product design process in a large variety of ways. It is possible for a designer to not only select a textile material for their product, but also to design it in great detail. For example, textile decisions in a product design process can consist of creating a new woven fabric for the product, adding a new colour to a previously designed material, selecting a sold by the metre fabric, or creating a specification for a material that is then handed over to someone else to finalise. In what form the designer incorporates textile design decisions is an important clue regarding the role they play in the process, and what type of decisions the designer will work with in their process.

The textile area is a diverse field, containing numerous techniques and applications. Textile design can encompass all of these aspects. The area can be divided and considered in multiple ways, e.g. by techniques (weaving, knitting, non-woven, dyeing, embroidery), or the type of fibre the textile is made from (e.g. natural or synthetic fibres). Albers divides textile design into two areas; the inner structure, which deals with the construction of the material, and the surface, related to appearance and touch (Albers, 2000). For this article, the area of textile design is divided in a way that makes it possible to describe how the design of the textile material enters the textile product design process. The textile design area is divided into four groups, based on what type of textile decisions and activities the designer deals with when designing a textile product. The first relates to construction, the second, alterations, the third, selection, and the fourth, specification:

- **Construction**
  This is a type of textile product design where the construction of the textile is a part of the design process. The material can be designed in extreme detail e.g. in designing a new fibre for the product. It can also take the form of combining materials to create a composite textile, or selecting yarns and fibres to create a new material that is designed and produced for that specific product.

  Example of textile techniques: Weaving, knitting, warp-knitting, non-woven.

- **Alteration**
  Here, an alteration of an existing textile is part of the design process. The material can be designed by changing the surface; e.g., changing the colour by dyeing, adding patterns by printing, or adding structure by flock printing, pleating, etc.

  Examples of techniques: Dyeing, printing, embroidery, laser cutting, pleating.

- **Selection**
  A type of textile product design where the selection of textiles is part of the design process. In this type of process, the designer does not design a new material for the product, but instead selects a textile that works with the rest of the choices made in the design. The fabric is in this case designed outside of the product design process, and is incorporated into the design as a finished material.

- **Specification**
  In this type of process, the specification of textiles is part of the design process; thus, the designer does not design or select a specific textile for their product, and the choice of textile is left outside of the design process. Instead, a type of material or a set of properties that the designer believes will work with the rest of the design choices are specified.

The first four categories of experience in this article are termed ‘textile influence’, and relate to descriptions of how the nature of textiles and the considerations that come with working with textiles influence the design process. The other four categories of experience are termed ‘approach to textiles’, and describe four different ways in which the students incorporated textiles in their textile product design processes, and the effect this had on the role which textile design played in the design process. Each category is described in the same manner; a description of the students’ processes, followed by a discussion and deep analysis of their ways of working, in which different aspects of the relationship between the design of the product and the design of the
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The descriptions start with a short introduction to how the experience relates to the considerations that come with designing with textiles, followed by a short fictional version of how this category can manifest itself in a design process (a summary of the different students’ processes), which is illustrated by quotes taken directly from the observation. The category is then discussed in relation to previous writings and research on materials and the design process, and textiles and the design process. The discussion continues with a detailed description of how and where textile materials and textile design decisions come into the design process, and ends with a reflection on the challenges and opportunities that can come with designing with textiles in this way, and how this relates to the process of learning to design textile products.

1. Textile influence - SCALE

The size of a piece of fabric has a large impact on how that textile material behaves and functions in a product. A textile that is stiff and easy to fold when it is a small swatch can become heavy and unstable when the size of the fabric increases and its properties change. This type of change can come to influence other important decisions in the design, such as form and how the product can be constructed. Not considering the influence of scale, e.g. by working with textiles in one scale in the design process and using another in the final product, can lead to unexpected changes in the design and influence the design process. During the observation, the combination of textiles and scale was seen to influence the process of designing with textiles:

DESIGN PROCESS

In the beginning of the design process, the designer explores a number of textiles, testing and handling small pieces of the materials, thereby becoming more familiar with their properties. One textile swatch catches the designer’s attention, and the potential found in that material inspires the initial stages of idea development. After several possible applications for the textile are explored, an idea for a large textile product is developed, in which some of the main decisions build on the fabric and its potential. The design gradually becomes defined through sketching on paper, use of CAD programs, and the making of small models. During this process, the textile material becomes an important part of the construction and expression of the product. A small textile model is made at the end of the development process. For the designer, the scale model defines the shape of the design, and confirms the use of that specific textile in the final product. At the end of the project, a full-size prototype is made to visualise the design; the properties of the fabric when used in a large scale are, however, not what the designer anticipated. The new properties change the expression and construction of the product, and the choices that the designer made during the design process are no longer compatible with the chosen textile. The designer is left with the choice to either redesign the product to work with the properties of the material in a large piece, or search for a material that can recreate the expression and construction of the small textile model.
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QUOTES

In the first quote, the student describes the idea which later becomes the main concept of the project; taking a folded swatch of fabric and scaling it up to create a decorative element for a room. In the second quote, the student describes how the strict and origami-like expression of the small-scale textile sketch is reduced when it is enlarged in scale. Based on this experience, the student concludes that a different material is needed.

- I thought about how this can be used in different spaces. You can use it as a room divider, as a cinema curtain.
- It will fall down and lose its structure. Because it is hanging and it is pretty heavy. So I think you need some kind of special fabric also to make it work.

In the next quote, a student describes how the same textile used in a scale model and final prototype unexpectedly created very different results.

- Since this model was too big, it couldn’t hold the shape like that picture, but originally the expected shape was like this

CONTEXT

A material introduces certain functional possibilities. Manzini uses the term ‘behaviour’ to discuss this range of possibilities: “A material is something that, under given conditions (ex. environmental conditions, a specific load), behaves in a given fashion (supplies certain performances)” (Manzini, 1989, p. 34). Material behaviour is specifically central to material thinking in the textile product design process, where textile properties can differ significantly depending on how the material is used. The influence of scale is one example, in that the properties in the final scale will have a strong impact on the shape, expression, and function of the product, regardless of whether or not this is considered. The importance of considering the behaviour in relation to scale of textiles becomes most evident when the textile is not just a surface, but instead part of the construction of the product. Research into designing large scale textile structures by the architects Ahlquist and Menges (2011) points to the importance of working with a combination of material and form, with the behaviour of the textiles in the final scale in mind. “In working with textiles, geometry is always a by-product of the material structure. One cannot define the geometry before first understanding the capacities of the material. When setting a textile as a structural surface, this is an even more significant condition” (Ahlquist & Menges, 2011, p. 13).

DISCUSSION

In the category 'Scale', the students experienced that it is not certain that a textile product is complete in its design until all design decisions are compatible with the textile properties in the final scale. They also experienced how this aspect of designing with textiles can influence the design and the process of designing. During the observation stage, this type of design process exhibited three common characteristics: Firstly, textile materials were present in the form of small swatches and samples. Secondly, information and sketches that resulted from small samples became directional design decisions, and thereby strongly influenced other decisions throughout the process. Thirdly, the designs were developed in a direction which required a large piece of textile. During these processes, the students were designing with one scale, and using another in the final design. Thus, textile properties and decisions did influence the design, but in a misleading way.

This clash of scales resulted in a design where the meeting of the properties of the material and the rest of the design was not actively considered by the designer. It therefore becomes uncertain whether the behaviour of the material in a larger scale will work with design decisions made during the design process. In this type of design process, the full-scale textile properties meet the rest of the design first in the prototype. The unexpected change in properties which then occurs influences the design, changing the dynamic between material, form, and construction. This change in the design influences the design process, forcing the designer to go back and re-make important design choices.

The following figure (3) describes how textiles comes into and influence other design choices in the divergence, transformation, and convergence phase of the design process. In the divergence phase, the students’ explorations of the design space included textile materials. Small pieces of fabric were used to sketch and become accustomed to the fabrics. These small-scale experiences of the material were, at the end of the divergence phase, brought into the next step of the process, becoming a part
A textile material enters the process in the form of a small sample, and the properties of the textile in a small scale become one of many possible design decisions.

The 'small scale' textile properties and an idea for a large product application become two of the directional design decisions.

The rest of the design is built around the directional design decisions, and all other design decisions are therefore influenced by the textiles 'small scale' properties.

The large scale textile properties come into the design when the design is examined or when a prototype is made. Will the design decisions that were made in relation to small scale properties work with the full scale material?
of the foundation for the upcoming idea development. In the transformation phase, the
behaviour of the textiles in the small scale was combined with other design decisions
to create a direction for the design. Several different scales and contexts were explored
before this combination of design decisions was defined. The behaviour of the textile
remained constant as the design became larger and, as such, the properties of the material
in the small scale influenced the design, regardless of the intended scale
of the product. In the convergence phase, the design was gradually developed, and
design decisions were based on the directional design decisions of the transformation
phase; thus, the properties of the material in the product scale were not considered.
The properties of the material in the final scale entered the process when all of the
decisions had been made and the material and design met in the prototype. What the
designer thought was a finished design was questioned by the unexpected properties
of the textile. The properties of the material in the new scale distorted the design, and
in several cases made the original idea and form impossible to achieve. This forced the
design students to reconsider major aspects of the design, and go back to the process.

To create a complete design, the full-scale properties of the textile must work with all
other design decisions. The students did not consider these relevant textile properties
when they explored the design space, formed the idea, or finalised the details, and
instead had to go back and reformulate their previous decisions so as to complete
the product. The process can, at this point, take several directions: One possibility is to go
back and open up the design space and explore the properties of the material in the
product scale (new divergence phase) and, based on that experience, re-formulate the
design direction (new transformation phase).

The direction that the students took was to change the textile of the original design,
as the students ascribed the failure of the design to this original material. The natural
solution was, therefore, to remove it and search for a new material that could complete
the design. As was stated in a preceding quote; “…I think you need some kind of
special fabric also to make it work”. By dealing with the inconsistencies in the design
in this way, the students were able to retain what they perceived to be the core of the
design. A consequence of this strategy was that textile decisions went from having
a strong role in the design process (influencing other design decisions) to no longer
being a part of the design in a physical form. At this point, the students wanted to
find a material that was compatible with the rest of the design, i.e. a material that
influenced other decisions as little as possible. The designs were originally based
on the textile behaviour in the smaller scale, and so the new material specifications
generally described a material that, in a large scale, had properties similar to those of
the original small textile samples.

How this strategy influenced the type of textile design decisions that the students were
working with is illustrated in the figure below. Textile decisions were, in the beginning
of the process, made mainly through selecting textiles, and in some cases through
altering the material by collecting and working with small pieces of textile. After the
students realised the incompatibility of the material in the full scale with the rest of
the design, they changed their way of working with textiles, moving away from the
physical material and instead making their textile decisions through specification.
The type of textile design decision would have remained the same if the students
had instead chosen to stay with the material and change other design decisions to
accommodate the properties of the material.

The students’ experiences described in this category draw attention to how important
it is for a designer to be aware of and work with the behaviour of textiles, rather than
just the specific properties in one scale. The above discussion, while it describes how
these aspects come to influence the design and the design process, does not, however,
deal with how this issue should be handled so as to avoid this type of influence. It is not
possible to definitively state how these issues should be addressed in textile product
design processes based solely on this study, but the experiences that the students had
in dealing with this issue when designing textile products point to the divergence
phase being crucial; this is the phase where the misleading textile decisions first enter
the design process, and where a change in practice may therefore have an effect. For
a designer or design student learning to design textile products, a broader or more
nuanced exploration of potential textile decisions in the beginning of the process
could open up for an improved understanding of textile behaviour in relation to scale.
Looking at the properties of the material in several contexts could help the designer
to obtain a better understanding of the possibilities and limitations that they have to
work with, and thereby create a more reliable foundation of information and sketches
for the upcoming transformation and convergence phases.

During the observation, the full-scale prototypes were used as a means of illustrating
what the students considered to be finished designs. The influence that the properties
of the large-scale textiles had on the design was therefore seen as a problem.
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However, the combination of textile and scale could also be used as an opportunity, possibly as a means of redirecting the design process. Changing the scale of the material could be used as a tool for challenging and developing the design, e.g. in order to push a designer out of their accustomed form-language by adding an unpredictable element to the design process. During the observations, the students mainly worked with small samples and then used larger pieces of the fabric in their prototypes, but a change in scale, from large to small, could just as well influence the design in an interesting way.

2. Textile influence - CAD MODELLING

The visual appearance of a textile material can easily be placed as a surface on computer-generated models in CAD programs such as Alias and Maya from Autodesk (2014) and Rhino from Rhinoceros (2014) making it possible to sketch and design products that appear to be constructed of textile materials. It is a less common and more complicated process to incorporate textile properties in these design tools, and it is not certain that these programs are able to predict what effect the behaviour of the textile will have on the design. Textile materials with properties such as softness and elasticity are very different to the materiality of CAD programs, which have a stronger resemblance to hard and stable materials such as wood and metal. Designing textile products with this type of design tool therefore makes it difficult to consider how textile decisions may influence the form, expression, construction, etc. of a design. When designing primarily with this type of program, there is a risk that material and design will be incompatible when the design is constructed outside of the computer program. During the observation, the combination of textiles and CAD modelling was seen to influence the design and the process of designing with textiles:

DESIGN PROCESS

At the beginning of the design process, the designer explores a wide range of possible design decisions, including several different textile materials. One textile material catches the designer’s attention, and inspires the idea development. Initial ideas are explored by making fast sketches in a CAD program; to do this, the textile material is scanned and introduced into the computer generated model as a surface. In this part of the process, the selected fabric and the potential it offers become some of the central design decisions. The designer continues to develop and define the design by working in the CAD program. The ‘textile parts’ of the product become important for the construction and expression of the product. The properties of these areas are not considered by the designer, and instead the CAD model is used to define all aspects of the design, including the usage of the specific textile in the product. At the end of the project, a rendering is made to visualise the design. The image gives the appearance of a real product, built of real materials, but the unrealistic combination of form, construction, and material choice are revealed when the course teachers examine the image. The soft quality of the intended textile would create something completely different to what was seen in the rendering, most likely a design that is impossible
DESIGNING WITH TEXTILES

to construct in a physical form. The designer must either redesign the product to work with the properties of the material outside of the CAD program, or search for a material that can realise the expression and construction of the computer model.

QUOTES

In the following quote, the student describes the reason for their move away from the previously presented design; that it was impossible to create outside of the CAD program.

- I got so many problems with the details and the structure, because I was doing this completely in 3D except this, that I had done before. I don’t think so… it can’t be real. It can’t keep this structure actually in the reality. So I was dropping this idea.

In the quote that follows, a teacher and a student discuss a design that started with a textile rope. The design was developed in a CAD program but could not be made in reality; to solve the problem, the textile rope was replaced by a metal rod.

- Teacher: So you have actually translated it into something else. But it is still there in one way or the other, I think.
- Student: Yes, it has to be there, because stand-alone rope is not enough...

CONTEXT

With an increasing focus on computer-aided design processes, less attention can be given to the dialogue between abstract ideas and concrete aspects such as material properties (Moles, 1995). CAD programs can be used as an instrument for exploring the meeting of form, force, and material. However, they have become a medium in which materiality can be disregarded, and where the focus is primarily on geometry (Ahlquist & Menges, 2011). There are a few examples of research focused on how to incorporate materials, and specifically textile behaviour, into computer modelling, which highlight some of the challenges that come with using primarily CAD-based processes when designing with textiles. One challenge is related to the complicated and computer-intensive process required to introduce and use fabrics in CAD programs. Another comes from the diversity of the material group - 'textiles' is a wide field, ranging from very stable materials to loose netlike structures, and their influence on a design can therefore differ significantly. The effect of this heterogeneity is discussed in 'Modelling and 3D simulation of garment products', where the process of incorporating and working with textile behaviour in a CAD program required the testing of every new material and the creation of a unique modelling system for each fabric; a continuous or particle-system model incorporated in Lectra Modaris 3D-fit (Lectra, 2013), (Aileni et al., 2011).

There are risks associated with relying solely on this medium when designing textile products, such as the difficulty in accurately predicting the influence of a textile material on a design. Ahlquist and Menges suggest that modelled textile behaviour should be seen as providing basic, and not specific, material feedback, and should be used as a starting point, rather than the only solution, for linking CAD models and the physical environment (Ahlquist & Menges, 2011). "The study of the interrelation of textile composition and form performances demands a linkage between the computational design simulation, the materialization process and resulting form dynamics. In comparison to utilizing engineering-oriented tools, a design process based-upon the use of more efficient and abstract algorithms needs informing to register and translate necessary material properties. Such is a shift process where computational behaviour and material behaviour are iteratively informed through cyclical processes which make precise the computational process and the resulting material system." (Ahlquist & Menges, 2011, p.18-19)

DISCUSSION

In the category of experience termed 'Textile and CAD modelling', the students experienced the fact that a textile product is not fully designed until all design decisions are compatible with the properties of the textiles as they exist in reality, outside of the program. During the observation, this type of design process had three common features: Firstly, the design was mainly developed in a CAD program, and textile design decisions were subsequently reduced to include only visual surfaces. Secondly, the design was presented in the form of renderings that appeared to include materials. Thirdly, textile properties came to influence the design, but only after the design was taken out of the computer program. Designing textile products in this way meant that the students focused only on the textile surface when making important design decisions, and how the properties of the material and the rest of the design
were to be combined was never actively considered. The result of this way of working was an uncertainty as to how the behaviour of the material would work with the design. The physical properties of the material influence the design in some way, and this is revealed first when they meet in a prototype, or when the design is examined. This change in the design influences the design process, forcing the designer to go back and remake important design decisions.

The following figure (6) describes how textiles come into and influence other design choices in the divergence, transformation, and convergence phase of the design process. In the divergence phase, the students’ explorations of the design space included textiles. One material in particular was seen as an interesting possibility, and the student obtained a brief overview of possible properties, expressions, etc. by handling and examining a piece of that material. These experiences were, at the end of the divergence phase, brought into the next step of the process. In the transformation phase, the textile material was combined with other design decisions to create a direction for the design. The design direction was sketched and developed in a CAD program; as a result, only some parts of the material decision were incorporated into the design (e.g. just the expression of the surface, and not properties such as elasticity or softness). Several different applications for the textile material were explored before the final combination of design decisions was defined. In this process, the textile remains in the form of a surface on the computer model, regardless of what role the material may have in the construction of the product. In the convergence phase, the CAD program was used to develop and define the design. The design was built around the directional design decisions from the transformation phase, and the surface of the textile was therefore the only aspect of the material that could have influenced the development of the design. The properties of the textile material were not considered when making important design decisions. This influence was instead replaced by the boundaries and possibilities of the CAD program. The properties of the material entered the process when all decisions had been made, either when a prototype was created or when renderings were studied by a more experienced designer. What the designer thought was a finished design was now questioned by the full impact of the textile selections that had been made. The properties of the material influenced the design and, in some of the students’ processes, made the textile product impossible to achieve outside of the computer program.

To create a complete design, the properties of the textile must work with all other design decisions. To do this, the designer must go back and reformulate previous decisions so as to incorporate material properties in some form. The process can at this point take several directions. One is to go back to the initial explorations of the material made in the divergence phase and, based on these experiences, re-formulate the design direction (new transformation phase) and defining decisions (convergence). The alternative that the students in the observation chose, however, was to remove the original textile from the design, and instead specify and search for a new material. By handling the inconsistencies in the design in this way, the students hoped to retain the design created in the CAD model. In this situation, it was very likely that they would consider materials that resembled the materiality of the computer program rather than textile materials, thus moving the material choice away from textile materials and into other material areas. Textile decisions thus went from influencing the design through the surface of the material, to no longer being a part of the design.

How this strategy influenced the type of textile design decisions that the students worked with is illustrated in the figure below. Textile decisions were, at the beginning of the process, made mainly through selecting textiles, and in some cases through constructing a new textile by combining two existing materials. After the students realised the incompatibility of the material properties and the rest of the design, they changed their way of working with textiles. In a similar manner to the ‘Scale’ category, the students started to move away from the physical material, and instead made their textile decisions through specification. The type of textile design decision used would have remained the same if the students had instead chosen to stay with the textile and make changes in the design to accommodate the properties of the material.
DESIGNING WITH TEXTILES

A CAD 3D-program is used to develop the design direction. The surface of the textile material is incorporated into the program and becomes part of the design direction.

The design is built around the directional design decisions, and the design is therefore influenced by the surface of the textile.

A textile material enters the design process - it is one of many possible design decisions.

Will the design decisions work with the full textile properties?

The full textile material come into the design when the design is examined or when a prototype is made.

Figure 6. CAD-MODELLING
being actively considered. In the early phases of computer graphic representations, the
finished appearance of sketches were considered to be something that could influence
an inexperienced designer, and make them consider the design more finished than
it actually was (Myerson, 1997). This aspect of working with CAD programs could
perhaps be similarly misleading for a student learning to design textile products.

It is not possible to draw definitive conclusions regarding how to include CAD
modelling in the textile product design processes based solely on this observation
study. The students’ experiences instead bring attention to what was left out of the
design with this type of design process, and the risks that are associated with that way
of working. In the students’ processes, the transformation phase turned out to be a
crucial point; it is here that textile decisions are reduced to a surface and misleading
textile decisions first enter the process. The influence starts here, but the effect of this
way of working with textiles also influences decisions in the convergence phase. The
effort which the designer has made in the divergence phase to understand or even
create a new material has no real effect on the design if the surface of the material
is the only aspect that is worked with later in the process. For a designer or design
student who is learning to design textile products, an awareness of these issues and
the limitations of these programs in relation to textiles could be a good starting point.

Including material behaviour in the CAD-based design process by alternating between
CAD models and physical prototypes, as suggested by Ahlquist and Menges (2011), is
another interesting option. This could make it possible to reduce the distance between
material properties and decisions made in the CAD program by including physical
materials and material decisions in the transformation and convergence phases.

Although the challenges and risks that come with using only one aspect of the
material when designing and the full set of properties in the final product should not
be disregarded, this type of process could also provide interesting possibilities for
re-directing the design process. Just as was described in the ‘Scale’ category, this way
of working could be used as a tool for challenging and developing the design. The
research described in the context section of this category primarily deals with how best
to model and incorporate the behaviour of textile materials in the CAD-based design
process, but there are other examples where the opportunities presented by computer
modelling instead focus on other aspects of textiles. One comes from Felicia Davis of
the FAD Studio at MIT, who creates digital versions of knitted textiles by modelling
these structures in Rhino. Instead of trying to replicate the visual surface or behaviour
of the material, the focus is instead on how the yarn creates the structure. This is
modelled through a customised Rhino script code, which produces an interwoven
three-dimensional curve that is then modified to create knitted structures such as
rib-stitch, moss-stitch, etc. These models are then combined with non-textile materials
in a physical form through CNC printing, resulting in materials that differ significantly
from the original material and how it could be used (Desbiens, 2013). This unorthodox
combination of textile materials and CAD points to the many possibilities that could
result from exploring the combination of textiles and modelling, and that, through this
combination, it may be possible to design products which could not be created through
working only with physical materials.
3. Textile influence - MATERIAL RESEARCH

Good material research can help a designer to understand the materials they are designing with, their properties, and how they can be used in products. It can also give the designer an idea of which design decisions can be affected by material issues, and the consequences of making such decisions. Misinterpreted, simplified, overestimated, or partial material research can, conversely, misinform the designer of the potentials and limitations of the materials they are designing with. What may appear to be small details can, when working with textile materials, have a large impact on the behaviour of the materials and how they will work in a specific product. A lack of awareness of this sensitivity to detail and context can lead to incomplete or misguided material research. With an ill-informed perception of the textiles, it becomes difficult for a designer to fully consider how textile decisions will influence the form, expression, construction, etc. of their design. During the observation, the combination of textile and material research was seen to influence the process of designing with textiles in multiple ways.

DESIGN PROCESS

At the beginning of the design process, two designers explore a wide range of possible design decisions, including a number of textile materials. One textile material and its potential catches the first designer’s attention. In researching this material, the designer focuses on the possibilities of the textile, and does not fully consider its limitations or how it can be affected by the context in which it will be used. The potential that the designer finds in the material inspires the idea development. The textile becomes one of the main design decisions and, as a result, the understanding that the designer has of the material comes to influence the development of the design. Towards the end of the process, a full-scale prototype is made; here, the textile does not work in the way the designer had anticipated or intended. The properties of the material had been misunderstood and, as a result, the textile is unable to fulfil the requirements of the design. The second designer finds potential in a number of specific properties from a range of different textiles. The material research that follows is focused on specific properties, rather than the material they were found in or how they were created. The properties inspire the idea development, and the design direction that results from this process includes the aesthetic appearance of one material and the physical properties of several others. These properties continue into the design, and become some of the main features of the product. The design is presented through illustrations and a specification of the material properties that the designer needs to complete the product. Whether a combination of these properties can be found or created is not considered before presenting the design and, in the end, both of the designers have uncertainties in their designs. The two designers have two options: To search for or develop a new material that could fulfil the defined design, or to go deeper into the details of the materials, explore what is possible, and then adapt the design with these explorations in mind.

QUOTES

Here, the student explains that the design is to be used outdoors. The function of the product was inspired by the effect which the material for a blind had on light. The full properties of the material were not researched, and the fact that the chosen textile was unsuitable for outdoor use was overlooked; as a result, the textile material could not be used in the design.

- I would like to see it outdoors, hanging in like a garden in a tree, to really use the benefits of this material, because it is a blinder. It could be a really nice effect with the sunshine.

In the quote that follows, a teacher and a student discuss how the textile materials that were selected at the beginning of the process are likely to absorb sound well. The student had previously learned that textiles can be good sound absorbers and, without further research, had concluded that this specific textile could be used for that function. The design that was created with this material had sound-absorption as one of the main features, but it was not certain that this specific textile could create that effect.

- Student: It’s probably a great sound absorber.
- Teacher: Uhm...
- Student: I think it would be.

In the first quote that follows, a group of students describe some of the properties that they would like to have in their design. These desired properties are the result of a material research phase in which the group looked at a large number of different fabrics and found several properties which they thought had potential. In the second
 quote, the students describe how, later in the process, the group found another textile material which had the expression that they wanted for their design, but which did not have any of the other properties that they required. At the end of the process, the students presented a prototype which illustrated the visual expression of the product, but they did not select a specific textile that could realise the intended functionality, instead listing properties collected from a group of different textiles.

And then we had some different materials; we did a lot of material research because we wanted something that was able to fold the structure in, either by heating or just creasing. And then preferably something that would, to have something that would be waterproof and sustain water. So these were all different samples - some worked, and some didn’t at all.

- So what we like about this fabric also is that it has the transparent right transparency quality that we want. But now it’s a sun curtain from Almedahls, but it doesn’t sustain the water as good well as this.

CONTEXT

Material research can provide designers with an understanding of how material decisions can influence the product that they are designing. How material research is made differs significantly from process to process and from designer to designer. Van Kesteren (2008) relates a designer’s material research needs to how material decisions are connected with other design decisions in the design. The amount and type of material research undertaken in a design process is, from this perspective, guided by which design decisions can be influenced by material decisions and what one needs to take into consideration when designing. Designers work with different levels of detail in their material research at different times in the process. Beiter divides this into two types of information; “soft constraints”, which are used at the beginning of the design process, and “hard constraints”, which are used at the end of the process (Beiter et al., 1993 p. 54). Soft constraints are characterised by general information, e.g. finding out which materials are suitable and acquiring basic knowledge about these materials. Hard constraints come in when the design is being defined and developed towards a physical object, and entail increasingly specific and detailed information as the design develops (van Kesteren, 2008).

Small changes in the construction of the material or in the context in which the material will be used can affect the behaviour of a textile material; detailed and specific material information therefore becomes important input when designing with textiles. The importance of details is partly related to the fact that the performance of a textile is determined by a combination of a large number of variables. E.g., the behaviour and expression of a woven fabric is determined by factors such as which fibres are used, how the yarn is spun, which bindings construct the material, which machine it is made on, which after-treatments and coatings are used on the fabric, etc. (Wilson, 2011). Changing one variable changes the combination, and therefore possibly the behaviour of the textile. Due to the interconnected variables of textiles, it can be complicated to work with and research textile properties separately from the full material. Another complication comes from the fact that not all qualities can be changed or added to a textile material, or combined to create a new one. Textile properties are intrinsically connected to the fibre or fibres that the material is created from. For example, the properties of cotton fibre that create a textile which is nice to touch and is comfortable to have on the body make it impossible for such a fabric to have the same light- and mould-resistance that synthetic fibres such as polyester have (Wilson, 2011). It is important for designers to be aware of the limitations and possibilities that come from the specific textile fibres, and to keep in mind that not all properties, functions, etc. can be combined in, or added to, any textile material.
DISCUSSION

In this category, the students came to experience the effects of partial or misleading material research when designing textile products. The material research, which was mainly done at the beginning of the process, provided the students with an unreliable foundation for the design, and was not updated by more specific research later in the process. A limited understanding of a material can come in several forms, but in this specific observation it manifested itself in three ways: in the first example, the material research created a general overview of the material, but did not provide details or specific information. With this type of material research, the student risked leaving out relevant information, e.g. by only researching the potentials and ignoring the boundaries of the material. In the second example, the material research led the designer to an overestimated or incomplete view of the material. Here, the students thought that the material could do more, or behave differently, than it does in reality, and therefore risked basing design decisions on incorrect information. In the third example, the material research was focused on textile properties, rather than complete textile materials; thus, the students looked at a number of textile materials, and found interesting potential in a few properties from these materials. The materials that these properties were found in, in what context they could be used, and how they are created was not part of the investigation and was therefore not considered when making design decisions. What the examples have in common is that the full consequences of the material decisions only entered the design when the product was regarded as finished and a physical prototype was made. The meeting between the full material and the rest of the design was therefore never actively considered when designing. This way of working creates an uncertainty in how the behaviour of the material can work with the rest of the design, and in some cases whether a suitable material could even be found or created. This uncertainty leads to high risks for unwanted changes in the design which, if they occurred, would influence the design process by forcing the students to go back to the process and re-make important design decisions in order to complete the design. The following illustrations and text describes how textiles and material research comes into and influences other design choices in the divergence, transformation, and convergence phase of the design process (figure 7 and 8).

In the divergence phase, the students’ explorations of the design space include researching textile materials. The research provides them with a limited understanding of the possibilities and limitations of the material. In the first illustration, the material research is performed through partially investigating one textile; in the second, it is achieved through looking at textile properties which are found in a number of different textiles. This limited understanding of the materials is brought into the next step of the process, and becomes part of the foundation for the upcoming idea development. In the transformation phase, a number of design decisions are combined to create a direction for the design. The designer’s understanding of materials is based on the previous research, which becomes part of the design direction. In the first illustration, the designer’s understanding of one textile becomes one of the main elements of the design; in the second, the designer’s understanding of a number of textile properties, found in several different textiles, become part of the design direction. In this process, textile properties are worked with in the same way as other ideas and possible design decisions, in that the design student freely combines and adjusts them, adding them to and removing them from the design direction until they are satisfied with the combination.

The design is gradually developed and defined during the convergence phase. The design direction, including the limited understanding of textile materials and their properties, is the basis for this development. Design decisions that are related to material issues are consequently based on an incomplete picture of the textiles in question, rather than the specific behaviour of the material. The decisions that are based on incomplete material research meet the full material behaviour at the end of the convergence phase, i.e. when a prototype is made. What the designer believes to be finished designs are questioned by the so far unconsidered properties of the textile. In the case where the designer works with an existing textile material, the end result is a design in which it is uncertain how the full material will influence the design. In the case where properties were the main textile input, the result is a design and a material specification. The design may appear to be finished but, due to the insufficient material research, it is unclear whether an appropriate material can be found or created based on this specification.

To create a complete design, all design decisions need to be compatible with the full consequences of all material decisions. Incompatibilities or uncertainties between the design and the materials can be handled by removing the original textile and searching for a material that fits the current design, or by going back to the material and acquiring a better understanding of its behaviour. In the design processes that were studied, the latter strategy was most common in this category. The students could just as well have chosen the first strategy, but they chose to continue with the material they had chosen because they felt that it played a significant role in the design. In the process described in the first illustration, the students lacked the relevant material information needed to reformulate their design and, as a result, needed to go back to
### Designing with Textiles

#### Possible Textile Decisions
A textile material enters the design process. Material research provides the designer with a limited understanding of the textile.

#### Directional Textile Decisions
The textile material, or specifically the designer’s limited understanding of the material, becomes part of the design direction.

#### Defining Decisions
The design is built around the directional design decisions - the design is influenced by the designer’s limited understanding of the textile.

#### Examining the Design
The full textile material comes into the design when the design is examined or when a prototype is made. Will the design decisions work with the full textile material?

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**Figure 7: Material Research 1**
Several textile materials enter the design process. The designer finds and researches properties in them that they believe have potential and could become part of the design.

**POSSIBLE TEXTILE DECISIONS**

Several properties, and specifically the designer’s understanding of them, become part of the design direction.

**DIRECTIONAL TEXTILE DECISIONS**

The design is built around the directional design decisions - the design is influenced by the designer’s understanding of the selected textile properties.

**DEFINING DECISIONS**

If a suitable material can be found, how will the full properties of this material work with the design?

**MATERIAL SPECIFICATION**

The design is presented with a material specification. Can a material that fulfill these requirements be found or created?
the divergence phase and improve their understanding with more specific knowledge; only after acquiring this information, then, could they adapt their designs. The new information generally resulted in a simplified or scaled down design, due to fact that the textile properties had originally been misunderstood or overestimated. In the process described in the second illustration, the first cycle of the design process ended with an uncertain design and a material specification. During the observation, the students had no time left to take the design further, but said that they would like to continue by searching for a material that matched the specification or developing a new one. In this hypothetical continuation, the material that the students found or constructed would have contained properties that the designer had not considered when originally creating the design. This scenario would therefore most likely require a new divergence phase, in which the designer re-familiarises themselves with the behaviour of the material, followed by new transformation and convergence phases in which they adapt the design in line with the specific properties of the full material.

In this category, material issues enter the design process through some form of insufficient material research in the divergence phase; thus, the design decisions based on that work are present in the design direction and, as a result, influence the design throughout the rest of the process. To create a design in which material properties and the rest of the design can come together, the design students needed to gain a better understanding of the behaviour of the material in that specific context. In the students' processes, this took the form of moving away from specifying abstract properties, and towards dealing with real materials; in other words, moving from general to specific. The influence over the material of the textile remained the same but, through more specific material research, the textile was able to gradually influence the design in a more relevant way.

The form of textile design decisions that the students made differ between the two types of processes that have been discussed in this category. Textile design decisions were, in the process described in the first illustration, made in the form of material selection. This way of making material decisions remained constant, even when uncertainties were revealed. In the type of design process described in the second illustration, the students worked with properties, which were combined to create a material specification. To complete the design, the students changed the form of the textile design decisions they were working with, from specification to selecting an existing material, or constructing a new textile material.

The preceding text describes how different forms of limited material research can provide the designer with an unreliable foundation for the design process, and how this in turn can affect both the design and the design process. However, it does not discuss how material research could or should be approached so as to avoid uncertainty or incompatibility in the design. The experiences of the students in dealing with this issue point to the divergence phase being crucial; here, the misleading textile information first enters the design process, and, moreover, a change in practice could have an effect. The students’ material research provided them with a general understanding of the textiles they were working with. This information, which was acquired in the beginning of the design process, was used as the main material input, and was not added to or corrected before the main design proposal was presented. This type of general information can be a good tool for idea development, but if the designer never incorporates the specific aspects of the textiles, it can be difficult to create a balance between material and other design decisions.

The students’ experiences draw attention to the importance of performing relevant material research when designing textile products. Being aware of the need for not only general, but also specific, material research, as well as reflecting on what information influences important design decisions, and at which stage in the process this occurs, could be useful for students who are learning to design with textiles. In cases where students focus on material properties, this awareness becomes especially important, as this way of working makes it easy to overlook the fact that the design will at some point need to work with the full behaviour of a material, and not just some of its properties. Failure to do so opens up for the possibility that the students, as they did in this observation, focus only on potential, and ignore the limitations or the context required to create this potential. Specifying and creating new materials for a single product may not be an option for a student or designer working without the possibility for extensive R&D with textile suppliers. Researching the boundaries of materials and maintaining an awareness of these when designing, rather than simply concluding a project with the material specification, can thus be an important experience when learning to design with textiles.
4. Textile influence - PHYSICAL MATERIAL

Designing with textiles can be a challenge for students who are learning to design products, or designers accustomed to working with hard materials. Soft properties and production techniques which differ from previous experiences are a part of this challenge. Predicting how a fabric will fall, bend, stretch, etc. can be difficult when sketching on paper or in CAD programs, and so textile materials can come to challenge students’ normal sketching techniques and design tools. One way to deal with these challenges is to incorporate physical materials and work in a more hands-on manner with them in the design process. Textiles work well with this strategy due to the properties of the materials, which make it easier to form, sketch, etc. The fact that the techniques used for sketching and making prototypes resemble those used to produce textile products (cutting, sewing, etc.) also opens up for designers and students being able to sketch and make full-scale prototypes, with the right materials and in the relevant scale and context.

DESIGN PROCESS

In the beginning of the process, the designer is uncertain as to what can be done with textiles and how to design with them, and thus explores a wide range of possible design decisions, including a few different textile materials. However, reading about the properties of the materials provides only part of the knowledge they need, and the designer therefore decides to use handling, testing, and experimenting with physical samples as the main method of exploring the boundaries and potential of the textiles. One textile swatch catches their attention, and the potential found in that material inspires the idea development. The designer begins to sketch and brainstorm, developing ideas of how to use the material and how it could be combined with other design decisions. In this part of the process, the designer feels limited by their normal sketching techniques and, to deal with this, they incorporate textile materials in the idea generation stage, e.g. by mixing discussions and paper sketches with small sketches in textiles. By working in this way, a basic direction for the design is formed, in which a textile material is one of the main elements. The designer gradually develops their designs based on the product idea, but is unsure as to how the behaviour of the material can affect the function, expression, construction, etc. The designer therefore decides to work with physical models and prototypes when defining the design, as they want to ensure that the materials and the rest of the design are compatible; they also decide to present their design as a full-scale prototype, using the selected textile materials.

QUOTES

In this quote, the student describes the fact that his group required more experience with textiles before they could start to design with the material. Their strategy for obtaining this was to work in a hands-on way with pieces of textiles through testing, making small prototypes, etc.

- Because I think for all of us, textiles is something new, we haven’t worked with it, so it’s best just to learn the material before we start to do stuff.

In the next quote, a student describes how the tools which her group normally would use did not work with textiles, and they therefore changed their design process and used more physical materials and small prototypes. The student also describes how the group was very happy with this strategy, because it created an interesting design and resulted in them learning more about textiles.

- And we think that it has been really interesting to use textiles in this way. For example, in the workshop we had with the triangles, we had to do a form and shape study in textile, instead of what we are used to, the most of us. Mainly, we are used to using clay and computer programs and things, so it was really interesting. And it gave us a new view of textiles.

In the final quote, the student describes how they learned about the properties of their textile through handling and testing pieces of the material. The properties that this group found through this process became some of the main features of their design.

- When we were playing with the Svensson textile, we discovered the advantages and disadvantages of the Svensson textile.

CONTEXT

Written information about materials can provide designers with a general understanding of material properties, but it does not inform the designer how the material will behave in each specific product, and how that can change over time. Basing design decisions solely on this type material information can therefore be problematic or challenging. Manzini suggests including testing, material experiments, etc. when researching materials, to complement information from other sources and to help the designer relate the materials to their specific context (Manzini, 1989).
Exploring material samples is a common strategy for incorporating physical material into the design process, and can play an important role in providing the designer with an understanding of what materials can add to the product which they are designing. According to a study on product designers’ information needs, conducted by van Kesteren (2008), product designers consider material samples to be an important source of material information. Designers mainly look for sensorial aspects such as colour, texture, and production possibilities, and attempt to gain an understanding of the material options they can find at different suppliers, when they study material samples. Different types of samples provide designers with different types of information, and the designers in van Kesteren’s study considered processed materials (those ready to be used in products), along with samples in which both materials and production techniques can be seen, to be the most useful, as they provide an understanding of how the material will work and look in a finished product.

Materials in a physical form play different roles in different parts of the design process. As previously described, they can be used as a source of material information, but can also play a more active role when designing. An illustrative example of how physical materials and samples are used in different ways at different stages of the design process can e.g. found in how the design agency IDEO use their sample collection ‘Tech Box’. Here, IDEO mainly use material and technical samples as a form of inspiration and basis for discussions when communicating with suppliers at the beginning of the process. By the middle of the process, materials are used in ideation in order to help trigger new ideas and solutions; at the end of the process, samples are used mainly when specifying which materials should be used in the final product, and testing so as to make sure that they are suitable (van Kesteren, 2008).

The relationship between the choice of material and production process is critical when designing products in hard materials. To emphasise this, Manzini describes the physical product as the meeting point between materials and production processes (Manzini, 1989). Methods used for sketching and techniques used for production can, in this type of product, differ from each other; e.g., when a design is created in a CAD program and the final product is produced by injection moulding. The difference between sketching techniques and production techniques, as well as the nature of the materials, can, when designing products in hard materials, make it difficult to sketch and make prototypes with the materials that will be used in the making of the final product. The flexibility and softness of textiles, and the production techniques used when making textile products, on the other hand, make the material used in the final product more accessible and easier to use in the design process. This opens up for including materials more when exploring the design space, creating and forming ideas, sketching, defining the design, and making prototypes. An example of a product design process in which physical samples of textiles played an important role is the development of the design can be found in a Master’s degree project in industrial design by Hedvig af Ekenstam at Konstfack, University College of Arts, Crafts and Design, entitled ‘Many design problems carry a textile solution’(2008). Here, af Ekenstam designed industrial design products such as a radiator and a vacuum cleaner using mainly soft textile materials. To accommodate the soft properties of the textile materials, she changed her working process, and engaged in a hands-on way with the material. The following quote from her report summarises her experiences of designing textile products; how textiles had a significant role, and how interacting with the material created new opportunities when designing: “With textile material you have to consider working with the hands and putting the computer on hold. To calculate the exact outcome in a 3D rendering is very hard due to the textile quality. You do not need any expensive tools when you come to model making it is possible to finalise an idea very far your self. This in it self bring many opportunities too try out ideas with a short time.” (Af Ekenstam, 2008, p. 5).

**DISCUSSION**

In the ‘Material Research’ category, the students described their unfamiliarity with textile materials and their uncertainty of how to work with them in a design process. To deal with these issues, some of the students concluded that they needed to adjust their working process, and choose to do this by incorporating more physical materials in their design process. The decision to do so was in some cases triggered by the material clashing with their usual design tools and ways of working; in others, it was related to the students not having a suitably thorough understanding of the material through only reading about it, and needing a more specific understanding of what the material could do and what could be created with it. The students in the observation incorporated samples and pieces of textiles in the divergence, transformation, and convergence phases, but material was not necessarily introduced in all three phases in the same process. The influence that this strategy had on the design and process depended on where and how it was incorporated. How this strategy was used in the three phases of the design process and how this influenced the design is described in the following illustration (figure 11) and text.
In the divergence phase, the students explored one or several textile materials; this was done mainly through touching and testing samples of the materials. This way of investigating materials provided the students with an understanding of not just the properties that the producer described, but also of how the textile behaves when it is handled, stretched, folded, etc. The properties that the students uncovered while working with the materials in several cases inspired them to explore non-textile options that they would not otherwise have considered. The students’ understanding of the material was, in the divergence phase, strongly influenced by their experiences of the physical material, and the outcome of that stage became part of the foundation for the upcoming idea development.

In the transformation phase, the students found it difficult to sketch and come up with ideas using their normal ways of working. To continue in their process, the students decided to use pieces of textiles in their idea generation process. The physical material was used to test, sketch, or illustrate ideas in a group. The potential that the students found in the material became a starting point for discussions on possible functions, etc. This process led to the formation of a design direction, in which the textile that was used in idea development also became one of the main ideas.

The design direction was developed further, and gradually became a defined product in the convergence phase. Textile materials were present in the design direction, and therefore needed to work with all other decisions made later in the process. The students in some groups questioned how this could be achieved using their normal methods, and therefore decided to work more with physical material when defining the design. This was done through working with models and prototypes in the intended materials, or mixing other design tools with testing part of the design in the material. Design decisions in the convergence phase are, in this type of process, related to both the prior experience which the students had with the material, and the behaviour of the physical material which they used in the development. The end result is a design presented in a prototype using textile materials, or possibly through digital visualisations, where material decisions or solutions are shown in a physical form. Whether the design is finished at this point or needs further development depends on how well material decisions are connected to the rest of the design, and how the materials used in the process relate to the material that will be used in the future product.

This category differs from the previous categories in the way in which it describes the students’ approach to preventing problems, rather than dealing with them as they occurred when the material and the rest of the design did not function together. In this category, the students worked with selecting or altering existing materials, and their way of working with textile decisions remained constant during the process. One explanation for this stability could be that the students incorporated materials to a greater extent when making their design decisions, and therefore had fewer problems when the rest of the design met the material in the final design. As there were fewer problems, they had less reason to make changes in the type of textile design decisions they were working with.

In this category, the students realised that the materials they were working with would most likely influence their design, but were unsure how this would occur. To increase the probability of designing a product that would work with the materials in which they were interested, the students decided to work more actively with physical materials, which were used in many different ways in all three phases. The common denominator was that this gave the textile material more influence over the design, and made it easier for the students to relate other design decisions to the material in the process. In this category, textile materials and textile design decisions influenced the design in two ways: Firstly, by being one of the important design decisions throughout the process; secondly, as a tool in the design process, where the physical form, properties, expression, etc. of the textile entered and influenced the students’ perception of the material, how and in what direction the sketches and ideas could develop, and how the final design could be defined.

The design process becomes less complicated if the material used in the process is relevant to the product that is being designed. Which textile the designer uses, and in what way it is used, determines whether or not the influence that the material has on the design is constructive. Working with textile materials rather than sketching without textiles can bring a designer part of the way, but working specifically with the textile that will be used in the final product can, as the experiences of the students
DESIGNING WITH TEXTILES

The textile material becomes part of the design direction. Samples of the material are used as sketching materials when defining the design direction, thereby influencing its development.

The design is built around the directional design decisions, and is influenced by the previously selected textile. The same textile is used as a sketching material when defining the design, the textile’s properties and expression therefore also influence the final design.

The full textile material come into the design when the design is examined or when a prototype is made. Will the design decisions work with the full textile?

**POSSIBLE TEXTILE DECISIONS**
A textile material enters the design process and becomes one of many possible design decisions. Samples of the textile are used to explore the boundaries of the material.

**DIRECTIONAL TEXTILE DECISIONS**
The textile material becomes part of the design direction. Samples of the material are used as sketching materials when defining the design direction, thereby influencing its development.

**DEFINING DECISIONS**
The design is built around the directional design decisions, and is influenced by the previously selected textile. The same textile is used as a sketching material when defining the design, the textile’s properties and expression therefore also influence the final design.

Figure 11. PHYSICAL MATERIAL
in the observation illustrate, make it easier to tie all of the decisions together. Using a different textile, or working with the material in a different way than it will be used in the final product, can result in the types of problem that are described in the previous categories.

In this category, the students themselves saw discrepancies in their normal way of working and designing with textiles. They achieved solutions by incorporating physical material to a greater extent in their processes. In their final presentation, several students described how this strategy helped them in the design process, but also how it made them learn more about textile materials in general. It is not possible to make definite conclusions regarding this strategy based solely on this observation, but the students’ processes, as well as their comments, point to this being a good start for students who are learning to design with textiles, as the presence of textile material makes it easier for a design student to understand the material and work with textile decisions when designing.

5. Approach to textiles - DETAIL

Materials can be regarded and worked with as a minor detail of the design. Material decisions will, with this approach, be based on what can best realise more important aspects of the design, and material decisions thus become subordinate to others when designing. A designer working in this way will give material decisions little or no influence over the rest of the design, and decisions regarding materials will most likely be made late in the process, together with other details. Material design and material decisions can also be handed over to other professions, thereby leaving these choices out of the process completely. Textile producers often supply e.g. furniture companies with finished materials that have been designed for a general application. In this industry, numerous textile materials are produced and sold by the metre, ready to be used in products where their properties, expression, etc. work with what the product designer wants to create. Access to this great variety of textile options opens up for a way of working where textiles come into the process as a minor detail, and are regarded as something that can be selected late in the process. The soft and flexible properties, as well as the fast changes that can be made when sketching and making prototypes in textiles, also allow for the adjustment or substitution of materials late in the process. In the observation, this approach to textiles was seen to influence the process of designing with textiles and the role which textile design plays in the process.

DESIGN PROCESS

The designer starts the process from the brief; to design a textile product. For the designer, this means that textile materials will be used in the design, but which textiles they will use, and how they will become part of the product, are not in focus. At the beginning of the process, the designer explores a wide range of possible design decisions, including several different textile materials. The textile possibilities are considered briefly, but none of them are viewed as important. A number of ideas about what type of function the product could have, and the context that the product could be used in, are instead what hold the designer’s attention. Several cycles of defining and redefining the idea are mixed with fast sketching on paper and using computer programs. This development of the design direction is done without considering textiles, and the designer does not refer to materials when they describe the product that they are working with. When asked about materials, they say that textiles will be used in the product, but that they have not considered in what form. When the
designer defines the design, a number of textile areas are added to the product, and
the designer thinks of this part of the design as a textile surface, but does not have a
specific material in mind. The designer starts to think more actively about the textile
parts of the product when most of the other decisions have been made, and searches
for a material that could work with the rest of the design. An existing textile material
is selected, and the surface of this material is added to computer models. What can be
seen in these visualisations is what the designer considers to be the final design and
the result of the design process. If the textile that the designer selects or creates turns
out to conflict with the rest of the design, it will be removed from the design and a
search for a more suitable material take place.

QUOTES

In this quote, one of the teachers for the course advises a group of students regarding
the order in which they should make decisions so as to create a successful design; firstly
defining the form, then technical solutions, and finally materials and other details.

- … and you have to settle down for the shape. And the second one is the connecting part
And from that, if you have those two. There you have a system. And then you can
investigate which kind of material do we apply to that system. For example: felt or the other
one, semi-transparent, or colour, or whatever. That is an issue that, if you have the right
shape and the right connecting point, then you can add anything. And you have knitted
materials for stretching and so on. And it’s the last point is adding issues like adding pockets
and things like that. So I think it’s the system from the top, to the details.

In the quote that follows, a student describes the materials that they would like to
use in their design. The student has worked with textiles in the form of surfaces in a
CAD model, and the design is presented as computer renderings. The materials that
the student mentions were selected at the end of the process, based on materials that
were found in products that have some of the functions that the student would like his
design to have.

- The bottom is made out of polyester and Gore-Tex, with an inside of foam, made to resist
water and wind. The upper part is made the same way as sleeping bags, and can be
detached from the bottom part. The rack is made out of carbon fibre, with additional rubber
The idea is that I would like to make this in collaboration with a Swedish outdoor sleeping
bag manufacturer, like Fjällräven or Haglöffs. To have top quality in details and material.

CONTEXT

Before the Industrial Revolution, man-made objects were generally created by crafts-
men, who worked with each piece of unique material, adapting and using its specific
properties to construct their designs. The new methods of production that came with
the Industrial Revolution brought with it a separation of tasks; the designer no longer
produced their objects, which were instead created by a number of different people
with different skills, from homogenous and standardised materials. This development
created a distance between the person who was designing the object and the physical
material that it was to be made from (Manzini, 1989). The increasing complexity of
materials has also influenced the relationship that the designer has with the materials
in their products. The enormous range of alternative materials makes it more difficult
for a single designer to have an overview, fully consider their options, and select the
right materials. The designer who defines the shape, function, etc. of the product is
therefore often not the person who selects or designs the material. When working with
materials in this setting, knowing where and how to acquire relevant information on
any given material becomes more important than being specialised in a specific mate-
rial (Manzini, 1989).

A greater distance between the designer and the material can lead to material
decisions being viewed as details and having a low priority in the design process.
Oxman describes this way of approaching materials as “shape over matter” (Oxman,
2010a, p. 73). The main characteristic of this way of working with material decisions
is that materials are selected based on how well they can realise other, more important
design decisions, such as shape, function, etc. The following quote from designer
Philippe Stark in Ultra Materials (Beylerian & Dent, 2007) describes the way in which
he designs products, and how materials come into this process, which corresponds
to the detail approach: “I start by trying to understand what the human benefit is,
what impact the result will have on the lives of the people I love, on the people around
me. It’s above all choices about human values and then I look for the best materials
to express this goal and these ideas. […] I am completely open to using any type of
material as long as it’s coherent with the direction, the cost, and the technology the
project requires.” (Beylerian & Dent, 2007, p. 136)

Materials are through this approach selected or created based on what the designer
considers to be more important design decisions. Material selection is, according to
Ashby, about finding usable materials from a set of design requirements; in other
words, finding materials with properties that can create the desired design (Ashby &
Johnson, 2010). How a designer should go about finding a suitable material depends on what type of information the designer has been provided regarding the rest of the design (design requirements), and how delicate the choice is. For example, a systematic analysis and material databases can be used when the desired properties can be expressed as quantitative measurements, but looking at products with similar functions could be a better option if only qualitative and general definitions of the required properties are provided (Ashby & Johnson, 2010). With the enormous range of materials that are available to designers, several different materials can be considered to be suitable for the same product, and it thus becomes important to go through the potentials and limitations of the materials, and decide which materials in particular should be used (Manzini, 1989). How to select materials in this increasingly complex spectrum has become the focus of research in the field of industrial design. Studies have been conducted which focus on, e.g., how product designers make material choices (Karana et al., 2008), what type of information they need (van Kesteren, 2008), and how stakeholders such as clients, manufacturers, users, and designers influence the material selection process (Pedgley, 2009).

The approach in which material decisions are regarded as details can also be used when designing textile products. In relation to fashion design, Townsend terms this approach a “garment-led process”, in which the garment design is defined first and, based on these design decisions, fabrics that the designer believes can best create or enhance this design are created or selected. The fabric is thus what physically manifests the design, but is not the main priority for the designer when creating the garment (Townsend & Goulding, 2011). Another example of a textile product process in which textile choices are made based on other design requirements can be found in ‘A Three-Stage Design Process Applied to an Industry-University Textile Product Design Project’ (LaBat & Sokolowski, 1999); here, a textile-based athletic ankle brace was re-designed, with the designers focusing their attention on creating a stable and visually appealing construction. Based on these requirements, a number of different textile materials were tested, and a final material selected.

DISCUSSION

In this category of experience, the students considered materials, and specifically textiles, to be minor details of the design, and this perception influenced how and when textile decisions were made. The brief which the students received was to design a textile product; thus, they were aware from the beginning that their product would incorporate textile materials, but worked in a way that did not allow material factors to significantly influence the development of the design. Textile materials were a major part of the surface, construction, and visual expression of the product in the projects that used this approach, but this did not lead to their playing a major role in the development of the design. During the observation, this type of design process had two common features: Firstly, the design direction and the most important design choices were made independently of the choices regarding textiles and materials, which occurred at the end of the design process, when most other decisions were made. Moreover, they were selected or created based on what could best fulfil other design requirements. Secondly, the students decided to change their textile decisions when material decisions and other design decisions became incompatible.

For the students working with this type of process, textile materials were approached as an abstract idea until the end of the process, when the details were defined. In some processes, material choices were never defined by the students; these were not included in the design that was presented, and were seen as something that could be decided later, or handed over to someone else. How textile decisions were incorporated in the three phases of the design process, and how this influenced the design and the design process, is described in the following illustration and text.

As textiles are introduced in the design brief, they enter the design process in the divergence phase. Textile possibilities that arise during this phase are not actively explored, and no decisions or ideas regarding textiles are taken forward into the transformation phase. These possibilities could, depending on the design develops, come in as a minor decision when the design is being defined in the convergence phase. In the transformation phase, several ideas are combined to form a direction for the design. The students did not consider any textile decision in this part of the process, and this exclusion can be seen in the way in which the students described their product at this stage of the process, where textile ideas, solutions, choices, etc. are not mentioned; e.g. “the product is a swing where children can play”.

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No textile design decisions become part of the design direction.

The design is built around the directional design decisions, and is not influenced by textile decisions. Textile decisions are instead made when most of the design has been defined.

Textile materials are part of the brief, and therefore enter the design process, but textile materials or properties are not actively explored.

The selected or constructed textile materials come into the design when the design is examined or when a prototype is made. Will all the design decisions work with the textile material?

The designer searches for a material. The previously made design decisions and the material specification directs which materials the designer can consider. Can a suitable material be found? If so, how will that textile influence other design decisions?

To complete the design, the designer searches for a material. The previously made design decisions and the material specification direct which materials the designer can consider.

Figure 12. DETAIL
DESIGNING WITH TEXTILES

The design direction that is formed in the transformation phase becomes the foundation for the convergence phase, and influences all other design decisions. Textile decisions are not included in this, and are therefore not part of this influence. When most of the main elements of the design are defined, the designer starts to work more actively on what they consider to be minor details. This is the point at which material choices come in; textiles are selected, specified, or designed, based on the other design decisions.

During the observation, the students who worked with this type of process dealt with two forms of textile design decisions. Firstly, the selection of finished materials, in which textile design decisions are made by finding materials which suit the product. Secondly, specification, where the designer leaves the material decision open, and instead creates a specification based on other design decisions. When working with the textile as a minor detail of the design, it is, of course, also possible to work with alteration and construction, provided this does not influence the rest of the design and is based on the requirements from other design choices. If a designer decides to create a specification, it later becomes the base for a new divergence phase, in which the designer searches for and explores which textiles could realise their design. Finding or creating a material then causes a shift from specification to either selection, alteration, or construction.

<table>
<thead>
<tr>
<th>Construction</th>
<th>Alteration</th>
<th>Selection</th>
<th>Specification</th>
</tr>
</thead>
</table>

Figure 13

The textile decisions are, in this approach, viewed as a way to create or build the textile product, but are not given the power to change it. Problems can, in relation to this, occur in the meeting between the textile and the rest of the design and, as a result, this way of approaching textiles may lead to the type of problems described in categories 1-3. Designers working with this approach consider other aspects of the design to be more important, and they are therefore likely to change their material decisions if this type of incompatibility in the design occurs. This approach may work when designing or learning to design textile products in which the textile material is added as a surface, and is not a part of the construction of the product. It could also be used if the designer has experience with the materials in question, but could be a challenge for a student learning to design textile products, particularly if the material will be used in large areas or as a major part of the product’s construction. This approach makes it more difficult to work with more demanding or complicated textiles, since little or no adjustment to the design is made to suit the textile’s expression, physical properties, etc. This approach would therefore be unsuitable to combine with e.g. smart textiles, where new elements such as electronics, programming, etc. create new possibilities for products, but also impose limitations on how they can be applied (Nilsson et al., 2011a). Leaving material choices out of the design and collaborating with those with more knowledge or skills in relevant areas can be an option for students with little experience of designing with textiles, but this strategy is a poor approach to learning more about textiles and how they can be incorporated into products.
6. Approach to textiles - STARTING POINT

A material can be a designer's starting point when creating a product. The material can come in through the brief, when the designer is asked to use a specific material. A design process can also be based on a material that a designer thinks has potential and wants to use in some way in a design. In this type of design process, the material becomes the point of departure for the process, and possibly a source of inspiration, and the initial work is concerned with exploring the material and finding ways to use it or some of its properties. Any type of material can function as a starting point, and its properties, expression, etc. influence the designs that can be created and the experience of designing with them. When textile materials are selected as the starting point, the designer is provided with a general direction, but the flexible and adjustable nature of textiles keeps many options open. This is partly connected to the fact that the same material can be used in many different functions, contexts, etc.: e.g., the same textile may be used to create a garment, a piece of luggage, and a sound-absorbing element in interior design. The openness of the textile material as a starting point is also connected to the fact that the expression and properties of the material can, with the right techniques and tools, be adjusted and re-designed. The same piece of fabric can thus become more three-dimensional by pleating, it can be dyed or printed, and it can be cut with a laser or combined with other materials to create something very different to the original material. When working with textiles as a starting point, the material and its design sets the scene for the process, and its behaviour, expression, etc. influence how the design develops. In the observation, this approach was seen to influence the process of designing with textiles and the role that textile design plays in the process.

DESIGN PROCESS

The designer begins the process with the intention of using a specific textile material, and handles, researches, and tests the material in order to explore its potential and limitations. At this point, the focus is on the material itself, rather than what it may be used for, and the designer finds a number of properties especially interesting and decides to make a product which takes advantage of these aspects of the material. The designer continues the design process by focusing on how they can best make use of the potential of this material. The designer's understanding of the material is used as the foundation for idea generation, in which the properties of the material direct, inspire, and create associations that lead the designer forward. After the idea generation, the designer has a large number of possible design decisions to choose from, relating to everything from applications and functions to decoration. The designer selects and combines a number of these ideas, thereby creating a direction for the design in which the choice of material is an essential aspect. The rest of the design is gradually defined based on the choices made as part of the design direction, including the textile material. In the final development of the design, the textile material becomes an important part of the main function and expression of the product. The physical material meets the other design decisions when a full-scale prototype is made. If the design and the material cannot be combined, the designer must go back to the process to reformulate the design, regardless of whether or not this takes place, the decision to focus on the potential of the material remains at the core of the design.

QUOTES

In this quote, the student describes how she wants to use and base her design on felt. She has identified a number of qualities which she thinks are unique to this particular textile and wants to bring out in her design.

- So I decided to use, and make something with this material. Felt has so many unique characteristics that other cloths don't have, and one of them is different from many products; felt can be stripped, we can choose many thicknesses and strengths and colours... And I wanted to use this character for my product.

In the next quote, a student describes what she thinks is interesting with regard to a material that she and a group of students previously created by combining a textile and another material. She has created her own design based on the potential she found in this material, specifically its nice touch and malleable properties, which she thinks open up for interaction with the product.

- My interpretation of our materials are: flexible, irregular, and playful. As we see, our materials, itself doesn’t have a regular form or regular shape. And it can be bent into different irregular shapes and forms. So this cover is textile, so people are tempted to touch it and play with it. So my concept is to keep these characteristics to encourage people to interact with the material and with the product.
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Here, two students describe how they have used the first part of their design process to experiment freely with a combination of pleating and printing textiles, and that they, at this point, have not focused on how and where the potential they have found in these textile techniques could and should be used.

- So and we don’t know yet what we are going to do with it. The last weeks we just wanted to experiment and...
- So now, we have a structure that works, that’s a start, we don’t know what we will make out of the structure.

CONTEXT

This approach can be described as “material driven” or as “material first” (Oxman, 2010b p.81), and is characterised by the designer basing a design on a specific material or material possibility. In this type of process, the designer initially moves away from the overall perspective and questions dealing with functions, conceptual ideas, etc., and instead uses a microscopic perspective which focuses in on materials (Manzini, 1989). This way of working can be seen as the opposite to the “shape over matter” approach that is often employed when designing products in the industry today, where material decisions are the consequence of other design decisions (Oxman, 2010b, p. 81).

When working with this approach, materials and production techniques can enter into the design process through a brief provided by a client or other stakeholder, which specifies or suggests a particular material, type of material, or technique (Pedgley, 2009). In such a scenario, materials become part of the starting point for the design, but can be focused on to varying degrees during the design process, dependent on the importance placed on them in the brief. Materials can also come into the design process when a designer finds a particular material or technique inspiring and decides to base a new design on it. Hella Jongerius is an example of a designer who often uses materials as the starting point and inspiration for her designs: “The basis of my work is often materials rather ideas [...] Once I have the materials in hand I start bending, gluing, sewing, or experimenting with other techniques” (Quinn, 2010, p. 195). At the beginning of this type of design process, the outcome of the design is completely undefined, and the designer starts by exploring and experimenting with the material and then follows where these experiences take them. According to Beylerian and Dent, this way of working with materials is similar to the way in which some artists approach and use materials; creating a work by freely exploring and reacting to the experiences they have with the material (Beylerian & Dent, 2007).

The boundaries and possibilities that come with each material can, in this type of design process, have a strong influence on the type of product that may be designed with it. Textile materials, due to their flexible and adjustable nature, direct the designer, but they can also open up for many different applications and uses. The designer Stephen Burk is inspired by textiles and, in the following quote, describes how starting with a textile material provides him with a broad and open platform for his design process: “[A textile is] a material that seems to have infinite possibilities because of its ability to conform to shape, be joined, folded or overlapped” (Beylerian & Dent, 2007, p. 63). Textile materials are also used as the starting point and brief when textile furniture is developed at Paula Lenti. In this quote, Paula Lenti, the designer and founder of the company, describes how textile materials are defined at the beginning of some of their design processes and, from this, three-dimensional objects are created: “the approach starts from the material that I propose to the designer, asking them to design something that would fit this particular material” (Beylerian & Dent, 2007, p. 128).

Design processes that are based on or inspired by a specific textile are, according to Townsend and Goulding, quite common in the fashion industry, and are by them referred to as “textile-led” processes. The authors describe how decisions that are important to the design of a garment can be influenced by the different characteristics and properties of the fabric: “This initial 2D-approach can lead the fashion designer to shape a garment in accordance with the placement, direction or repeat structure of a design. Working with the textile as a catalyst can dictate issues such as length, width, fullness, grain, and overall style considerations, with cutting-edge qualities leading to new approaches to cut and construction” (Townsend & Goulding, 2011, p. 304).

Using materials as a starting point can open up for new solutions and innovations; this is sometimes termed “material-inspired innovation” (Fischmeister, 1989). Experiments with materials and techniques can lead to the creation of new applications and uses, and is therefore beneficial for both producers and users of the materials in question. Cross-utilisation, the exchange of materials and techniques between different areas (e.g. from architecture to product design or art), is one way of increasing the usage of a material and creating new solutions, and material libraries such as Material ConneXion (Material ConneXion, 2011) can play a part in this exchange of material
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possibilities (Beylerian & Dent, 2007). Finding new uses for materials can be simpler in small-scale designs, such as those of products or furniture, as opposed to large-scale permanent solutions in architecture. The smaller scale of products therefore opens up for experimental material applications to actually reach the market in the product design area (Beylerian & Dent, 2007).

It is important to first explore and understand the unique attributes that materials have to offer when they are used as the starting point for a design. It can, however, be challenging for the designer to understand, and for the supplier to communicate, the full potential of a material; Ashby suggests bringing these creators together in workshop settings to open up for new designs and overcome communication problems, as this would allow experienced designers and material scientists to work together and explore the potential of specific materials. Participants in workshops held by Ashby are given the following questions to help explore and discuss the potential in the materials in focus: "What is it? What processing possibilities and limits exist? What is its character? How does it behave? What are the competing materials? Where has it been used before? Where – from a technical viewpoint – might applications lie?" (Ashby & Johnson, 2010, p. 166).

DISCUSSION

The brief that the students were given was to design a textile product, and in this category they took this idea one step further and made a specific textile material or possibility the foundation and starting point for their designs. This category is characterised by the material being placed before other aspects of the design, which is related to the designers’ or students’ intention to use the material in the design, and to them putting time and effort into exploring the material. This leads to a design process in which other decisions are influenced by the designer’s experiences with the textile material; its properties, expression, etc., and the associations and ideas these experiences create.

Several students in the observation used this approach and worked with the same textile material as their starting point. Due to the fact that each person became interested in different aspects of the material, and let that aspect of the textile strongly influence the design, one textile came to result in a range of widely differing designs.

For example, one student was interested in the formability of the textile and the possibilities for interaction that this opened up for; another liked how the textile could be used to create large structures; a third was inspired by the shape that it created in one textile sketch, and built a product around that.

The students who worked with this approach started their process from the potential that they found in existing fabrics, materials that they had created by combining other materials, or textile techniques that can be applied to existing textiles. How textile decisions were incorporated into the three phases of the design process, and how this influenced the design and the design process, is described below.

The divergence phase starts with, and is strongly influenced by, a textile material or possibility. Here, the designer explores their design space; in this type of process, this is primarily the material and the potential that can be found in it. This part of the process is therefore about opening up the designer’s understanding of what the textile is; its boundaries and potential. The designer considers a number of possible design decisions that are related to the material, but does not work with how or in what way they should be used. In some of the students’ processes, this was a short phase which focused on learning about the material and handling it; in others, it was a longer phase, in which several aspects of the material possibility were explored through experiments and sketches. In the transformation phase, the first design direction is created, based on the experiences which the designer has had with the material. The potential that the designer has found in the material becomes the main element of the design direction, which at this point is to design a product that takes advantage of the potential of the material.

A new divergence phase starts, based on the first design direction; the designer opens up the design space, and explores how and in what way the potential of the material could be utilised. In this phase, the designer creates a number of different possible expressions, functions, and ideas for contexts that the material could be used in. The associations that the designer has with the properties of the material influences which ideas are created; e.g. the students who worked mainly with a reflective, metallic-looking textile, their ideas often related to using light, while those students who worked with stiff, stable, and paper-like textiles often came up with ideas that included folding and origami techniques.
The full textile material come into the design when the design is examined or when a prototype is made. Will the design decisions work with the full textile material?

Figure 14. STARTING POINT
A new design direction is created by selecting and combining the design decisions created in the second divergence phase. For the designer, the potential of the material is a crucial aspect of this direction. Several decisions are added to or removed from the design direction before it is defined; the fabric is, however, a constant and other decisions are, to a large extent, made based on how well the designer thinks they work with the material. The design direction becomes the foundation for the convergence phase, and influences all other design decisions. Textile decisions are an essential part of this direction, and are therefore part of this influence. The aspects of the material that the designer considers to be central to the design remain constant, but it is possible that other textile design decisions could be altered or added to the design in the convergence phase, depending on how important the designer considers them to be. In the case of the student who was working with felt, some of its properties became part of the design direction, but exactly which felt should be used, the colour, and whether it should have a printed pattern were seen as a detail and decided later in the process, based on other design decisions. At the end of the convergence phase, the full material meets the rest of the design. Even though material decisions in this type of process are an essential component, the problems described in categories 1-3 can still occur if the material and other design decision prove to be incompatible or create a design that does not fulfil the designer’s expectations. Whether the design and the rest of the material can meet depends on how well the material input in the design process represents the material input in the final product.

If it so happens that the design and the material do not create the intended design, the designer must go back in the process. A design that results from this type of process is to a high degree connected to the material that was the starting point, and it is therefore unlikely that the material would be changed; the material is, from the start, a fixed part of the design, and in a situation where other ideas, solutions, etc. clash with the material, the material will likely be prioritised. Alteration to the material and other minor adjustment can be made, but what the designer perceives to be the core of the material will remain intact in the design.

In the observation, the students who worked with this type of process dealt with all four forms of textile design decision. The starting point was generally a selected material, but in some cases the students worked with altering or constructing their own materials or material specification. The form of textile design decision remained the same throughout the process, or was changed to alteration, when the original material was changed slightly to work better with the rest of the design, e.g. by changing the colour or surface pattern of the material.

The designer’s intention to use a specific material in their design is a crucial element of this type of design process, and influences which designs can be created, as well as the role that the material plays in the process. This approach allows textile materials and textile design decisions to strongly influence the design, particularly as compared to the previous category, in which material issues are given low priority. Textile materials and the experiences that the designer has with the material enter into and influence the design in several ways in this type of process: First, as the basis for exploration of what it is and can do. Here, the designer’s understanding of the material becomes the foundation for idea generation, related to what the product should be. The material influence also plays an important role in the transformation phase, where it becomes a leading decision in the design direction. It also steers the development of the rest of the design, as well as all of the other design decisions that are made during the convergence phase. Rather than being a detail that is selected or designed to suit the requirements of other decisions, the textile and its expression, properties, etc. lead the design. From a textile design perspective, this type of approach to material is especially interesting, as the choices that the textile designer makes regarding texture, colour, stretch, etc. have a significant impact on the product that is created. The design decisions that the textile designer makes set the scene for the design process.

In this observation, the material-driven approach was quite common among the students; this is probably related to the nature of the task, and the material-centred group workshop that the students participated in at the beginning of the course. This approach to textiles has both advantages and challenges when learning to design textile products. Working with this type of open-ended design process and using textiles as a starting point was challenging for some students; several mentioned this in their final presentation, where they described how this way of working differed from their normal design process, and that they found it difficult to base a design on a material and not a function, user need, or other idea. One group also mentioned that they had problems starting their process from a piece of textile material on its own, and needed something more in order to begin the process, such as examples of how this material
had been used by others or information about techniques that could be used to turn
the material into a product. It is not possible to make conclusions based only on this
observation, but the experiences of the students in this category illustrate how this
approach resulted in them actively working with the material and thereby having the
chance to test how it works and relate other design decision to textile issues. This way
of working is, of course, not suitable for all projects, but can be a useful experience,
especially if this way of working differs from the students’ previous experiences of
dealing with materials when designing.

7. Approach to textiles - DIALOGUE

Material design can be part of a product design process, and influence the development
of the design through a form of dialogue with other aspects of the design. In this type
of design process, ideas regarding function, context, overall expression, and material
design decisions such as colour, texture, and stretch, adapt to and influence each other
as the design develops. The dialogue is about two aspects; the designer gradually
obtaining a better understanding of the material boundaries and adapting other design
decisions to it, and the development of the material design in relation to other design
decisions and other possibilities that arise during this process. When designing textile
products, the material can be designed in innumerable ways, from working with the
fibre to adjusting the colour or adding a print to an otherwise finished material. This
range of material design options opens up many possibilities for creating interesting
textile products, but also for material design to enter into the product design process in
an active way. During the observation, the dialogue between textile and other design
decisions was seen to influence the process of designing with textiles and the role
which textile design plays in the process.

DESIGN PROCESS

At the beginning of the process, the designer explores a wide range of possible design
decisions, including several different textile materials. The designer gets a general
understanding of the materials they are considering by reading about their properties
and experimenting with samples. One textile material and the potential the designer
finds in it inspire one of the main functions and ideas for the visual expression of
the product; an idea for the design is formed around these decisions and the textile
material. Based on this design direction, the designer gradually defines the design.
During this process, they realise that the material does not work in the way they had
anticipated, and cannot be used to realise the design they had intended. In order to
obtain more specific knowledge of how the material can be used, the designer returns
to material research and exploration. The designer adjusts the idea in line with the
new understanding of the material and, in doing so, several new design decisions
are incorporated while others are removed. Based on this new design direction, the
designer again defines the design and the details of the material. The development
of the material gives the designer new ideas regarding some of the other features of
the product, and they return to the design direction to make changes to it so as to
make these new ideas possible. The changes they make in turn influence some of the previously made material decisions, requiring a new look at the material design. The design process continues in this way, alternating between exploring and designing the material, and redefining the design direction and other design decisions until a final direction is created and the designer defines the design based on their final design direction. Part of this work involves defining the aspects of the material that the designer considers to be details in relation to the design. At the end of the process, the final design is presented in the form of a prototype, which uses the designed material or visualisations and samples of the material. If the design and material do not work together, the designer will be forced to go back in the process to reformulate their design, including the design of the textile.

QUOTES

This quote is from a student who designed a knitted material for her product. The fabric became the surface of the product, but also played a major role in its function. She describes the reasoning behind the design of the fabric, i.e. how material decisions, such as the visual appearance and construction of the textile, relate to the overall concept and inspiration for the design.

- I wanted to make this random feeling as the graphic of log and to make it more diverse and change the surface of this. And I go to Borås and use the tube knitting to make more details, like the different feeling of the moss. And when it comes to choose the colour and the yarn, I feel that I want to give a feeling of the ‘storytelling’ - like, a tree is more like a chest, not real, and more storytelling. I like the imagery of like the trees in the… So I choose the blue one, and the moss maybe look a little bit the impression of the light and shiny and still… So, and then I end up with this, and I’m quite satisfied.

The next two quotes are from a group of students who based their design on the potential they found in combining shape memory wire and textiles, and a conceptual idea that they created earlier in the course. The students describe how they experimented with their material, and how the outcome became the basis for their subsequent idea development. The second quote describes an example of the group’s dialogue with the material in the process; here, they describe how they changed the size of the product to accommodate the properties of the material they wanted to use.

- We tried holding it right next to a bulb, light bulb, and that also works. And then you can also have an electric current run through the wire, to get the old shape back. So we decided to work with this. And we felt that it could really connect back to our old ideas.
- We wanted ...to have more bigger one, because we wanted to cut out a place for the lamp. Because of the limitations of the material, the memory metal, we decided to make a smaller model.

CONTEXT

Materials can be more than the physical matter that bring the product to life – it can constitute a significant part of the design problem (Doordan, 2003) and be an active participant in the dialogue that shapes the product. Before the Industrial Revolution and the introduction of standardised materials, a form of dialogue between materials and other design decisions was commonplace. Each piece of material was unique, and it was part of a craftsman’s skillset to adapt to its specific properties, as well as to use its unique potential to create their products. The direct interaction with the material not only provided the craftsmen with limitations in developing the design, but also impressions that could work as a form of creative stimuli. The changes in practice that came with the Industrial Revolution changed this dialogue, causing a disconnect between the material and the rest of the design. More recent material developments have also influenced the ways in which it is possible to work with materials in relation to products, albeit in a different direction. Material options have changed, from a few standardised materials, to a vast range of possibilities, and the opportunity now exists to create new materials for one’s designs, down to a microscopic level. This change has opened for product design processes that include material design, rather than just material selection. Manzini refers to this type of custom-made material as “made to order”, and emphasises how it is now possible to integrate material design in the design of the product, to the extent that the material does not exist in this specific form before the product has been manufactured (Manzini, 1989, pp. 37-38).

The design process and the interaction between different design decisions, such as materials, can be described as a form of dialogue or conversation. This view of the design process and the role of the material in it is influenced by Schön’s description of the design process as a “reflective conversation with the materials of a design situation” (Schön, 1992, p. 3). According to Schön, the design is developed through a dialogue between thought and actions. The designer makes decisions based on their
understanding of the situation, and the elements that are part of the situation, such as materials, ‘talk back’ and make the designer reconsider their way of creating or perceiving the design situation (Schön, 1992, 2003). Similarly, Mazé argues that the creative process with materials constitutes a form of collaboration, and describes the influence which material has in the formgiving process in this way: “Form is a result of a material’s own behaviours, interactions with other materials, and operations of a maker. Rather than imposition of a form on inert materials or material reality, this resembles something more like collaboration - active materials, in combination, through experimentation, in embodied practice, ‘find form’” (Mazé, 2007, p. 75). Bolt provides another example of a dialogue perspective, and suggests that we should move away from the predominant view of materials as something that should be mastered in the creative process to produce our designs or pieces of art. She argues for a way of working, which she refers to as “material thinking”, which is characterised by materials being an active and equal participant in the creative process. Bolt also stresses that, when working with materials, the outcome can never be known in advance. We may have previous experiences of that type of material, but every new design situation has new dynamics and, as a result, each process is unique - thus, the materials should be worked with this in mind (Bolt, 2007).

Textiles are often designed separately from the rest of the product, but they have the potential to play an active role in the design dialogue, informing other decisions and being themselves informed. Bang, in her Ph.D. thesis, worked with the textile producer Gabriel, who seeks a move away from piece goods and towards context- or product-specific textiles. In her research, Bang explores methods for including textile design decisions in the client’s furniture design process, and including context-specific input in the textile design process. This may involve e.g. presenting materials and material inspiration at the beginning of the product design process, when the client’s initial ideas are being formed, and incorporating input from several stages of the product designer’s process into the development of the materials (Bang, 2010). Textile material design can also be an active part of a design dialogue in the fashion design process. Townsend and Goulding describe this as a “simultaneous design” or “mixed fashion process”, which is characterised by the designer considering surface design and form to be equal and letting both influence and drive the design (Townsend & Goulding, 2011).

The opportunities that have accompanied digital production techniques open up for designers to work in dialogue with the material. An example of this can be found in Oxman’s research, which explores the potential of working with material design in 3D printed objects. She has been inspired by how material properties influence the development of form in nature, and has allowed the design, properties, and aesthetics of the material, together with the intended function, determine the shape and aesthetic of products. In her work, she uses the flexibility of the technique to create sections in the products with different properties (Oxman, 2010a). The ability to custom-make materials and create sections with different properties and expressions can also be found in several textile techniques, e.g. digital knitting machines, where different structures and materials can be produced, together with the shape of the product. These and other technical possibilities could open up for this form of dialogue between material and function being used when designing textile products.

DISCUSSION

Material design is in this category a substantial part of the design of the product, and textile design decisions played an active role in the students’ design process. This way of working can be described as a dialogue between the material and other important elements of the design, and it is the interaction between these elements that drives the process forward. The material and other important design decisions are re-framed and re-worked until a successful meeting between the material and the rest of the design is achieved. In the students’ processes, the re-framing of the design was achieved through alternating between the divergence, transformation, and convergence phases of the process. The direction of the design was mainly re-framed in the transformation phase, but the directions were influenced by new possibilities, information that the students acquired during the divergence phase, or the outcome of the convergence phase, when the students discovered the consequences of their previous design direction. How textile decisions were incorporated into the divergence, transformation, and convergence phases, and how this influenced the design and the design process, is described in the following illustration and text.

In the first divergence phase, the students explored a number of possible design decisions, including a number of textile materials, which provided the students with a general understanding of the materials that they were interested in. The students returned to the divergence phase several times during the process, i.e. when the
DESIGNING WITH TEXTILES

The final design include the design of a textile material. The full textile material come into the design when the design is examined or when a prototype is made. Will this textile material work with the design?

The designer returns to the transformation phase to reform the design direction in relation to input from divergence and convergence.

Textile decisions are constantly present in the design direction, but the exact decisions are reformulated as the design develops.

The final design is defined based on the design direction. This includes defining the textile decisions that are outside the design direction.

The consequences of the current design direction is tested by making more and more detailed decisions. The defining decisions are influenced by the textile decisions in the design direction.

The designer returns to the divergence phase to explore the boundaries of the textile material and find new possibilities for how it can be developed.

The first design direction is formed by combining the potential found in the textile material and a few other essential design decisions.

A textile material is one of many possible design decisions. The potential that the designer finds in the textile influences which other possible design decisions will be explored.

The full textile material come into the design when the design is examined or when a prototype is made.

Will this textile material work with the design?
The decisions that they had made in the transformation and convergence phases resulted in the need for new exploration and knowledge of the materials. The new explorations were mainly focused on gathering more specific information on the boundaries of the materials, or finding new solutions that could develop the materials further.

In the first transformation phase, the students combined a number of essential decisions, including a textile material and its possibilities to create a direction for the design. The ideas that the students had for the function, context, etc. of the product were influenced by their experiences and understanding of the material. New decisions and information brought about the need for the students to reform their design direction, and thus the development of the design direction was strongly influenced by the development during both the divergence and convergence phases. In the students’ process, new information or decisions regarding the textiles were two of the factors that influenced the design direction to the greatest extent. Textile materials or textile decisions were constantly present in some form in the design direction, but the exact decisions did not remain constant; instead, they were part of the dialogue, and were influenced and altered by other issues as the design developed.

The students entered the convergence phase several times during the design process. The decisions made in this phase were influenced by the current design direction, including the textile decisions. The aspects of the material design that were not part of the design direction were defined in the convergence phase, and had a varying degree of influence over other design decisions, depending on how important the students considered them to be. By making more and more detailed choices, the design students tested the consequences of their directional design decisions and, as a result, clashes between the material and the rest of the design were revealed in this phase. e.g. when a full-scale prototype was made. A clash can here force the designer to enter a new transformation phase to reformulate the direction, or enter a new divergence phase in order to get a better understanding of why the material and design were incompatible. The design that is presented at the end of the process contains a material design. If the design and the material turn out to be incompatible or do not create the intended design, the designer must go back in the process to complete the design. With this approach, the process would most likely continue with similar cycles, in which the material design and the rest of the design influence and adapt to each other. Whether the first step would become a new divergence or transformation phase would depend on the reason why the design did not work. The material design is quite probably still central to the design, and will most likely remain a part of the design direction in some form, but it is possible that the designer decides to adjust it to better suit the requirements of the rest of the design.

The students who worked with this type of process all worked with designing the textiles in some form, most frequently through the construction or alteration of existing textiles. For example, one textile was constructed through flat-knitting, another was constructed by combining existing materials, while a third was created by altering the surface of an existing textile. The students who worked in dialogue with the material were open to adjusting their materials if it was to the benefit of the product; they were, therefore, also open to changing the way in which they made textile design decisions if the design took them in that direction.

The students’ intention of designing the material in their product influenced what design they could create, but also the role that the material was able to play in their design process. Textile materials and design decisions entered into and influenced the design in several ways in this type of process. Its influence over the design was in some ways similar to the ‘Starting point’ category, in that textile decisions were present and influenced the exploration during the divergent phase, and then became a significant part of the design direction, in turn influencing all of the decisions made during the convergence phase. However, what is characteristic of this category is that the textile input that influences the design is not constant, that it can take the form of anything from new material research, experiments, ideas, sketches, etc., and that it influences the design direction and the designer’s perception of how it should develop throughout the process. An important point here is that not all textile design decisions and input have the same level of influence over the design. The design of the material consists of a large number of small decisions, some of which the designer considers to be important and some of which are perceived to be minor details in the design; thus, not all aspects of the textile will play an influential role in the dialogue.
DESIGNING WITH TEXTILES

Working with materials in dialogue when creating a product is very interesting from a textile perspective, since this approach can open up for new solutions, ideas, and expressions that best utilise the potential of textile materials and techniques. For example, this approach can open up for the use of more demanding textiles such as smart textiles, which can be difficult to use in products if the designer is not willing to adjust other decisions to accommodate the needs of the material. The diversity of textiles, and the variety in the way and degree to which a textile can be designed, also open up for material design being done inside the product design process. The designer or design student can, depending on their skills and the product they are designing, work with anything from designing the surface by adding a print, to constructing a new material through knitting or weaving.

This approach to textiles has both advantages and challenges when learning to design textile products. It allowed the students a chance to really work with textile design issues, and see how material design can be a part of a product design process, as the students who used this approach in their projects actively worked with the material and its boundaries, and obtained experience in relating other design decisions to textile issues. This approach can, when it is used in a relevant way, also help a student or designer avoid some of the problems that are described in categories 1-3, through them being more aware of the material and its boundaries. Students who are new to the material can find it challenging to design with textiles, and can therefore struggle if they are also expected to create a new material. The majority of the students that took part in the observation had little or no previous experience of working with textiles, and so the students who worked with this approach during the observation dealt with this by either working closely with textile technicians, or by collaborating with students who possessed more knowledge of textile techniques.

8. Approach to textiles - TOOL

Materials can, when designing products, be used as a tool or a form of creative stimuli. The materials that are used in this way will play an important role in the process, but will not necessarily have a place in the final product. The students in the observation who used this approach when designing textile products used textile materials in two main ways: Firstly, as a form of sketching and prototyping material, used to develop the form and construction of the product. Textile materials work well as a physical tool, partly due to their soft and flexible properties, which make it easy to form and sketch with them, as well as because the techniques used for sketching and making prototypes resemble the methods used to produce textile products; this opens up for materials being used throughout the process, from fast sketches to full-scale prototypes that illustrate the final design. Secondly, textile materials were also used as a form of creative stimulus, to aid in the exploration and development of ideas. The wide range of properties and expressions that can be found in textiles can be used by a designer to help trigger ideas and to take designs in new directions. With this approach, textiles are an important part of a designer’s process, but the specific textiles or textile decisions come and go, and are not considered to be an essential part of the design. During the observation, this approach was seen to influence the process of designing with textiles and the role which textile design plays in the process.

DESIGN PROCESS

The designer begins by exploring their design space, and a number of textile materials are part of this exploration. During this process, the designer becomes particularly interested in one textile material, which they decide to use in their design, and the properties of the textile introduce and trigger new ideas for the possible function and expression of the product. A design concept is developed based on the initial explorations, which include a textile material and the decisions that were inspired by the material. The designer continues their design process by exploring the design concept to obtain a better understanding of its potential. Part of the exploration is focused on the original textile material which they experimented with, e.g. by combining it with different textile techniques. The designer also works with other textile possibilities in order to further expand their options. The impressions and associations they obtain from working with these materials spark new ideas, and the designer comes up with a number of new functions and new contexts in which
the product could be used. A new design direction is formed based on the previous decisions and some of the ideas that came up during the exploration. Several of the original decisions are altered and others are taken out; e.g., the textile that played an important role in the creation of the first design concept is replaced by a material that works better with the new ideas. The designer decides to continue with the new design direction, but they find the main functions too limited, and decide to add some new features to the product. The designer goes through a collection of textile samples and comes up with a number of possibilities that could be realised by adding these materials to the design. The designer decides on two materials, which they add to their concept, and continues by working with the form and construction of the product. To define the shape, the designer sketches and builds prototypes in textiles, using some of the materials that have been a part of the design, but also other textile materials. The designer uses the fact that different textiles create very different forms and expressions in their sketching process to create many alternatives and develop the form of the product. Afterwards, the designer selects one of the textile sketches for their design, despite the fact that this particular sketch does not feature one of the previously used materials. They are happy with the elements of the design, and present it in the form of a prototype. The material in the prototype manifests the shape of the product, but not necessarily all of its intended functions; the exact textiles that are to be used to create the design have not been selected or constructed, and the design is instead presented with a list of material requirements.

QUOTES

In the following quotes, a student describes some of the ideas that they were working with in the middle of their design process. The material that the student describes in the first quote was selected because it could realise an idea that the group had previously worked with. The properties of the new material led them to ideas that focus on water resistance and related ideas for outdoor use, which are described in the second quote. The design later developed in a direction that made the group change the material in their design again.

- Ah, well we first started talking about... water and an outdoor structure. So maybe have it as a roof over a bus station or something. Or you could just have it as a marquee or an awning.

In the next quote, a student describes how textile materials came into their group’s design process. The students created a design idea based on the potential they found in one specific textile material; as the design developed, the material no longer worked with the design, and other material possibilities were considered.

- I think it has taken that turn now; first we were choosing a material and then finding something we could do with that material, and now maybe other possibilities opened up...

The three quotes below are taken from different stages of a student’s design process. In the first quote the student describes the material she works with and bases a number of important design decisions on. In the second, the student describes how she has started to use the material not only as a part of the design, but as a tool with which to sketch and define the shape of the product. In the third quote, the student describes her final idea, in which she has taken the visual appearance of the original textile and scaled it up. The original material can no longer be used in the design, and instead a stronger, non-textile material is needed to create the product.

- The material I want to play with, it’s a wire inside, and a kind of plastic monofilament outside, knitted probably. I choose this material because, when you have white environment colour, you can’t see the wire, the white wire inside. When you have black background, then you can’t see the black cover outside. To me, this is an interesting visual effect.

- So, this shape is what I like, and by simple repeating, the simplest solution, like just repeating this. I can’t... I just bend with my fingers, so I can’t do it exactly like a machine and the angles... I’m not an engineer, I can’t structure architecturally but now this is feeling... It’s a rough feeling I want.

- Well, I think I will just enlarge it. With the steel, like a kind of glass, it has some strong fibres, and then it could be quite strong, like you use to make huge sculptures, that kind of material inside. And outside I will probably use similar yarns, but thicker.

- Because this material is PVC coated, we managed to make the structure that I showed you before - and that lead us to the water aspect of it. It can actually protect you from water, in a way. And also, the structure makes it when you tilt it, the water moves, and you have a soft pattern.
context

Materials fabricate the designed object, but can also be used as tools by designers in their creative process. Materials that are used in this way can be described as a ‘medium’ or ‘design material’. These terms apply to anything from raw materials to digital design tools, and can essentially encompass all objects and techniques that are used to develop or visualise ideas when designing. What differentiates design materials/tools from other materials, however, is the designer’s intention to use the material in the process, but not necessarily in the final design (Mazé, 2007).

Design materials can be used for a number of different purposes, and the role that they play in the development of the design is connected to how the materials are worked with and at what phase in the process they are introduced. Materials can e.g. be a useful tool when visualising or communicating ideas in a creative process. The materiality of samples and prototypes engage our senses, and can make it easier to give rich descriptions of complex design concepts. Using materials in this way can be especially useful when designs are developed in collaboration with other designers or stakeholders (Jacucci & Wagner, 2007). Materials can also be used as a form of creative stimulus with which to develop or challenge ideas. Interacting with samples, images, or information related to materials can be used as a source of inspiration, to spark the initial ideas at the beginning of the design process (Ashby & Johnson, 2010).

However, physical materials or information about materials can also be used later in the process, to expand and re-direct the ideas that have already been formed. The wide range of properties and expressions that can be found in materials make it possible for designers to explore different perspectives on the same design. Louise Campbell is an example of a designer who interacts with and uses materials in this way: “I often find completely new directions to work by toying with materials without a specific purpose. This sandbox approach always provides inspiration, and the ideas seem to follow” (Beylerian & Dent, 2007, p. 66). The designer Hella Jongerius describes how she interacts with materials in a similar way: “Sometimes I’ll decide to bring in other materials into the process as well, and that can mean that the product moves in an unexpected direction. Responding and reacting to what a material can do gives the whole thing an element of spontaneity that I really like” (Beylerian & Dent, 2007, p. 99).

Jacucci and Wagner recommend alternating between different design materials in the creative process. They believe that the transition between representational formats can lead to important realisations and decisions for the designer (Jacucci & Wagner, 2007). New insights and interesting input can also be created by a process that they describe as “performing materiality”. This means that materials are taken out of context and transformed from one thing to another, e.g. by dissecting their properties, taking out details, or changing the scale (Jacucci & Wagner, 2007, p. 79). Schroepfer and Margolis have combined this way of working with access to collections of material samples, and have introduced the combination as a design tool for architecture students. The students interact with samples in 1:1 scale, and are encouraged not to think of them as possible material solutions, but instead to look freely at their properties and expression, in order to see anything from a detail to the structure of a whole building (Schroepfer & Margolis, 2006).

One interesting aspect of using textiles as a design materials/tools is that the flexibility of materials and production techniques makes it possible to use the same textile as both a tool in the design process and an element of the final product. Unlike design materials/tools such as CAD programs and modelling clay, textile materials are seldom intended to be a design material. One interesting example of textile materials that have been created with the purpose of functioning as tools in a creative process can be found in a project by the researchers Heimdal and Lenau (2010). Their work focuses on creating “physical inspirational tools”, which they hope can open up for new and creative uses of textiles in new products and contexts. To do this, they created a small collection of materials, which includes traditional textiles and samples that, through smart textile techniques, can react to their surroundings. These tools have been introduced in workshops at the beginning of the process, where they were used to start the design process and trigger ideas, as well as later in the process as possible material solutions for the participants’ design ideas. According to Heimdal and Lenau, the nature of the materials, as well as the stage in which they were introduced, influenced the type of ideas that emerged from the different processes. For example, more finished prototype samples resulted in more concrete and realistic design ideas, whereas simpler and less thoroughly designed samples created a wider spread of possible applications that were further from what is possible to produce at this time (Heimdal & Lenau, 2010). Another example of textile materials that are aimed at a design process rather than a specific product or application area can be found in the Smart Textiles Sample Collection at the Swedish School of Textiles in Borås. This collection has a similar intent as the inspirational tools; to spread information
and open up for the use of smart textiles. Here, this is done by creating samples and prototype materials that that make it easier for students and designers to access and explore smart textiles, as well as creating materials that can be used for prototypes and experiments among the researchers working in this field. (Nilsson et al., 2011b)

DISCUSSION

The students in this category designed products that incorporated textile materials; what characterised their approach was that they also incorporated textile materials as tools in their design process. This approach resembled the ‘Starting point’ and ‘Dialogue’ approaches in the way that the textile materials and textile decisions played a significant role in the development of the design. What differentiates this category, however, is the fact that the design students did not have a strong commitment to the textiles they were working with, and instead were open to entirely changing their material decisions if this would take the design in a more interesting direction. The students’ processes were not centred on one textile, and instead a large number of different textiles were used to develop the design, and several textiles entered and left the product as the design was developed.

The students in the observation used textiles as a tool in two ways: Firstly, as a sketching or prototype material when developing, defining, and visualising the design; secondly, as a creative stimulus with which to better understand or develop the design. Textiles can be used as a tool throughout the process, and examples of textile tools were found in the students’ divergence, transformation, and convergence phases. Exactly how and where textile materials were used as a tool differed from process to process. A summary of how textile materials came into and influenced the design as a tool is described in the following illustration and text.

In the divergence phase, the students used textile materials and information to explore their initial design space and create a number of possible design decisions, which formed the foundation for their upcoming design process; e.g., textile samples were used to trigger ideas and provide inspiration. The specific textiles that the students used in this part of the process not only became possible design decisions that continued into the transformation phase, but also created associations for the students that influenced the other ideas regarding function, context, etc. that they came up with. The students returned to the divergence phase one or several times during the design process. Textiles were here used as a way to provide new input and options for their design, and to challenge their existing ideas and design direction. This was achieved by experimenting with textile samples with different characteristics and properties in relation to their previous decisions, as well as by researching materials and testing new aspects of materials that it would be possible to incorporate into the design. Textile materials were used as sketching tools and for visualising and communicating ideas when forming the design direction in the transformation phase. The design direction was reformed several times throughout the process in relation to new developments in the design. In some cases, the design direction was altered to accommodate new textile possibilities from the divergence phase, or to deal with inconsistencies or undesirable design decisions that became apparent during the convergence phase. Textile design decisions were in some form part of the design direction throughout the process, but the exact decisions changed in relation to the development of the design.

In the convergence phase, the students defined the design based on the design direction. The decisions in the convergence phase were re-made each time a new design direction was created. During the observation, the students used a number of different textile materials to help them to define the design, and the materials were mainly used as sketching and visualisation tools. With this approach, a number of different textile properties and materials were added to and removed from the design, and the product designs that were presented at the end of the process generally contained decisions from several materials; the surface of one textile, the lightness of a second, and the pattern and colour of a third. To complete the design, the students needed to find a material that could fulfil all of their material requirements. In the students’ processes, neither the material used in the presentation prototype, nor any of the materials that they had experimented with in their processes proved to be suitable. The design process therefore generally ended with a design and a material specification. The meeting between the behaviour of the final material and the rest of the design had therefore not been fully considered. To complete the design, they had to go back and search for or create a textile material that would work with their design, and then find a way for this material and the rest of the design to meet.

Several forms of textile decisions were used by the students at the beginning of their design processes, e.g. material selection and material alteration. The form of textile design decisions changed to material specification towards the end of the process. This was the result of more and more textile materials and decisions being added to and removed from the design throughout the process, giving them all the chance to influence the design as tools. In the final design, no specific materials were chosen; instead, the material component of the design was defined as a set of requirements.
DESIGNING WITH TEXTILES

The design contains decisions from a number of textiles. The final design is therefore presented with a material specification. Can a material that fulfills these requirements be found or created? If a suitable material can be found, how will the full properties of this material work with the design?

POSSIBLE TEXTILE DECISIONS
A number of textiles are explored to better understand their potential as possible design decisions. Textiles are also used as tools when exploring the initial design space.

DIRECTIONAL TEXTILE DECISIONS
Textiles are used as tools when forming the first design direction. The potential found in one textile material becomes a major part of the first design direction.

POSSIBLE TEXTILE DECISIONS
Textiles are used as a sketching tool or creative stimuli with which to explore the design direction, to find new solutions, or question previous choices. New textile possibilities are found, and incorporated into the process.

DIRECTIONAL TEXTILE DECISIONS
Textiles are used as tools when forming the new design direction. The previously central textile material has in the new direction been replaced by another textile.

DEFINING DECISIONS
The design is built around the directional design decisions, and is influenced by previously selected textiles. Other textile decisions are also added to the design but, have less influence over other decisions. Several textiles are also used as sketching material when defining the design.

Figure 18. TOOL

The design contains decisions from a number of textiles. The final design is therefore presented with a material specification. Can a material that fulfills these requirements be found or created? If a suitable material can be found, how will the full properties of this material work with the design?
This approach is in several ways similar to the 'Dialogue' approach, in how material decisions and other ideas influence one another. The difference, however, is that, in the previous approach, the designer works with one type of textile, gradually becoming accustomed to it and working with its potential and boundaries. Conversely, in this approach the designer has no intention of keeping the materials; a textile that is a part of the design can, at any given moment, easily be replaced or developed in a new direction and, if there is a conflict between ideas and a material, the changing of the material is the likely outcome. The students who worked with this approach saw no added value in sticking with a specific material, and material aspects were not allowed to restrict the design if other decisions were considered to be more important.

This approach has several similarities to how some of the students worked with textile properties in the 'Material research' category. In both these approaches, the students can, due to a limited understanding or focus on the full properties of the material, end up working with only part of the material in relation to their products.

Textile materials and textile decisions are, in this type of process, part of the design direction and, as a result, will textile decisions strongly influence the design in some form. The properties, expression, etc. of the textile also influence the design when it comes into the process as a tool. The experiences that the designers have when handling the materials, and the associations that the properties of the material create, influence which ideas can be created and which design decisions can be made. The students' choice of textiles tools can therefore have a strong influence on the design, e.g. by the behaviour of the selected material determining which forms can be constructed when using it as a sketching tool. There is a risk that the material and the rest of the design doesn't create the design that the designer had intended, if it so happens that the material influence that is used to define the design does not match the material that will be used in the final product. The way in which the students worked with materials in this category meant that they never considered how the full behaviour of their final material would and should impact their design. Depending on how important the textile material is for their specific products, this way of working could create anything from an incompatible design to minor unexpected changes.

This approach for how to work with textiles can be both useful and problematic when learning to design with textiles. The students who used this approach incorporated materials as tools in several different ways, and this way of working helped them in their design process and provided them with options that they can use when designing textile products in the future. This approach also provided the students with the chance to experience and learn more about a large number of textile materials, but the numerous materials that were used in their processes also resulted in many of them not having the chance to really experience working with and adapting a design to the boundaries of textile materials, which can be an important experience when learning to design textile products.
CONCLUSION

There is no right way to design with textiles; each way of approaching and working with these soft and flexible materials brings its own opportunities, risks, and challenges to the design process. Thus, the objective of this article has not been to find ‘the right way’ of designing with textiles, but rather to broaden the perspective on what it means to design with textiles, and to highlight the diverse roles that textile materials and textile design can play when designing textile products. Thus, the main contribution of this article is the detailed descriptions of different ways of designing with textiles which, taken together, illustrate the diversity of experiences and approaches that can exist when designing with textiles. The examples that are presented herein also illustrate the strong influence that textile properties and expressions can have on the final design and the design process, as both a material in the future product and as a medium/tool for developing the design. The examples highlight how the behaviour of textiles influence not only what we can design, but also what we can do when designing. Nordy and Morrison introduced the term “design affordance” to describe and discuss technology such as RFID-tags in relation to the design process: “A design affordance may be defined as what the technology offers the designer in the activity of designing” (Nordby & Morrison, 2010, p. 82). This term, however, and the perspective it opens up for, can also be used to look at physical materials such as wood and textiles in relation to the design process; the design affordance of a material would then be the design activities that the material affords, the possibilities and activities that the material opens up for in relation to the design, and what it brings to the process of making it. The ways of designing with textiles that are presented in this article can, from this perspective, be seen as examples of textile design affordances, and how these can manifest in a design process. Thus, the students’ design processes exemplify some of the qualities of textiles in relation to the design process; the challenges and opportunities that come with designing with textiles, and how designing with textiles can differ from designing with harder and less flexible materials.

One of the most interesting aspects of textile design affordances is the open qualities of textiles in relation to the design process; the breadth of possibilities in terms of properties and expressions that can be created, the wide range of ways of designing with textiles that are possible, and the fact that textiles are not necessarily finished in their design when they take part in another design process, but are instead open for construction and alteration, and can be defined in relation to the future product. This openness can give designers freedom to work in many different ways; however, other textile characteristics, such as the importance of detail and context in relation to how a textile will work in a specific product, add considerations and limitations to what a design can do and how they can work in the process. Each way of working brings both possibilities and challenges, and to a designer of textile products, it is important not just what but how one designs with textiles. The examples presented above are the result of one observation study, and can therefore not give any definite answers regarding how to design with textiles. What they can do, however, is illustrate how the different ways of approaching textiles can give textile materials and textile design decisions more or less influence over the development of the design. Those projects in which the students gave the textile a great degree of influence over the development of the design (i.e. those which are discussed in ‘Starting point’ and ‘Dialogue’) often resulted in designs with more advanced textiles, and textiles that were designed in detail, specifically for that product. Conversely, those projects in which textiles were approached as minor details often resulted in conventional textile solutions, the selection of existing materials, or specification. The way in which the students approached textiles when designing thus opened up for more or less specialised textile solutions, at the same time placing higher or lower demands on the designers’ understanding of textiles, access to equipment, and production possibilities. Developments in the textile field, such as smart textiles, could thus influence how we design with textiles, as the flexibility of traditional textiles is altered when electronics, programming, etc. come into the picture, which mean that working with these textiles can require textiles to play a more influential role in the process in order to realise their full potential.

Different ways of approaching textiles also have their own possibilities and challenges in relation to learning to design textile products. Working with textiles as an abstract element or as a detail in the design can create interesting textile products, but it is not necessarily the best way to become familiar with textile materials and how to successfully design with them. Working in a hands-on manner with the material may not be the best solution for all design processes when the designer is experienced and has an advanced understanding of textiles; however, as several of the students suggested during the observation, however, it can be valuable for a design student, as it gives them the chance to learn how this type of material behaves and how best to use it in developing a design. This is clear in the ‘Physical material’ category, where the students altered their normal design processes and worked in a more hands-on way with the materials; at the end of their process, several of them described how this way of working not only helped them in their design process, but also improved their understanding of textiles.
Failure to consider the design affordances of the textile when designing textile products can, as several of the examples show, lead to discrepancies between textile decisions, properties, expression, etc., which influence the development of design during the design process and the decisions and material that influence the function, expression, etc. of the final product. Depending on how crucial the behaviour or expression of the textile is for that design, this discrepancy between product and process could create significant and unexpected changes to the design. In the students’ design processes, discrepancies often took the form of working with one form of textile influence during the design process, and another in the final design; e.g. working with small-scale textile pieces during the process, and larger pieces for the final design. An increased awareness of textile design affordances when designing textile products could help design students, as well as practicing designers, to prevent unexpected changes in the design, or open up for using this type of change as a design method, to re-direct and develop the design into something new. The following quote by Beylerian highlights the importance of the designer understanding their materials and design tools, as this influences what it is possible to design: “Materials are the core of the built environment: everything we touch and smell, and most of what we see and hear, is based on material of some kind. Design is the practice of making those materials into products and environments that, hopefully, meet the needs and desires of the consumer. If a practitioner is creating designs based on a limited knowledge of materials, the designs themselves will in turn be constrained. We all use tools to accomplish our work: some might use a computer while others use a pencil; many use both. It is the understanding of what each of those tools brings to a task that is ultimately important. Knowing what materials are available is knowing what tools are available.” (Beylerian & Dent, 2007, p. 17)

Not being familiar with textiles as a tool and as a material for products risks limiting what a designer can design. Textile materials and textile decisions influence the design and the design process; it is thus important for a designer to reflect and actively consider how to handle and use this influence in their textile product design practice in order not to limit their own efforts. This type of reflection is also relevant for design fields that work with textile products, and design educations that are connected to textile materials. The examples presented in this article could be used for this form of reflection, and hopefully add to our understanding of the considerations and possibilities that come with designing with textiles; thereby opening up for reflection on how textile design affordances/textile influence can be used and handled when designing textile products.

REFERENCES


DESIGNING WITH TEXTILES


Smart Textiles as Raw Materials for Design

Authors: Delia Dumitrescu, Linnéa Nilsson, Anna Persson, Linda Worbin

Abstract

Materials fabricate the designed artefact, but they can also play an important role in the design process; as a medium or method used to develop the design. Textiles can, with their soft and flexible properties, be easily transformed and altered in numerous ways; for example, by cutting, folding or printing on the material. This transformative character makes textiles interesting sketching media for surface explorations when designing artefacts. The development of transformable materials; for example, fusible yarns and colour changing pigments, have expanded these inherent transformative qualities of textiles and have opened up the design field of smart textiles. Accordingly, this new material context has created a new area for textile designers to explore, where it is possible to enhance and play with the alterable character of their textiles, and control their transformation through physical manipulation and programming. However, these expanded transformative properties also open up a new task for textile designers; to design "smart textiles as raw materials for design". By this term we mean, textiles that are not finished in their design but that can be developed and enhanced when they take part in a product or space design process.

In this article, we explore and start to define what smart textiles as raw materials for design can be, and look at how these materials can come into and add something to another design process. The foundation for this exploration is a number of textile examples from the “Smart Textiles sample collection” and our experiences when developing and designing with them. (The Smart Textiles sample collection is a range of textiles that is designed and produced by the Smart Textile Design Lab, to give students, designers and researchers direct access to different types of smart textiles). The possibilities and limitations of smart textiles as raw materials for design are explored by looking at the textile examples from two perspectives: firstly, by looking at the considerations that come with designing this type of textile design, and secondly by looking at what these transformative textiles can bring to another design.
process. Each example is analyzed and classified according to what transformable design variables for structure and surface change can be embedded in the textile design, and what design variables this subsequently creates for a design process that uses these materials i.e., describing what type of transformation different examples of smart textiles introduce to the design process/design space; whether the change is reversible or irreversible, and whether the change occurs through physical or through digital manipulation of the material.

This article ends with a discussion of how smart textiles in the form of raw materials for design could influence how we design textiles and how we design with textiles. Can transformative materials enrich material explorations in a design process? Can further development and alteration of the material design be introduced or defined by the textile designer? Could smart textiles as raw materials for design open up a stronger connection between the design of textiles and the design of the product or spaces where they will be used?

Keywords: smart textiles, design affordances, sketching methods for artefacts.

Textiles as design materials: inherent and smart qualities

Textiles can form shells for products, spaces, or the body, and can have either a structural or a non-structural function in artefacts. Alongside functional usage as covers, textile materials are also media which express decorative qualities; consequently, they define the aesthetic surface appearance of artefacts by offering a specific visual and tactile language for design (Albers, 2000). Subsequently, there are two perspectives that are of value in relation to the design of textile artefacts; one which considers surface appearance and the textile's visual expression, and another which focuses on the physical surface characteristics; for example, tactility, elasticity, and pliability. These basic design features are dependent on structural decisions, such as the construction techniques chosen, yarn quality, type of binding, and/or surface treatments; for example, printing, coating, and dyeing. These variables and techniques define the basic character of a textile, and thus define or suggest a desired expression or use in a specific context.

In terms of the character of the surface, textiles, with their soft and flexible

properties, can be easily transformed and altered in numerous ways; for example, by cutting, folding, or printing on the material. Pliability as a key material characteristic means that textiles can be used to define and/or enclose a three-dimensional shape; thus, they are used for sketching processes in fashion; for example, by draping or folding the material. Subsequently, the transformative character of textiles means that they are not simply materials to be applied to a specific product or context, but can also function as an interesting sketching medium for surface explorations when designing artefacts.

The development of transformable materials, such as fusible yarns and colour changing pigments, has enlarged the range of inherent transformative qualities of textiles, and has introduced the field of “smart textiles”. These are materials with dynamic properties, and are designed to sense and respond to environmental conditions or user stimuli (Addington & Schodek, 2005; Ritter, 2007). “Smartness” as a descriptor relates to a large category of materials, which have complex surface properties or are enhanced by digital technology. Consequently, the design of smart textiles combines traditional methods for textile fabrication with advanced technology, and so smart textiles have created a new area for textile designers to explore; one in which the ability of the designer to alter the characteristics of the textiles is enhanced, as this can be controlled by both physical manipulation and digital technology.

The transformable properties of smart textiles have been used to create innovative products, such as “Portable Light” by KVA (KVA, 2014) or “Skin: Dresses” and “Fractal: Living Jewellery” by Philips (Philips, 2014), where changes in the surface or structure of the material allow for new thinking regarding the uses of products or new ways of designing for environmental interactions. Alongside examples of product development, research programmes with a focus on the development of design methodology have explored different perspectives on smart textiles: “IT + Textiles” (Redström, Redström, & Mazé, 2005) examined the relationship between textile design and digital technologies as a means of integrating new textiles into our daily lives, while Buchley and her research group investigated the inherent characteristics of handcrafted textiles and sought to propose methods for expressing new technologies and computation through textiles (Qiu, Buchley, Baafi, & Dubow,
2013). Additionally, Worbin expanded this field with a new methodological framework, which outlines basic dynamic principles for textile design (Worbin, 2010). Through textile interaction design, Hallnäs and Redström connected textile aesthetics and technology and, in so doing, offered a new perspective on smart textiles based on interaction design methodology (Hallnäs & Redström, 2006). Consequently, they described the relationship between material function (what the textile does) and interaction (what one can do in relation to the textile) as one which is essential to consider when discussing new methods for the design of smart textiles (Hallnäs & Redström, 2008).

In a complementary manner to the previously mentioned explorations of smart textiles, our article and the research programme that it presents focus on the possibilities of smart textiles as explorative materials when designing, in terms of how the transformable qualities of traditional and smart textiles can be defined and used as sketching tools when creating artefacts. Accordingly, the perspective on textiles is here shifted, from materials with finished expressions to developable sketching mediums; at the same time, relating the design of textiles to research into interactive material-based sketching tools.

Interactive material-based sketching tools

Materials not only give form to the designed artefact, but can also play an active role in the design process, as an influential medium through which the design may be explored and expressed (Bolt, 2007). The emerging field of interactive sketching tools, which combine physical materials and digital design technologies, highlight and expand the possibilities that accompany working with materials in this way. The tools and other research performed in this field open up for design processes where materials may function as active partners when forming the design, and can assist in generating questions related to how we can interact with materials when designing, and how the more or less designed properties of materials influence this interaction.

When discussing the design of such complex design tools, it becomes of interest to examine the ways in which inherent material expressions and properties inform specific actions during the design process. Norman refers to "affordances as the perceived and actual properties of a thing, primarily those fundamental properties that determine just how the thing could possibly be used" (Norman, 1998, p. 9); thus, his theory relates the appearance of designed objects to the way they suggest a specific action. Moreover, Nordby and Morrison introduce the term "design affordances", that is, the affordances that materials introduce to form-making processes (Nordby & Morrison, 2010) and, in so doing, expand the concept of "affordances" by relating material properties to the design activities that the medium in question affords during a sketching process. Consequently, each material can also be regarded as a way of opening for not only a specific use in daily life, as is argued by Norman, but for ways of operating in a design space, thus shifting the perspective on to the designer as a user.

These new digital and physical sketching methods for designers facilitate an explorative use of materials; for example, through direct manipulation of the artefact in physical space, and enable multiple iterations in the early stages of the design process. "Skin Tool" is a project which provides sketching methods that allow ceramic artists to explore surface imagery in relation to three-dimensional shapes; this allows the user to project dynamic patterns and textures onto ceramic objects while simultaneously manipulating the material and shape in physical space, allowing greater control over the final surface expression of the artefact (Saakes & Stappers, 2009). "Illuminating Clay", "Relief", and "Bosu", are related examples of interactive and tangible design tools, wherein computational behaviour complements different materialities, such as clay, sand, and shape memory alloys. These tools not only illustrate a new way of sketching artefacts, based on the basic character of different materials, but also allow for the design of dynamic affordances (Ishii, Lakatos, Bonanni, & Labrune, 2012). Accordingly, such a methodological framework relates static and dynamic affordances, which is based on the basic and programmable character of material tools; thus, "facilitate", "restrict", and "manipulate" are criteria with which to design programmable behaviours (Follmer, Leithinger, Olwal, Hogge, & Ishii, 2013); these define multiple form iterations during the design process in relation to the interaction. Such sketching tools also suggest a shift in design thinking; away from the traditional use and expression of materials, and towards defining interaction forms during the design process. With regard to textiles as materials for design, then, the concept of sketching tools for designers is
one which requires exploration, as textiles, in the same way as clay, sand, or ceramics, afford and facilitate certain processes while, at the same time, being in and of themselves a design.

Exploring Smart Textiles as raw materials for design: a design program

Smart textiles can, as the examples discussed at the beginning of the article illustrate, be used to create interactive and transformable artefacts. However, we believe that combining smart textiles with the process of designing products, spaces, and so on, also opens up another application for these materials; as interactive design tools/media. This article and the design programme that it is based on focus on exploring this possibility, specifically in terms of how the transformational character of traditional and smart textiles can be used when sketching and developing designs. To do this, we created the concept of smart textiles as raw materials for design; by this term we mean textiles with an unfinished design, where the expression can be explored, developed, and enhanced when they are used in a design process. In this article, we explore the concept from two perspectives:

- Firstly, by looking at how to design textiles, which, as a result of their transformable qualities, allow for further development of their properties and expression.
- Secondly, by considering what these textiles can bring to other design processes; the actions in the sketching process that they, through their properties and expressions, influence and/or suggest.

The foundation for exploring these perspectives is a collection of smart and transformable textiles, which includes thermochromic printed fabrics and heat-reactive knits, along with our own experiences of developing, designing, and giving workshops with them. The samples come from the Smart Textile Sample Collection, and were originally designed to give students, professional designers, and researchers direct access to and hands on experience with smart textiles. The samples are not designed for a specific context or application, but are instead intended to function as examples that provide an understanding of the material, and may be further developed to suit a specific context or design. Some samples originate from textiles that were designed for a specific context in other research projects, as is the case with the knitted textiles produced for “Touching Loops” (Dumitrescu & Persson, 2011), other textiles were designed specifically for this collection (see Figure 1).

![Figure 1. Printed and knitted fabrics in the Smart Textile Sample Collection.](image)

To better understand the connection between textile design and the expressions and methods that textiles open up in a design process, we held a series of workshops in which designers and students worked with the different materials of the collection in relation to their own area of interest or current project. The first workshop was conducted with textile design students, and the second with a group of designers and researchers from various design backgrounds. The diversity of design backgrounds represented by the participants facilitated the exploration of the properties of the various textiles in relation to different types of sketching processes; for example, the textile design students worked primarily with structure and surface explorations, while other participants generally focused more on form-making processes and three dimensional prototypes.

Smart Textiles as raw materials for design: a methodological framework

In order to better understand and discuss the ways in which smart textiles as raw materials for design influence the sketching methods and design processes that they
are a part of, we created a methodological framework, and examples from the Smart Textile Sample Collection and workshops were used to develop and test its structure. For us, the key to understanding the connection between textile and process is to look closely at the transformation that takes place in the material, and the actions this opens up in a design process; this relationship is thus the focus of the framework.

Similar to the perspective on smart textiles in relation to textile interaction design methodology (Hallnäs & Redström, 2008), our framework is divided into two sections; one which defines the transformation of the textile (TEXTILE), and another that deals with what the designer does with the material (DESIGN PROCESS). Each section is divided into one part that looks at the transformation in its basic form, which is to say the material variables and possible actions in the process that define the main character of the transformation, and another part that looks at how the transformation is expressed, the specific changes that take place in the textile, and the design activities this opens up (see Figure 2).

**TEXTILE**
The form of transformation describes the changes embedded in the material as a result of the basic properties of the transformable materials; for example, thermochromic inks or melting yarns, and how these are incorporated into the textile. Basic textile variables define, whether the change in the textile is temporary or permanent, or whether the changes occur at a structural level or only on the surface.

The expression of the transformation describes the specific changes that the textile expression, through its design, allows for. This could, for example, be the addition or subtraction of colour from the original expression, or the changing of the expression or properties of the textile by shrinking or breaking.

**DESIGN PROCESS**
The form of use describes the basic actions in the design process that a textile allows for, which is to say the basic ways it can be experimented with in a design process. This could, for example, be whether the material can be manipulated by physically or digitally interacting with it, or whether what triggers the changes in the textile is defined in the material or not.

The expression of use describes the specific sketching methods that the textile opens up; these may include explorations of pattern designs and explorations of patterning in relation to three dimensional form.

We see this framework as a basic structure for discussions, which can be introduced when designing smart textiles as raw materials for design or in the initial stages of design processes where exploration of the meeting between material and shape are essential in defining the end product. The textile properties mentioned in the framework and the following examples are related to the materials that we have worked with so far, and should be seen as examples, rather than general variables, which can be applied to all smart materials explored in this context. Below, the framework is applied to four examples from the Smart Textile Sample Collection, illustrating the type of transformations that can be embedded in a smart textile when
Examples of smart textiles as raw materials for design

Raw print: thermochromic colour
This sample is a woven cotton fabric with grey thermochromic ink printed evenly over the whole surface. The ink becomes transparent at 32 degrees C, temporarily revealing the white colour of the base fabric.

Form of transformation: The properties of the ink create a temporary change in the surface, from grey to white, as the colour reverts to its initial state when the textile returns to ambient temperature. The area of transformation is not defined; it can take place throughout the fabric, as the entire surface is printed with thermochromic ink.

Expression of transformation: The expression of the surface can be temporarily redefined through subtraction of the grey colour from the original design. The new expressions that can be created are influenced by the heat sources used to create the colour changing effect, and can range from gradient effects to distinct forms created on the surface.

Form of use: The trigger of the transformation in the textile is not defined, as there is no conductive yarn or other trigger embedded in the textile. The textile allows for multiple forms of physical manipulation, as the surface can be transformed using any type of heat source, including warm water, a hair dryer, or a clothes iron. The temporary nature of the surface change allows for an exploratory design process in which multiple design possibilities can be created and considered.

Expression of use: The temporary colour changing effect embedded in the textile facilitates exploration of patterning by, for example, working with the visual organization of patterns, graphic forms, or gradient effects. The textile also suggests patterning in relation to form; exploring where and how a pattern should be placed, or testing pattern scale in relation to a three dimensional form (see Figure 3).

Raw print: thermochromic pattern

This sample is a woven cotton fabric, printed with a combination of thermochromic ink and pigment colour, in a halftone pattern consisting of lines and circles. The ink becomes transparent at 32 degrees C, temporarily revealing the pigment colour; in one version the change is from grey to blue and, in another, from red to blue.

Form of transformation: The properties of the ink create a temporary surface change, as the surface colour reverts to its initial grey or red state when the textile returns to ambient temperature. The area of transformation is defined by the arrangement of the pattern on the surface, as the colour changing effect only takes place in the areas of the textile that are printed with the pattern.

Expression of transformation: The expression of the surface pattern can be temporarily redefined through the addition of blue colour to the original design. The new expressions that can be explored are directly influenced by the heat sources used in the sketching process, and how these relate to the geometric forms in the initial pattern design. The character of the transformation is determined by the heat source used to create the transformation, and can encompass a vast spectrum of effects, from gradient colour changes to distinct blue forms added to the pattern.

Form of use: The trigger of the transformation in the textile is undefined, as there is no conductive yarn or other form of trigger embedded in the material. The textile allows for multiple forms of physical manipulation; the surface can be transformed using any type of heat source, including warm water, a hair dryer, or a clothes iron. The temporary nature of the surface change allows for an exploratory design process, in which multiple design possibilities (in relation to the surface pattern) can be created and considered.

Expression of use: The temporary colour changing effect embedded in the textile opens up re-patterning in the form of exploration and recomposition of the visual organization of the pattern, and re-patterning in relation to form, which is to say explorations of where and how different colours in the pattern should be placed so as to create an interesting meeting between this pattern and a specific form (see Figure 3).
touch, by sending an electrical current through the manipulated area. One wale of melting yarn is placed in the knitted structure between the conductive and wool yarn; when a current passes through the conductive threads, the Grilon yarn melts, breaking the structure and making it possible to tear apart the affected section and create holes in the material.

Form of transformation: The melting property of the Grilon yarn creates a permanent change in the structure of the knit in the areas that are exposed to heat. The area of transformation is defined by the placement of the three different yarns in the knitted structure, specifically the meeting points between the conductive and fusible yarns, where holes in the textile can be created.

Expression of transformation: The expression of the knitted structure can be redefined by exploring breakage so as to create new expressions in the structure; for example, by creating open and closed areas on the surface or creating different tactile textures.

Form of use: The trigger of the transformation is defined in the textile. Thus, the conductive yarns embedded in the structure make it possible to explore the expression of the textile through digital manipulation; for example, by programming the material to create different transformations in the textile in relation to interaction. The expression of the textile can also be transformed through physical manipulation from sources of heat, including warm water, a hair dryer, or a clothes iron; however, the transformations are restricted to the areas where conductive and melting yarns are embedded. The permanence of the structural change suggests a defining design process, wherein alterations to the structure may gradually be added to the expression of the material, but never removed.

Expression of use: The permanent structural change embedded in the textile opens up for texturizing the surface of physical artefacts, in terms of both visual and tactile expression. Using this type of transformation in three-dimensional form-giving processes, by shaping objects or adding to or altering the form by breaking and removing parts of the material (see Figure 4).

Figure 3. Raw prints: placement in the methodological framework.
Raw knit: shrinking textile

This sample is also a simplified version of the interactive knitted structures designed as part of the “Touching Loops” project (Dumitrescu & Persson, 2011). The textile is knitted with Pemotex yarn in an interlock structure. The yarn shrinks when exposed to temperatures of up to 100 degrees, transforming the affected area from loose and elastic to dense and thick (see Figure 4).

Form of transformation: The properties of the Pemotex yarns create a permanent transformation of the structure following exposure to heat. The area of transformation is undefined, as the whole structure is knitted using the same binding and yarn, and therefore reacts in the same way throughout the fabric.

Expression of transformation: The textile expression can be transformed through shrinkage; development of the textile can be done by shrinking part of the structure or creating areas with different opacities, tactile textures, or permanent folds.

Form of use: The trigger of the transformation is not defined in the textile, as there is no conductive yarn or other trigger embedded in the structure. The textile allows for multiple forms of physical manipulation through direct interaction with the material; the structure can be transformed using any source of heat, including warm water, a hair dryer, or a clothes iron. The permanence of the change suggests a defining design process, in which alterations to the structure may be gradually added to the material but never removed.

Expression of use: The possibility for permanent structural change that is embedded in the textile opens up for texturizing surfaces (of prototypes), for example, in terms of both visual and tactile expression. This type of transformation can also be used when shaping objects in three dimensional form-giving processes, by altering the form through shrinking part of the material (see Figure 4).

Discussion

This article has presented a new approach to the use of transformable qualities of smart textiles and, in so doing, opens up a new task for textile designers; to design interactive textile sketching tools. In relation to this, the methodological framework in this article introduces a perspective which encompasses both methods for sketching and interacting with the material that the transformation of the material opens up, and textile variables that should be considered when designing the materials in question. Taken together, this methodology makes it possible to examine the connection between the design of a transformable textile and its design affordances as a means of facilitating artefact design.

The design affordances (Nordby & Morrison, 2010) of the textiles discussed in this article relate to the discussion of dynamic design affordances (Ishii et al., 2012), as in both cases the actions of a designer can be facilitated and restricted by a combination of the physical properties of the material and actions, defined by...
computation. However, when compared to using interactive tools which combine
digital technology and materials such as clay, designing tools with textiles becomes
more complex, as (smart) textiles, unlike many other materials, are in and of
themselves a design, with a large number of static and dynamic variables to consider
(Worbin, 2010). Similarly, small changes in the design variables for smart textiles as
raw materials for design can have a large impact not only on the materials
themselves, but also on which design methods they introduce or suggest for other
processes. For example, each smart material, such as yarn or ink, allows for certain
transformations, but precisely how these transformations take place, and which
design approach is facilitated is, to a large extent, defined by how and where the
textile designer decides to incorporate these transformations into the textile.

This can be seen when comparing the two thermochromic samples discussed
above, which have a similar form of transformation but differ in terms of the area of
transformation; in the first, the area of change is undefined, while in the second this
area is defined. These differences facilitate different approaches to the sketching
process; in the former case, we observe a wide range of possible visual expressions,
while the latter has clearly defined limitations regarding exploration, and is therefore
used primarily to consider and develop that particular pattern in relation to a specific
three dimensional form, context, and/or interaction scenario. The open and pliable
qualities of textiles as design materials also mean that, when compared to other
programmable physical tools (Saakes & Stappers, 2009; Ishii et al., 2012; Follmer et
al., 2013), it can be more difficult to facilitate and restrict specific actions in the
design process. As such, textile materials that may be altered through digital
interaction can often also be manipulated physically (see Figure 5).

In the article, a methodological framework was used to describe existing textile
samples from the Smart Textile Sample Collection; this framework, however, also
has the potential to aid in developing new smart textiles that may be used as raw
materials for design, by helping designers to see the potential in smart textile
prototypes and materials designed for other purposes. As shown in the picture
below, this was made with a set of interactive furniture prototypes created as part of
a project entitled “Recurring patterns” (Nilsson, Satomi, Vallgårda, & Worbin, 2011).
Here, a form of “textile system” was created, consisting of a thermochromic print, a
woven fabric with conductive threads, electronic components, microprocessors, and
a graphic interface; in sum, a programmable dynamic textile surface that can change
continuously or be activated by events occurring at various distances from the textile.
Our framework suggests that this combination of materials and techniques could
create interesting raw materials for design, which could allow for both temporary and
permanent surface change, and re-patterning through digital programming of the surface (see Figure 6).

Figure 6. The smart textiles in the Recurring Patterns prototype placed in the framework.

The Smart Textile Sample Collection currently includes textiles that allow for fast-paced explorative sketches (such as raw prints) or for defining sketches, where changes to the materials are gradually added (including raw knits). Our experiences from the workshops and working hands on with these materials suggest that the transformable properties of smart textiles have the potential to introduce a stronger synergy between material design and three dimensional form in the sketching process. More complex smart textiles technologies, such as the materials and programming used in the “Recurring patterns” project, suggest more elaborate methods that are both explorative and defining in character, which could possibly further develop the meeting between material and form in the design process; for example, when designing interactive artefacts.

In order to more extensively explore this way of working and the role of smart textiles as raw materials for design, we need to develop the samples in the collection further. Those presented in this article are basic examples, representing the possibilities of a number of separate smart materials and techniques. As such, an interesting next step could be to develop textiles with more complex forms of technology; for example, to explore what other opportunities for smart textiles as raw materials for design, and the design processes that use them, could come from incorporating more advanced programmable behaviour.

References


Videos and images of the final prototypes that were made during the project can be viewed here: https://openstructures.wordpress.com
Open Structures: designing 3D printed alterable textiles

Linnéa Nilsson, University of Borås

Abstract

The design of textiles is flexible. The soft, pliable nature of textiles means that their expressiveness and physical properties can be altered long after the material has been produced, by e.g. adding or removing colour, pattern, density, or by printing, laser-cutting, etc. This transformability means that the design of textiles can be further developed in another design process in relation to a specific product or context. In the emerging field of textiles produced using 3D modelling and additive manufacturing, structures can be defined in detail and, later, altered or completely redesigned in CAD programs. However, the designs of these textiles are generally fixed when the structures emerge from the 3D printer.

This paper describes a practice-based project that explores the transformability of 3D printed textiles, considers the question of whether some of the openness that characterises their digital form can be introduced to their physical form, and then explores what form this could take. It begins by describing the project which forms the basis for the exploration, the outcome of which thus far consists of two experimental 3D printed textiles with changeable physical structures. It then discusses the considerations and decisions involved when designing for such transformable textiles, proposing ways to understand and describe what is taking place: First, by relating them to the considerations made when defining open design systems; second, by introducing two types of design decisions, which together define which aspects of the textile's design are closed to further development, and which are open for others to develop.

Keywords
textile design; 3D printing; transformable materials; design process; open design.

Conventional and new forms of transformable textiles

Textile design is not fixed, but rather flexible. The soft, pliable properties of textiles mean that their visual and tactile expression and behaviour can be altered after the material has been produced by adding or removing colour, texture, pattern, density, or by pleating, embroidering, printing on it, etc. Wolff illustrates this potential by describing the ease with which the expression and behaviour of a single piece of textile can be altered by someone with a needle and thread: “They texturize, embellish, inflate, and support. They create puckers, folds, waves, puffs, projections, and openings. With stitching by hand or machine, they resurface, reshape, restructure, and reconstruct a flat, supple piece of cloth into cloth with an entirely different disposition” (Wolff, 1996, p. vii). The physical properties and visual and tactile expression of a textile are defined by the numerous interrelated decisions that the textile designer makes when defining the material (Wilson, 2011). The overall textile design influences what can be created with it, as well as how it can take part in another design process. This can be described as the textile’s ‘design affordances’, a term originally introduced by Nordby and Morrison (2010) to discuss technology in relation to the design process. The term can also be used to describe what the material designer’s decisions allow for in relation to another design process, e.g. what the properties of a textile bring to the table when designing. The transformable qualities of textiles are here a central element, as they facilitate the further development of a textile in relation to a specific product or context through e.g. physical manipulation of the material. As such, the final version of a textile design is not necessarily defined by the person who created the original material; rather, as...
the design can be involved in another design process, it can be finalised by those people working with the material as part of this other process.

New techniques and material developments have expanded the range of possibilities of not only what textiles can be but also what they can do, both changing and exaggerating some of their inherent characteristics by making them even more transformable and open to alteration. This can be seen in, for example, some of the so-called ‘smart textiles’, which have surfaces which can be programmed to repeatedly change their expression and adapt to different contexts. The new transformations offered also open up for new ways of interacting and sketching with material during the design process, and facilitate the exploration of anything from multiple expressions in one piece of material with reversible transformations to gradual development through permanent changes to the material’s design (Dumitrescu, Nilsson, Persson, & Worbin, 2014). The exaggerated properties of this category of textiles also influence the design decisions that are made when defining these materials: some become more complex (e.g. colour palettes expanding to include multiple states), whereas others which are not ordinarily considered to be central can become essential to the design process (e.g. how textiles change their expression over time) (Nilsson, Satomi, Vallgårda, & Worbin, 2011; Worbin, 2010).

Transformability is also a strong feature of the emerging field of CAD-modelled and 3D printed textiles. This new type of ‘textile’ material is currently made primarily from jointed structures of stiff material, such as digitally modelled knitted or woven textile structures (see e.g. Desbiens, 2013), and structures which mimic or are inspired by how fabrics are constructed, e.g. Pringle of Scotland (Beckett, 2014), Bingham et. al (2007), and Nervous System’s ‘Kinematics Dress’ (2014b). With this type of structure, the visual expression and construction of these materials can initially be defined in extreme detail, and later altered or completely redesigned in its digital form in relation to the object it is to become a part of. However, their design is generally fixed when they come out of the 3D printer, with a few exceptions - notably Translab’s materials (2014).

**Aim and scope of the paper**

The aim of this paper, and the practice-based project on which it is based, is to explore the transformability of 3D printed textiles in order to ascertain whether some of the openness which characterises their digital representation can be introduced in a physical form, and to then explore how this might be realised. The paper also considers the implications of this transformability with regard to what a textile designer must consider during the design process. Does this technique, like smart textiles, introduce new or more complex considerations to the process? Moreover, what might they look like?

Working in a hands-on manner with a design, e.g. by dealing with real materials and circumstances, can facilitate an understanding of the dynamics of design practice, which can be difficult to achieve through other research methods (Vallgårda & Bendixen, 2009). This is particularly the case when researching new materials; thus, the potential of transformable 3D printed structures was explored by designing and creating 3D modelled and printed textiles, documenting the design process, and studying the nature of the decisions made along the way. The paper continues with a description of the project that makes up the basis of the exploration, and then presents the resulting two examples of transformable 3D printed structures. Finally, the considerations and design decisions that were made when approaching this kind of textile design process are discussed, and ways to understand and describe what is taking place are proposed.

**The Open Structures project**

The Open Structures project developed transformable 3D printed textiles by alternating between modelling structures in Autodesk’s Maya software and printing samples using the PolyJet additive manufacturing technique, as well as working hands-on with the printed prototypes. First, an overall construction system was created to facilitate alterations to the character and properties of a textile. It was important to create stable elements that could be connected to and disconnected from each other. To accomplish this, a rubber-like polymer, sourced from Stratasys, was used, and different types of connections were tested with it. The resulting construction system formed the foundation of the rest of the project, and consists of spherical nodes and links which can be permanently or temporarily connected in order to construct elastic structures. Using these basic elements, it was possible to explore how they might be used and what possibilities they might allow for with regard to further alterations to their structure.

The initial characteristics and properties of the textile structures that were created using the system, as well as their alterability, were defined by the nature of the links and nodes, as well as by how the latter were combined in the CAD model. These printed structures can, depending on the original design, be altered by someone else, who can replace, remove, or add components. The structure can, for example, be made more rigid by adding stiff elements, or become more colourful or more sculpted by adding other nodes and links which afford such qualities. The openness of the original design makes it possible for other designers working with the textile to develop the design quite freely, testing different options in the same piece while still making definite decisions about the final design. When defining the initial structure using CAD, it is possible for the textile designer to limit the ability of others to change links and nodes by either removing the opening function on the nodes or by merging them together with the connecting links. These options make it possible for the textile designer to define which parts of the overall structure should be built to allow for alterations, and which areas or individual elements should remain fixed.

Working in a hands-on manner with a design, e.g. by dealing with real materials and circumstances, can facilitate an understanding of the dynamics of design practice, which can be difficult to achieve through other research methods (Vallgårda & Bendixen, 2009). This is particularly the case when researching new materials; thus, the potential of transformable 3D printed structures was explored by designing and creating 3D modelled and printed textiles, documenting the design process, and studying the nature of the decisions made along the way. The paper continues with a description of the project that makes up the basis of the exploration, and then presents the resulting two examples of transformable 3D printed structures. Finally, the considerations and design decisions that were made when approaching this kind of textile design process are discussed, and ways to understand and describe what is taking place are proposed.

**Based on this system, two alterable textiles were designed which offered two different kinds of alterability. This was carried out so as to obtain a broader understanding of the considerations and design decisions that a textile designer deals with when designing this type of textile. The framework of Dumitrescu et. al (2014) explored the use of smart textiles as a sketching material, examining the potential of transformable textiles as tools in a design process. The authors defined both the basic form of transformation that takes place in the material, and the ramifications of using it in a design process. This approach was used to frame the use of transformable materials in the Open Structures project. Firstly, the type of
interaction the materials should introduce was considered; secondly, what specific alterations to the design this should involve:

**Version A**

The first textile was designed to allow for invasive alterations, so that the material’s basic character could be explored and developed with few limitations. To do this, the material was built using separate nodes and links, all of which could be replaced or rearranged. The initial design consisted of two areas with different types of construction, which could be retained, altered, or removed by another designer as part of another design process. Other types of links, made from both stiff and elastic raw material, were also provided with the original textile, allowing for different construction techniques and properties to be added to the textile.

**Version B**

The second version was designed to allow for far fewer alterations, where the primary characteristics of the material were kept but alterations could be made in relation to a specific context. To accomplish this, the textile was designed in the form of a mesh structure with links permanently merged to the nodes, providing basic structure and materiality. The extra links and nodes provided can be used to restrict the elasticity of the structure, but also to change the character of the textile by adding colour, weight, texture, and pattern. This material is designed to have fewer possible alterations as compared to Version A: Some nodes in the mesh are split on one side, restricting the number of extra elements that can be attached, and only a small number of extra elements are provided with the original design – two types of links and one node. Each element introduced into the structure leads to broader consequences for the design; adding, for example, stabilising elements also results in the addition of threadlike extensions to the material, and extension nodes inserted into split nodes add colour but also increase weight.

The nature of design decisions in alterable 3D printed textiles

The experimental examples created in the Open Structures project illustrate the fact that 3D printed textile structures can be designed to be physically altered and re-designed – the system of nodes and links is only one example of how this can be achieved. In conventional textile production, basic techniques such as weaving or knitting can to a great extent define the nature of the final textile structure and its inherent transformability. With 3D printed textiles, the way the structure is built is less determined by a specific technique; therefore, the construction can be designed in very different ways and can be made to differ significantly between sections of the material (Bingham et al., 2007). This possibility extends to not only how textiles can be designed, but also to how they can be altered. It opens up for new types of substantial transformation to the textile’s design, e.g. by making it possible to alter not only visual appearance and construction, but also the raw materials that the textile is made from. Moreover, and as a result of 3D printing, a textile’s alterability can be designed in great detail. Open Structures uses these possibilities to define the type of transformations that the textile should facilitate, as well as in which specific part of the structure this change should be possible: e.g. in Version A, they are used to allow change throughout the structure and, in Version B, they enable alterations at many, but not all, intersections between links and nodes.
What does the possibility to define in great detail a text file’s alterability mean for the considerations and design decisions that are made when creating this type of structure? To better understand and reflect on how design decisions frame both present expressions and their possible developments, the textiles created in Open Structures were compared to examples of ‘open design’. This term is currently used in several different ways, from promoting transparency in consumer relations to describing open source designs with distributed development to referring to open access to knowledge and blueprints (Avital, 2011). However, the definition followed in this paper relates to designs that are not fixed in their composition. This form of open design introduces a shift in thinking, from working with something which is or has been completely defined to something that can be explored, extended, and re-defined by someone else (Lamontagne, 2013). One of the recurring ideas used when discussing this form of open design relates to considering the design to be a system or meta-design (Stappers, Sleeswijk Visser, & Kistemaker, 2011; de Mul, 2011).

From this perspective, the designer’s task is to create an ‘envelope’ which contains several options for the user, but which does not dictate an outcome. Atkins (2011, p. 32) elaborates: “The challenge will be to create systems that enable the design integrity of the end result to be retained and perhaps the identity of the original design intention to be perceived, while still allowing a degree of freedom for individual users to adapt designers’ work to their own ends”.

This form of open design thinking can be found in several of the digital design systems created in relation to additive manufacturing. One example is the software interface Automake, which Marshall, Unver, & Atkinson (2007) used to explore generative systems for creating numerous unique designs. The system provides a number of simple geometric forms which can be overlapped to create stable structures. The first iterations of the system were to a large extent controlled by algorithms. Users watched a continuously evolving combination of forms and selected their favourite version. As the project developed, the system’s designers opted to give the user more and more control over the final design, e.g. letting them freely place forms rather than only relying on algorithms. Another example of open design comes from Nervous System, a design studio which has developed a number of interactive design systems: the digital interfaces of these systems allow users to design and order unique versions of their products, e.g. customising jewellery by changing certain parameters such as the number of holes or its structure, its colour, raw material, etc. (Nervous System, 2014a). The decision designs that define the Nervous System and Automake systems do not specify a final outcome; instead, they frame the original versions of the design and how users can interact with them, e.g. by deciding in which directions the designs can be developed. In some of these examples, the systems’ designers quite strictly direct the possible outcomes of their systems, but in others the power over the final design is mainly handed over to the users of the system. Together, these examples highlight the fact that one of the most important aspects of defining the character of this type of open system is to decide how much freedom should be given to the user, and what the boundaries for the design should be (Atkinson, 2010). Exploring what these considerations can mean in relation to 3D printed textiles was an important part of the Open Structures project. Both structures were designed to be alterable; however, the degree to which the two original designs could be transformed differed significantly. Version A was intended to be more open, and therefore contained fewer limitations and greater customisability, whereas Version B was designed to provide more limitations and to restrict possible design decisions to a greater extent. Moreover, the boundaries in an open design can take on many forms – in the previous examples, they were defined in the digital interface. In Open Structures, it was primarily the material’s properties and expression which framed possibilities and boundaries for further development. Each version was built from a specific combination of nodes and links, as well as additional elements provided with them, and together they set the stage for not only the initial design, but also what can be created using them. The following diagrams describe the composition of the material systems for Versions A and B:

![Figure 10. Overview of the material system for Version A, including the original design and the additional links.](image-url)
Examining the design decisions made for Versions A and B, it becomes clear that there are two different types of decision that together frame the open textile systems. Firstly, ‘closed decisions’; those that are fixed in the material design, and which cannot be altered by physically manipulating the material. Secondly, ‘open decisions’; these are defined in the original material but, when printed, can be removed or altered by another designer. The design of the basic construction system made it possible to decide whether each element and intersection in the material would be either open for alteration or closed, and doing so made it possible to decide what was central to the design and should be kept, and what could be defined by others. For example, in order to keep the character of Version A but simultaneously allow for major re-construction of the textile, the shape of the links and nodes were made to be closed decisions; however, how they could be combined was open and so alterable. Contrastingly, in Version B, the shapes of the links and nodes were made to be closed decisions, as was how they could be combined – they were fixed into a mesh which provided the textile with a basic structure that, regardless of alterations, was present in the design. However, in a discussion regarding open textiles, one cannot define purely open or closed decisions; open decisions can come with limitations, and the same goes for closed decisions. The open decisions found in Versions A and B mean that certain nodes and links, and how they are connected, can be changed. In such cases, sets of alternatives are provided and each, if used, influences the material’s behaviour and expression in a specific way. The open decisions in these materials are as such open for alterations, but there are restrictions on which other decisions can be made regarding the material’s design, as set out by the material’s designer. This way of restricting openness by providing a limited set of options, and thereby still controlling what the changes can be, resembles the systems of Nervous System, where product type and some aspects of the design are left open to change. However, these choices are still quite limited; e.g. it is only possible to change a ring into a bangle, cuff, or sculpture, and not into anything else (Nervous System, 2014a).

In addition, the type of raw materials used to print 3D modelled structures can influence the nature of closed design decisions. The main material used in Open Structures was a stable but slightly elastic polymer, which made it possible to create an alterable structure, but it also put limitations on the permanence of closed decisions. In Versions A and B some decisions were considered to be closed, e.g. the shape of the components and the connection between merged links and nodes. However, with enough force, some of these decisions could still be altered, e.g. by using sharp tools to remove sections from the shapes or to cut links. Pieces of the structure that are printed with stiff and hard materials, such as metal and ABS plastic, are, on the other hand, much more difficult to deform or manipulate. The choice of raw materials in 3D printed textile designs is thus an important part of framing the material system, as these material choices not only define the properties of the material’s structural elements, but also have an effect on just how ‘closed’ a closed design decision can be.

Thinking in terms of open and closed decisions can, regardless of the raw materials chosen, be of assistance when designing this type of structure, as it calls attention to how design decisions define both the material’s original design and its alterability. However, when working with soft materials, such as the rubber-like polymers in the prototypes, perhaps it is best to think of the open and closed decisions in the design as a form of invitation to collaborate, with soft boundaries rather than strict and unchangeable rules.

Alterable digital and physical 3D printed textiles

The focus of the project presented in this paper has been to explore the openness of transformable 3D printed structures in their physical form. However, with this new textile technology, open and closed decisions can also be defined in relation to digital interaction with the material. As in Nervous System’s (2014a) interactive systems, this can take the form of digital interaction, controlled by clearly defined parameters. It could also be kept freely transformable, limited primarily by the capabilities of the software, leaving the physical form as the state in which limitations are introduced. Regardless, digital alterability is an interesting possibility to consider for future work, as it opens up for designing the material and its alterability in both possible forms; the printed physical state, and the 3D modelled, digital state.

Open conventional textiles

Thinking of textile design as a form of open design, with open and closed decisions, does not relate solely to 3D printed textiles. It could also be relevant to other forms of textiles, as many can be altered and re-defined after they have been produced. Conventionally, printed textiles in this way may not be relevant when designing for a specific context (e.g. upholstery for a specific model of car), as the properties and visual and tactile expressions of these textiles are, already in the design process, adapted to a specific use. However, many textiles are designed without a specific application in mind, such as those simply sold by the metre. In this case, the design may not be aimed toward a specific product, but rather intended for a certain application or market, and can be applied to a wide range of contexts. These materials will somehow, on their way to their various applications, participate in other design processes, become part of a dialogue with other elements of a product, and be adapted in terms of both their expression and properties. Similar to the designs created in Open Structures, a fabric’s initial design and the way it can be altered is framed by the textile designer’s decisions. Conventional textiles can from this perspective also contain elements that are open for alterations, as well as characteristics fixed in the design, and as such also contain open and closed decisions. For example, in a woven piece of cotton fabric with a squared printed pattern, the surface design, i.e. colour and pattern, can be changed by pleating the material, dyeing it, adding additional elements to the prints, etc. The design decisions that together shaped these aspects of the textile are as such open for change. However, the fact that a fabric is woven, constructed with a satin binding, and
made from cotton yarn cannot be removed or altered in the fabric’s design, and it can therefore be considered to be closed to further development. In conclusion, the open design approach discussed in this paper can be a platform for exploring and designing alterable 3D printed textiles, but it can also be a perspective with which to rediscover and develop the openness of conventional textile materials.

**Conclusion and future work**

This paper and the Open Structures project explored the possibilities of designing 3D printed textile structures that can be altered in their physical form, and provided two early examples of what this kind of textile could look like. The alterability of 3D printed textiles has primarily been discussed in relation to how textile designers can define the scope of the possible design decisions that the material allows for. However, these structures only reach their final form in other design processes, when designers redesign, explore, and adapt these textiles to a specific context. In addition to developing the Open Structures textiles further, future work should also explore what the extended transformability of 3D printed textiles can mean for other design processes, e.g. by creating and observing workshops in which designers work hands-on with these structures. So far, only a handful of designers have worked with small pieces of Versions A and B. However, the reversible decisions that can be made when redesigning them have demonstrated the potential for both free experimentation and more detailed decision-making. The qualities of this type of design material could, with further development, open up for new ways of interacting with textiles in the design process; they could, e.g., open up for design processes in which the properties of the textile design are re-defined in detail in relation to the requirements of the product, or those where interaction with the physical textile is a part of the design setting. However, further exploration and development of the textiles themselves, as well as methods and tools which could enable them to become part of and influence other design practices, is required in order for this way of designing with textiles to be possible.

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**References**


Linnéa Nilsson

Linnéa Nilsson is a doctoral student in Textile Design at the Swedish School of Textiles, University of Borås, and she will present her PhD thesis at the beginning of next year. In her research she explores the relationship between textiles and products in the design process, e.g. by looking at how new textile technology such as smart textiles and 3D printed textiles can come to influence how we design textile products and how we design textiles for products. She explores this subject through a combination of experimental and theoretical work; e.g. through practice-based design projects and observation of design practice. Her educational background is in both textile design and product design, and, before starting her doctoral studies, she worked with textile design in products, e.g. at Volvo Cars.
Nilsson, L., TEXTILE/PROCESS/PRODUCT—A framework for exploring the relationship between textiles and products in the design process.
(Submitted for journal publication)
TEXTILE / PROCESS / PRODUCT – A framework for exploring the relationship between textiles and products in the design process

Abstract

The textile field is changing; new technologies and other developments are transforming what textiles are and what they can be used for, thereby opening up for new functions and expressions in textile products. At the same time, the design practices which create these products are also developing, e.g. with an increasing use of advanced digital design tools. Awareness of and reflection on the relationship between textiles and products is always relevant when designing textile products or textiles for products, but with recent developments within both the textile and product fields it becomes particularly important. To this end, we need to find suitable ways of looking at and exploring the relationship between textiles and products. This paper presents a suggestion for how to do this: A framework that describes how textiles and products interact with and influence each other in the design process, and includes questions and methods that e.g. could be used to compare or plan design processes. The first section looks at the textile/product relationship from a product design perspective, i.e. how textiles enter and influence a product’s design and the product design process. The second section looks at the relationship from a textile design perspective, i.e. how the product, as well as the product design process that the textile design will participate in, becomes part of and influences the textile’s design and the process. The framework has been developed as part of a PhD project, through a combination of practice-based design projects, observation of design practice, and theoretical work. The projects that have been used to develop the framework are here also used to exemplify the theory that is presented. The paper is concluded with a discussion on what new textile technology can mean for the relationship between products and textiles, using the main ideas and some of the methods of the framework. It e.g. deals with how the new type of qualities that come with techniques such as smart textiles and 3D printed structures can challenge common ways of designing with textiles and bring new considerations to the design process, as well as how they can open up for new ways for design practice to develop.
Introduction

Textiles are found in diverse industries, each of which has very different material traditions and working methods. The soft, pliable, and alterable qualities of textiles, as well as the wide range of materials available, also open up for a broad range of ways to approach and work with textiles in the design process, as well as a wide range of perspectives on future applications when designing textiles for products. From processes where textiles are designed in detail for a specific product, to those where the textile is designed wholly separately from the product, its designers unaware of the product’s use, and then selected and introduced as a finished material into an otherwise complete product. However, the qualities of textiles that enable a wide range of ways of working can also create complications, and clash with the working methods that are common within product design practice, e.g. CAD modelling, sketching on paper, etc. (Nilsson, 2014a). Moreover, the textile area is developing, and so expanding what textiles can add to products in terms of both expressions and practical functions (Quinn, 2012). This relates to new types of textile products, such as the interactive garments of Barbara Lanes or MOON Berlin (Quinn, 2012), sportswear that senses the wearer’s pulse (Numetrex, n.d.), and products whose expression can be changed by the user, such as the “luminous textile” walls of Phillips and Kvadrat (Philips, n.d.). However, along with this new potential come changes to the qualities of textiles as design materials, influencing some of the properties that are intrinsic elements of the most common ways of designing with textiles in today’s practice. The product design practice that textiles become part of is simultaneously evolving, e.g. becoming increasingly computerised through more advanced digital design software (van Bezooyen, 2014), thus often exacerbating the clashes that occur with these pliable, soft textile materials.

Knowledge of what textiles can do in products, as well as how to work with them in a design process, is imperative when designing textile products. Similarly, it is important to understand the applications of textiles and the demands that come with them when designing textiles for products. Failure to consider the meeting between textiles and products can, in both cases, come to limit the designs that can be created, as well as the design practice itself (Nilsson, 2014a). Thus, as textile materials, techniques, and product and textile design practices change, it is not only important to develop new expressions and products, but to also re-examine how textiles and products can meet in the design process. Awareness of and reflection on the relationship between textiles and products here become especially important; to this end, we need to better understand and find ways of looking at the relationship between textiles and products.

The aim and scope of the paper

Design theory can help us to question, reflect on, and develop practice, e.g. by introducing perspectives or methods for how to view and consider different aspects of design and the design process (Friedman, 2003; Hallnäs, 2010; Löwgren & Stolterman, 1999). In relation to theory and methodology regarding the meeting between products and textiles in the design process, there are at present several notable examples that deal with specific parts of this relationship: Bang (2010), who introduces co-design strategies and methods to enable context- or product-specific textile designs to be produced together with the furniture industry; Townsend and Goulding (2011), who define categories for how print design can be introduced into garment design processes; Heimdal et al. (2012), who describe how textile materials can be used in design processes as tangible sketching tools. What these examples have in common is that they deal with only one part of the diverse relationship between textiles and textile products, describing and making suggestions for design practice solely in relation to their specific area of interest. Contrastingly, this paper presents a suggestion for how to understand and consider the diverse relationship between products and textiles in the design process as a whole. This is here achieved through a framework called ‘Textile/Process/Product’, which describes the key aspects that define the character of this type of relationship and includes questions and methods that can be used to describe and compare different ways of working.

Method

The framework presented here has been developed as a part of a PhD project that explores the relationship between textiles and products in the design process. It is the final part of that project, and has been developed through an interaction between experimental and theoretical work; alternating between formulating theory that can describe the relationship between textiles and products, and studying and participating in design processes that inform or challenge our understanding of the subject, e.g. the qualitative study of other designers’ practices and practice-based design projects. Similar to the research process described by Zimmerman and Forlizzi (2008), the initial theory was based on early experiments, which were then tested and developed through others’ projects. A study of Master’s level design students who were working with textile products, presented in ‘Designing with textiles’ (Nilsson, 2014a), was initially of great significance, as it was through analysing the students’ wide variety of approaches to and methods of working with textiles that the foundations of the framework were developed. Other projects were built on this initial theory and used to explore details and definitions, e.g. how (smart) textiles can influence other design...
The framework is, as such, not concerned with the context of the design process, e.g. what and how product design decisions participate in the textile design process. The specifically, how textile design decisions become part of the product design process, during the design process, and how they relate to and influence each other. More focuses on the core of the product/textile dynamic, i.e. the design decisions made during the design process, and how they relate to and influence each other. More specifically, how textile design decisions become part of the product design process, and how product design decisions participate in the textile design process. The framework is, as such, not concerned with the context of the design process, e.g. what type of designers are involved, how labour is divided, which stakeholders influence the design, etc.; instead, it offers an abstract perspective that brings how we design out into the open. Thus, the aim of this framework is not to promote a specific way of working, but rather to open up for reflection on how we design, and can design, textile products and textiles for products.

The overall structure of the framework is the same in that both the product and textile perspectives contain questions and methods that can be used to explore and define the textile/product relationship. In the product design section (figure 1), this is achieved firstly by looking at what form of textile design is incorporated into the process; secondly, by examining how the textile is approached/what role it plays in the process; thirdly, by investigating how the textile influences what can be designed and the design process itself. In the textile design process, the product can be connected to the textile’s design to varying degrees; the two can be developed in close dialogue or wholly separately. The textile design and the product design meet during some form of design process, and it is the nature of this process that to a great extent defines what the connection to the product will be when designing the textile. The meeting between the textile design and the future application is as such not only influenced by the specifics of the product, but also by the nature of the design process it will be part of and the potential role that the textile there will play. As a result, the design process that the textile is involved in on its way to being incorporated in the product should also be included when describing the relationship from a textile perspective. Thus, the textile design perspective contains questions and methods that define the relationship between both the textile and the product, and the textile and the product design process (figure 2). First, determining in what form the textile is incorporated into the process; secondly, by examining how the textile is approached/what role it plays in the process; thirdly, by investigating how the textile influences what can be designed and the design process itself.

Each section begins by introducing a way of thinking about the relationship, and then provides questions and methods for exploring a design process with this perspective in mind. The framework can be used in varying degrees of detail, from simply reading the introductory texts so as to reflect on the relationship in general to utilising all of the methods and questions in order to map out a specific design process from start to finish. Taken together, the framework highlights important points in the relationship between textiles and products, and could therefore be used for looking back to a previous textile product design process or textile design process, planning a future one, or reflecting on these practices in general.
part I: product design perspective

In what form does the textile become part of the product design process?

The textile area is a diverse field which involves numerous techniques and types of materials, and textiles enter the textile product design process in an equally diverse range of ways - as anything from a vague specification of textile properties to materials that are designed and produced for a specific product. The form that textile design takes when designing textile products, along with how and if this changes, is an important clue when considering the character of the relationship between textile and product in the product design process, as this provides a good picture of how the design of the textile in the product is connected to the design of the product, if the textile design is truly part of the product design process, and to what extent.

In order to be able to examine this part of the relationship between textile and product in a product design process, and to compare different processes to each other, the wide range of examples of what textile design can be in a product design process is divided into four groups, each relating to a different connection between textile design and product. Textile design can of course be divided and considered in multiple ways, e.g. by looking at the technique (weaving, knitting, non-woven), the type of fibre the textile is made from (e.g. natural or synthetic), or, following Albers, by classifying textile design using first the design of the inner structure, i.e. the construction of the material, and second the design of the surface, i.e. the visual appearance and tactile properties (Albers, 2000). In this framework, the area of textile design is divided so that it is possible to describe how the design of the textile material enters the product design process. It is based on what type of textile decisions/activities the designer works with when designing the product. As textiles can be a part of a product without being designed within or for that specific context, the four categories include design decisions that define the textile material itself, as well as ones that involve textiles in the product design process in other ways. The answer to the question ‘In what form does the textile become part of the product design process?’ is thereby reached by defining which of the four following forms of textile design decision are being utilised in that process:

### In what form does the textile become part of the product design process? (p.7)

- How does the textile influence the product design and the product design process? (p.19)

### How is the textile approached? (p.11)

- How does the product and the process influence the textile design and the textile design process? (p.25)

### How are the product and process approached? (p.31)

- How do the product and the process become part of the textile design process? (p.36)
Construction
This form of textile design decision deals with the construction of textiles, which means that the textile design is performed within the product design process. The construction of textiles can be more or less detailed, and the textile’s design can here be defined precisely, down to the construction of the fibres in the structure. It can also take the form of combining materials to create a composite textile, or selecting yarns and fibres to create a new material which has been designed and produced for that specific product. Weaving, knitting, warp-knitting, and non-woven are examples of textile techniques that can be combined with this form of textile design.

Alteration
This form of textile design decision deals with the alteration of textiles. This means that the original version of the material is defined by someone else outside of the process; however, the final version of the textile in question is defined inside the process for the specific product. The textile can be re-designed, by e.g. changing the colour, adding patterns, or adding to or changing the texture. Dyeing, printing, embroidery, laser cutting, and pleating are examples of textile techniques that can be combined with this form of textile design.

Selection
This form of textile design decision deals with the selection of existing textiles. The product designer selects a textile that works with the rest of the design, and incorporates it into the product as a finished material. Thus, the textile design is not performed inside the product design process, but is instead created in a separate design process by another designer.

Specification
This form of textile design decision deals with the specification of textile materials or properties. The designer does not design or select a specific textile for their product; thus, the exact choice of the textile is not a part of the design process. Instead, the designer defines a type of material or a set of properties that they believe will work with the rest of the design.

The form of textile design that is present in a process is not necessarily constant - changes often occur, and can be the result of the textile component of the product becoming more or less important for the design, or simply the practical consequence of not finding a suitable existing textile material. The following text provides examples of what the form of a textile design decision can mean in a design process - the considerations, possibilities, and limitations that come with different ways of including textile design in a product design process.

Different forms of textile design decision can be more or less suitable for different designs, designers, and design contexts. Construction, alteration, selection, and specification each require different levels of effort as regards the textile part of the product, but can also require different levels of textile skill and knowledge. This can be seen by e.g. comparing two of the types of design processes described in ‘Designing with textiles’ (Nilsson, 2014a). ‘Detail’ (pp. 53-61) refers to a way of working in which textile materials are a part of the product, but do not play a significant role in the design process. While there were some exceptions, the majority of the observed students who worked in this way did not actively deal with or define the design of the textiles in their products. Textile decisions instead took the form of specifications, i.e. with the desired textile qualities being specified, or in the form of selection, e.g. with textile decisions being made by choosing a suitable material from a nearby fabric store. In the latter case, it frequently transpired that the selected textile did not work with the rest of the product, and in order to complete the design in time it was replaced by a specification which was based on what was needed to complete the product. With this change to the form of textile design decision, the connection to the product changed; from the textile being part of the process as a real textile material, to it being represented by a vague description consisting of a set of desired properties. The students’ choice to work with selection and specification enabled them to expend little time and effort on the textile aspect of the product, and instead focus on other aspects of the design. This also meant that the textile skills needed to design the material could also be left out of the process, which suited the students who had little or no previous experience of designing textiles.

An example of a textile product design process in which the textile design had a much stronger presence can be found in e.g. the ‘Dialogue’ category of ‘Designing with textiles’ (Nilsson, 2014a pp. 73-82). Here, the textile strongly influenced the rest of the design, although the textile’s design itself was also influenced by the requirements of other aspects of the product. The students who worked with textiles in this way either constructed materials from scratch, e.g. by designing a knitted textile - selecting bindings, yarns, patterns, etc. - or took an existing material and either combined it with others in order to create new properties or expressions, or altered it by adding texture, colour, pattern, etc. In the latter scenario, the first version of the textile was actually designed outside of the process, but the final design of the textile was defined within the product design process. The students’ decision to work with alteration and
construction required more time and effort be spent on this aspect of the product, as well as more textile knowledge as compared to the students who worked with selection or specification. For designers who lack this knowledge, working with this type of textile design decision in their design processes can thus be problematic. However, access to or collaboration with textile producers or specialists can still enable this way of designing with textiles. It was doing this - by utilising the skills of e.g. technicians and teachers - that enabled those students with little previous textile experience to not only work with finished textiles, but also create new textile designs for their products.

As such, different textile design decisions require different amounts of time and effort, along with forms of textile knowledge, but these can also have an impact on what can be designed - what the textile product can become. There are, of course, exceptions, but processes that deal with constructing or altering an existing material generally open up for more unique solutions and innovations, as the textiles can be customised with a specific product in mind. Working with textiles that are designed outside of the product design process, on the other hand, means that no time and effort is spent on developing the textile material or its properties, and this can often lead to the use of more standardised textile solutions and designs which feature the same materials as similar products. Comparing the two ways of incorporating textile design discussed above, this difference in terms of the outcome of the process is clear. The first scenario generally involved the use of conventional textiles, while the second utilised more unique designs, in some cases using textiles that entailed more advanced textile techniques and solutions, e.g. using shape-memory wire to create movement in the textiles of the product.

Question: In what form does the textile become part of the process? Which form of textile design decisions are worked with in the design process? Do they deal with construction, alteration, selection, and/or specification of textiles?

Method: Place the forms of textile design decisions that have been utilised in the model, along with whether and how this changes over the course of the process.

part I: product design perspective

How is the textile approached?

The traditional approach of shape over matter, with materials selected or designed based on what can best realise the intended product, is a common one within many design industries (Oxman, 2010). Having access to a large variety of finished textiles, with different properties and expressions, opens up for this way of working, in which textiles enter into the process as a comparatively minor detail when designing textile products. The soft and flexible properties of textiles also enable this way of designing, as they make it possible for the same textile to be used in many different products and contexts and, moreover, allow for changes and adjustments in terms of how and where textiles are used, even in the later stages of the design process. However, this openness in relation to the design, and the fact that the textile is both a material and something that may be designed during the process, also open up for many other ways of designing with textiles. As such, there are numerous ways in which textiles may come into and be approached in a textile product design process, and each brings its considerations, opportunities, and challenges. The main difference in character between the various approaches is found in when and how textile design decisions and materials can influence the development of the design; specifically, whether the textile in the process is allowed to affect the design, or if its inclusion is a consequence of other decisions. The answer to the question of “how is the textile approached?” is as such arrived at by looking at how textile decisions enter the product design process, and how central they are in relation to the development of the product. The following section explores this part of the relationship.
Design decisions that are central to a design have a greater influence on the development of the design than decisions which take the form of relatively minor details which are resolved at the end of the process. How and when textile design decisions come in therefore provides important clues as to how much influence these decisions can have over the design, and what role they can play in the process. 

Jones (1992) divides the design process into three fundamental and logical phases; divergence, transformation, and convergence. Each phase represents a type of activity in the design process, a stage in the process at which a specific type of design decision is made. These decisions play different roles in the creation of the design, and in doing so influence the development of the product in very different ways. This perspective on what takes place in different phases of the design process opens up for looking at how something is approached, and how much influence it has; thus, this thinking is used as the foundation for this part of the framework. The following describes the influence that decisions made in the divergence, transformation, and convergence phases have in the design process. Design processes are rarely linear - proceeding directly from divergence to transformation and ending with convergence – instead, it is more common that a process involves several cycles of different phases, continuing until a design is completed. Thus, the manner in which these phases are discussed here does not represent the order in which they necessarily occur during a design process.

Divergence is the initial phase of the design process, and is described by Jones as “breaking the problem into pieces” (Jones, 1992 p. 63). In this phase, the designer takes the original brief and deconstructs it before expanding upon it, looking at aspects that are important to the specific design situation and searching for decisions that could be used in the design. The exploration and experimentation that the designer undertakes during the divergence stage inform the upcoming transformation phase, and give the designer a better understanding of the boundaries and potentials of possible decisions, along with an improved knowledge of the consequences of decisions that could be made in the upcoming design work (Jones, 1992). Textile design decisions can be present in the divergence phase of a textile product design process, e.g. by being part of the original brief, or by being one of several options that are explored in the design space. The outcome of the designer's divergent exploration becomes the basis for the rest of the process and, if textile decisions are a part of this foundation, the designer’s understanding of this design possibility has a chance to influence the development of the design.

Transformation is the second phase of the design process, and is described by Jones as “putting the pieces together in a new way” (Jones, 1992 p. 63). In this phase, the designer searches for and develops ideas and basic concepts. The transformation phase is concerned with fixing the objective for the design - in other words, defining what it is that the designer is designing, and deciding which design decisions are important and how these decisions are related. The choices made in the transformation phase define the design's general direction, and set the scene for the upcoming, more specific design choices (Jones, 1992). Textile design decisions that are present in the transformation phase, particularly decisions that eventually become part of the direction of the design, have a strong influence on its development.

Convergence is the third phase of the design process, and is described by Jones as “testing to discover the consequences of putting the new arrangement into practice” (Jones, 1992 p. 63). In this phase, the objective has been defined, and the designer gradually shapes the abstract idea into a finished design; thus, decisions become more and more detailed. Each decision in this part of the design process is influenced firstly by the directional decisions made in the transformation phase, and secondly by the decisions that the designer makes in the convergence phase. The order in which decisions are defined determines how much influence a specific decision can have on the design, and can provide clues to the importance that the designer places on different decisions, i.e. whether they are seen as a crucial element or a minor detail of the design. Textile design decisions that enter the process in the convergence phase are directed and influenced by previously established decisions. The more a decision is considered to be a 'detail', the less impact it will have on the overall development of the design.

The influence that textile decisions can have in a product design process can also be explored by comparing their importance to other aspects of the design. When designing products, it is natural that some aspects are considered to be central to the design, some are relatively unimportant, and most lie in the range between. By considering whether textile decisions are prioritised in the design process, one can start to obtain a better picture of if 'the textile' is high up in this hierarchy of design decisions. An important question here is how clashes between textile design decisions and other design decisions are handled. For example, when the form of a product cannot be created with the textile that the designer wants to use, which is changed? Is a new form that works with the intended textile created, or is a new textile, which can create the desired shape, selected or constructed?
In summary, different ways of including textile materials and decisions in the product design process enable textile materials and textile decisions to have varying degrees of impact on the development of the product. As a result, different approaches to textiles are suitable to various degrees for different types of designs and design processes, but also for different types of textiles. The effects that this choice can have on both what can be designed and the design process itself can be seen by looking more closely at and comparing different ways of approaching textiles: In design processes where the textile is selected, constructed, or altered to suit the requirements of the rest of the product, the textile has little room to influence the rest of the design, and the textile part of the product is not a central consideration but a consequence of other, more important, decisions. An example of this way of approaching textiles in the design process can be found in the ‘Detail’ category of ‘Designing with textiles’ (Nilsson, 2014a). Here, despite the fact that the brief that initiated the students’ processes specified the use of some form of textile in the product design, the textile design aspect of the product did not have a strong presence in any of the three phases of the design process: Little effort was put into exploring textile materials or options when expanding upon and investigating the brief and potential design decisions (divergence); textile materials or decisions were not part of the main design idea/product direction, around which the rest of the design was built (transformation), which could be seen in how the students’ descriptions of their product ideas generally omitted anything connected to textiles; the students instead selected or specified a material when most of the product had been defined, based on what could best create their product (convergence). As such, the textiles were considered to be a means of building or creating the product, but were not given any room to influence it - when clashes occurred between textile and other design decisions during the design process, the rest of the design was kept and the textile was changed. This way of designing with textiles greatly relies on the fact that there is a wide range of suitable textiles to choose from and switch between, or that the textiles that are present in the process can easily be adapted to the requirements of the product. This way of approaching textiles in the product design process can therefore be problematic in relation to more complex textiles or more demanding applications in products, e.g. textiles that are part of the construction of the product.

Textile materials or decisions can also be central to a design and play an important role in the design process. The product can be designed around the requirements and potential of the textile, which is given room to influence the product greatly, in some cases even determining what type of product will be created. The ‘Starting Point’ approach (Nilsson, 2014a) is an example of this way of approaching textile materials and textile design decisions in a product design process. For those students who used this approach, a certain textile or aspect of a textile was the inspiration for and genesis of the design, but it also had a strong presence in all three of the phases of the design process: It constituted the start of the process, in that time and effort was given to firstly exploring and understanding its potential and limitations, and secondly the ways in which it could be used to create a product (divergence). This understanding of the textile informed the idea development and subsequent decisions. The textile was also consistently a central part of the design direction (transformation), which was initially concerned with using the potential of the specific material but was expanded to include other types of decision. The design direction influenced how the rest of the design could be defined and, as such, the textile that initiated the process also had a strong influence on the design of the rest of the product (convergence). With this approach, the requirements that come with the textile can place strong demands on other aspects of the design. When clashes occurred in the students’ design processes between the textile and other aspects of the product, the textile was retained and the rest of the design was changed to accommodate it. Thus, this approach works well with most textiles, including more demanding or complex materials, as the possibilities and limitations of the textiles are allowed to influence other significant aspects of the product.

The textile product can also be developed through interaction with the textile, i.e. in a process in which the textile is given room to influence the rest of the design, and the requirements of the product also can influence the design of the textile. The ‘Dialogue’ approach (Nilsson, 2014a) is an example of this way of introducing textile materials and design decisions into a product design process, in that they are present in all three of the phases of the design process. The students who worked with this approach incorporated textile materials or design possibilities when exploring the brief and possible design decisions; e.g. by familiarising themselves with their properties (divergence), textile decisions were also included in the design direction (transformation), and so textiles in some form influenced the development of the rest of the product. Based on the design direction, the specific design of the textile - the colour, texture, pattern, etc. - was defined along with the rest of the product (convergence). When clashes between the textile and the rest of the design occurred, changes to the textile were an option, but other aspects of the design were just as frequently altered to enable the use of the textile. The textile was here not worked with as a fixed material; rather, it was continuously developed and re-designed in relation to the rest of the design. Some textile techniques can clash with this type of
dialogue approach, e.g. it can be difficult to combine with small-scale production of products with textile techniques that require large quantities to be produced (e.g. roller printing) (Wilson, 2001), but on the other hand there also exist techniques that fully facilitate the usage of this form of customised textile design, e.g. digital knitting and digital printing, where textiles can be both created in small volumes and designed exclusively for that application. The influence that the textile is allowed to have within this approach can also open up for the use of more demanding textiles as, in this way of working, the textiles are investigated, considered, and allowed to impact other aspects of the design.

The following sets of questions and methods can be used to explore how textile materials and decisions are approached in a product design process: The first does this in detail by examining in which phase of the design process the textile has influence, building on Jones’s subdivision of the stages of the design process; the second can be used to visualise how different types of design decision are prioritised in relation to one another, building on the previously presented ideas regarding hierarchy in the design process. The approaches described above are used as examples in the visual models (figures 6-8).

**Question:** In which phases of the design process do textile design decisions influence the development of the design?

**Are textile design decisions present in the divergence, transformation, and convergence phases?**

**Method:** In the model, mark the phases in which textile design decisions become part of the product design process and can influence the development of the product's design:

The model does not depict the chronological development of the process; rather, it can be employed to illustrate in what type of decision-making or process phase textile design decisions are present and in doing so describe to what extent they can influence the development of the design. The small circles in the following illustration represent design decisions, and can be used to mark in what phases in the design process textile design decisions are present. These decisions float freely in the divergence phase and combine to form a design direction in the transformation phase. The design direction represent the decisions that are most central to the design and become the core of the convergence phase from which the rest of the design is developed. The large circle in the convergence phase represents the design of the product as a whole, and the placement of the small circles (design decisions) within the large one is linked to the relative importance of each to the design.

**Method:** In the model, mark how central/influential the textile is in the product design process:

The circle can be used as a tool to visualise hierarchy in the design – to what extent textile design decisions have priority over others – and in so doing help to describe the roles that these decisions possess within the design process. In the model, colour intensity signifies importance in the design. The most influential decisions are therefore placed in the area with the strongest colour, i.e. at the centre of the circle, and the least influential are located in the most diffuse section, i.e. the far edges.
part I: product design perspective

How does the textile influence the product design and the product design process?

A textile introduces certain aesthetic and functional possibilities (Manzini, 1989) through its visual and tactile expression and material behaviour, which in turn influence what the textile can be used for in a design, as well as how it may be employed in relation to the design process. What the textile brings to the table when designing is here referred to as the 'textile influence', although an equally apt term is "design affordances" (Nordby & Morrison, 2010), which was originally used to explain what technologies such as RFID tags bring to design processes. However, design affordances can also be used to discuss how textiles as design materials influence the textile product design process. When designing with textiles, not just the materials that are to be parts of the final design should be considered in this way; textiles that are used as e.g. tools, sketching or prototype materials, creative stimuli, etc., also affect the design and should therefore also be considered when examining textile influence in the product design process. The following describes what form this influence can take, and what effects it can have, and includes questions and methods that can be used to explore and define what the textile influence is, either in general or in a specific process, and how this is handled or used.

Some examples of textile influence are generally applicable, and should be considered when designing with most textiles. The flexibility, stretchability, and adaptability of textiles are here interesting qualities, as they bring both opportunities and challenges to the textile product design process. These properties can e.g. make it possible to cut and form material into products without the use of expensive moulds or advanced production techniques; the soft and easily formable qualities of textiles also enable designers to use the same or similar techniques when making sketches and prototypes, e.g. cutting, sewing, or forming the material by hand. However, the soft and flexible nature of textile materials also lead to challenges regarding how designers can work when defining their product in the design process, as predicting how a fabric will function as part of a product, how it will fall, bend, stretch, etc., can be more difficult than with stiff and stable materials such as metal or wood (Ahlquist & Menges, 2011). The considerations that come with working with textiles can, as such, be very different from those that accompany many other materials, and textile materials can therefore be difficult to combine with some of the sketching techniques and digital design tools.
that are commonplace in product design practices. In addition to the general textile influence, the specific qualities of the textiles that are present in a specific design process also have an impact on the product design process. The form of textile design decisions that are present in the process (construction, alteration, selection, or specification) are here important for ascertaining what this influence is, as each form of textile design decision brings different requirements and also requires varying degrees of effort to be expended as regards the textile aspect of the product. The unique properties of the textiles that participate in the process are also an important part of the influence, as each combination of raw material and textile technique influences how that textile can be used in a product and what role it can play in a design process.

The intensity of both the general and specific textile influence can vary, depending on how the textile material is used in the product. For example, a product in which the textile is added as a surface, on top of another stable material, is less sensitive to the specifics of the textile than a product in which the textile material is a major part of the construction, function, etc. The behaviour and expression of the textile itself can also differ depending on what context it is used in, and different textiles can bring very different qualities to a product; using different materials in an otherwise similar design can result in very different outcomes, and even small differences in the textile can have a big impact on the product. Changes in what the textile influence is or in how it is used can as such influence the unity of the textile and its other components, and the product as a whole. A lack of awareness regarding this aspect of the textile influence, i.e. sensitivity to detail and context, can make it difficult for a designer to fully consider how textile decisions will, in the final product, influence the expression, construction, etc. Consequently, another important issue when examining textile influence in the product design process relates to looking at which textile properties, decisions, etc. influence the development of the product, and which influence its design. A lack of awareness regarding this distinction can lead to unexpected changes to the design when the final textile materials meet the rest of the product.

Three examples of how such a lack of awareness can manifest itself, and the effects that it can have, can be found in ‘Designing with textiles’ (Nilsson, 2014a). One deals with differences in scale (pp. 15-22); here, the students worked with textiles in one scale during the design process, and used another for the final design. They explored the material and made sketches using small samples (divergence), incorporated the properties/potential that they found in the small samples in the design direction (transformation), and used small-scale models with samples of the textile to define the form, function, etc. of the final design (convergence). The final product, however, was on a much larger scale, and contained a large piece of the textile. When the final, full-scale prototype was made, the selected material and the rest of the design did not combine to produce the intended design and, in so doing, much of the intended expression and function was lost. The second example (pp. 23-31) deals with how discrepancies in the textile influence can occur when only part of the textile is included in the design process; in this case, the visual expression of a textile surface, without its physical qualities, were factored in when the product was designed using a 3D CAD program. Here, the textile surface was an important part of the design when exploring possibilities, as well as when defining a design direction (divergence and transformation). The final design was later made using a 3D CAD program, with the textile represented as a surface/skin overlaid on the CAD model (convergence). The textile did not work with the rest of the design when the final design was examined and the full range of properties of the textile in the product were considered, as the soft character of the material clashed with how the product was constructed; thus, the material had to be replaced with a completely different type. Similarly unexpected changes to the design are presented in the ‘Material Research’ section (pp. 32-43); these occurred due to differences between the textile influence in the process and the product, as also only part of the textile was researched and considered in the design process. This was in this case the result of partial or limited material research, which led to unexpected changes to the designs.

By considering the textile influence/design affordances when designing, some of the challenges of designing with textiles can be mitigated, and some of the possibilities that come with designing with textiles can be taken advantage of. For example, an awareness of how the scale of a material influences the behaviour of the textile can help a designer to consider this aspect of the material and avoid some of the difficulties discussed above. ‘Designing with textiles’ (Nilsson, 2014a) exemplifies how it is possible to both control and utilise textile influence: The students described in the ‘Physical Material’ section acknowledged their lack of understanding/experience with textiles, e.g. their not knowing how the textiles they were using would affect the forms and constructions of their products. To better control the influence that the textiles would have on their designs, they decided to alter their normal way of working, introducing more physical materials, specifically textiles, into all of the phases of their process. For example, using the same textile materials as they had chosen for their products earlier in the process, e.g. as sketching and prototype materials, made it possible to fully work with and consider a textile’s qualities in relation to the rest
of the design. This meant that the textile properties and expressions that influenced the development of the design (in the divergence, transformation, and convergence phases) were the same as those which influenced the final product. Moreover, the context-sensitive and adaptable qualities of textiles as a design material, which can result in discrepancies in the textile influence when designing with textiles, can also be used during the design process, as they can e.g. be used as a tool to develop and explore possible options, or to take the design in new directions. This can e.g. be seen in the 'Tool' section (Nilsson, 2014a pp. 83-93), where the students included textile materials in the design process, not in order to use the exact textiles in the product but instead as a means of further exploring and developing their designs. They e.g. used the unpredictability of the material to create new product shapes, surface expressions, etc., which would be difficult to sketch by hand or create using CAD tools.

The following questions can be used to explore the exact nature of the textile influence in a given textile product design process, and whether this is considered, handled, or used within the process. The model for examining where textile decisions enter into and influence the design described above, which can be used to explore how the textile is approached, is here used again. In this case, it can be used to compare the textile influence that is present in the process with that on the final product. The examples of how discrepancies can occur when working with the different types of textile influence that are presented in the text above are used in the visual model as examples (figure 10-11).

**Question:** What is the nature of the textile influence?

- Which textile properties/considerations influence how the product can be designed?
- What general textile influences affect the design process?
  - Context-sensitivity?
  - Detail-sensitivity?
  - Soft or elastic properties in relation to design tools and sketching techniques?
- What specific textile influence affects the design process?
  - What considerations do the forms of textile decisions bring? (Construction, alteration, selection, specification)
  - What types of considerations and other influence does designing with this specific textile bring to the design process?
- Is this a product that is sensitive to textile influence?
  - Is the textile part of the construction or functionality of the product?
  - Are details regarding the textile important for the final product?

**Question:** How is the textile influence considered/handled/utilised in the product design process?

- Is the textile influence considered?
- Is the textile influence handled?
  - Is the design process altered to accommodate the textile influence? If so, how?
- Is the textile influence utilised?
  - Is the design process altered to take advantage of the textile influence? If so, how?

**Method:** Compare the textile influence in the process and in the product:

In the model below, place the textile decisions and materials that influenced the product’s design in the phase during which they affected the design (divergence, transformation, convergence). This includes textile materials that are not part of the design itself, but that feature in other ways in the process. Additionally, place the textile decisions and materials that influence the product in its final form.

**Figure 9.**

- Which textile decisions are part of the design process in the divergent phase?
- Which textile decisions are part of the design process in the transformation phase?
- Which textile decisions are part of the design process in the convergent phase?
- Which textile decisions and materials are a part of the final design?
part II: textile design perspective

In what form do the product and the process become part of the textile design process?

The textile design and the product design meet during some form of design process, and when designing textiles that will become part of textile products, the properties and expressions that are created influence and interact with both the future product's design and the product design process. E.g., a textile that is designed to be stiff and paper-like opens up for products that can use properties such as sharp edges and stable forms, but also influences the design process by enabling ways of working that take advantage of these qualities, such as sketching by folding the textile. Thus, from a textile design point of view, the product design process that the textile is involved in also is an important part of the product-textile relationship. However, it is not always certain that the product and/or the product design process are/is known or considered when designing textiles for products: Textiles can be designed with a certain product and/or product design process in mind - this is generally the case when textiles are designed within the product design process - or commissioned for a specific product or use. However, textiles are often designed separately from a specific use, e.g. when textiles are designed to be sold by the metre, for a type of application, or for no specific application at all. The same material will then likely become part of several types of products and, as a result, several different product design processes.

As such, textiles can be designed while both connected to and separate from the context that they will eventually become part of. An essential element in defining what the relationship between the textile and the product is (from a textile design point of view) therefore becomes to look at to what extent the ‘product’ and the ‘product design process’ are present and borne in mind during the textile design process. Thus, to answer the question “in what form do the product and the process become part of the textile design process?”, the first step is to consider how they feature in the textile design process, i.e. to define the connection between the textile decisions that are made in relation to the product and the product’s future use. In order to do this, the form of product/process that textile design decisions are made in relation to is divided into three categories:

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Figure 10. The visual model above depicts discrepancies relating to the textile influence between the design process and the product in the example ‘Scale’: In the process, small textile samples were used to sketch and develop the form, and the product’s design was influenced by the properties of small textile samples. The final product, however, required a significantly larger piece, and as such it was the properties of the textile in this larger scale that influenced the final product.

Figure 11. The visual model above depicts discrepancies relating to the textile influence between the design process and the product in the example ‘CAD’: In the process, the product’s design was mainly influenced by the visual appearance of a textile’s surface. In the final product, however, the full properties of the real textile instead influenced the design.
TEXTILE / PROCESS / PRODUCT

**Defined product/process**
Here, the product/process is defined during the textile design process, meaning that the requirements of the textile material in the product/process are known and can be considered when making design decisions. This may e.g. include scenarios in which textiles are designed in relation to a known, specific piece of furniture with a defined expression and use, or are designed in relation to a product design process in which the textile will enter relatively late, when most of the product is defined and there are few possibilities for altering other aspects of the design.

**Undefined product/process**
Here, the product/process is undefined during the textile design process. This means that the requirements of the textile material in the product/process are not known, and therefore cannot be considered when making design decisions. What the textile could be used for in a product/process is thus left outside of the textile design, and is for others to decide.

**Directional product/process**
Here, the product/process provides a direction during the textile design process. This means that the requirements of the textile material in the product/process are not known; instead, the textile is designed in relation to a type of application/use or process, which is defined during the textile design process. This may include scenarios in which a textile is designed as an upholstery material for furniture for the contract market (product), or is designed in relation to a type of process within which the textile enters as a tool/medium when designing furniture.

Whether the product/process is defined, undefined, or directional influences the extent to which these aspects are present in the textile design process, but also provides information as to the degree to which the textile design can be customised for its future use. Different types of products and processes require varying degrees of tailoring in order for the textile and product/process to work together. Depending on how important the customisation of the material is within a given design context, the presence of different forms of product/process can be more or less suitable. The effect that defined, undefined, or directional products/processes can have on the textile design process and the textile design’s connection to its future use can be seen by comparing design processes with differing product and process presence:

In the Recurring Patterns project (Nilsson et al., 2011a), an interactive textile surface was created and incorporated into two pieces of furniture (figure 12). In the textile design process that created the smart textile system in question, both the product and the process were defined. The knowledge that was acquired at the start of that process regarding the function, construction, etc. of the product in question, as well as how the textile would be incorporated into it, meant that the textile could be designed in relation to its future use to a high degree. Thus, it was possible to create a textile that would work with both the specific design of the furniture and the requirements of the product design process. Thus, textile decisions such as the scale and the placement of the printed patterns were designed so as to work with the shape and size of the furniture, and decisions regarding how the interaction with the textile would take place were made in relation to the product’s main function, i.e. to be something that one sits on, and therefore pressure sensors that could cause the surface to change were incorporated. The nature of the product design process that the textile also was designed in relation to meant that the textile and product had to be combined almost exactly as they were, with very little room to alter the design of the furniture to suit the requirements of the textile. Thus, the defined product and process, and the clear requirements of both, meant that it was possible to create a textile that would work with the design of the furniture but which also had significant limitations in terms of what the textile design could become.

Figure 12. Recurring Patterns project.

An example of a different type of textile design process, in which the product design process was directional and a central consideration in the textile design process, while the product itself was completely undefined and thus essentially ignored, can be found in the more experimental Open Structures project (Nilsson, 2015a). Part of the aim...
of the project was to explore what it could mean to design a textile in relation to a process while not factoring in the possible future use of the product. Thus, the textile was designed around a way of working with textiles in the product design process that was selected specifically for this project, in a manner similar to the dialogue approach as described in ‘Designing with Textiles’ (Nilsson, 2014a). The textile was designed to be altered in relation to the design of the product it would become part of through hands-on interaction with its properties and expression (figure 13). Textile decisions were as such made in relation to the requirements of the ‘directional process’, e.g. the components that constituted the structure were designed to enable different types of alteration, and were made in a size that would make it easy to work in a hands-on manner with the structure. The undefined ‘product’ of this textile design process meant that the textile was not designed in relation to any specific use in a product. Consequently, the suitability of the textile in future products was never considered.

Figure 13. Open Structures project.

Regardless, whether the product and process are present, the form they take, and whether this changes over the course of the process, will defining what the product and process are, provide important clues as to the character of the relationship in the textile design process. The wide range of techniques, properties, visual appearances, etc. of textiles mean that they can be used in many different types of products and various contexts, ranging from applications where the physical properties and performance are crucial, to products where visual appearance and tactile feeling are of far greater significance. The flexibility and adaptability of textiles mean that they can take part in many different types of design processes in different settings, from products made by a single designer in small quantities to mass-produced products designed by large companies, with numerous designers with different responsibilities. The openness of textile materials also make it possible for them to play different roles in these processes, from being a detail with little influence over other aspects of the design to being a dominant factor, with the textiles’ properties and expression informing and steering the design of the product. As such, in order to design a textile that will function well in its future use, it is not sufficient to simply state whether the product and process are defined, undefined, or directional; rather, the demands and requirements that these states involve must also be considered. The following questions and visual model can be used to examine in what form the product and the process become part of a given textile design process, and whether this changes over time. The examples from above are here introduced in the visual model (figure 15).
Question: In what form does the product/process become part of the textile design process?
Which form of product/process are textile design decisions made in relation to?
- Defined? If so, how is the product/process defined?
- Undefined?
- Directional product/process? If so, how is the product/process direction defined?

Method: In the model, mark the form of product/process that textile design decisions are made in relation to, as well as if and how this changes over the course of the process:

<table>
<thead>
<tr>
<th>Inside the textile design process</th>
<th>Outside the textile design process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defined Product</td>
<td>Defined Process</td>
</tr>
<tr>
<td>Defined Process</td>
<td>Defined Process</td>
</tr>
<tr>
<td>Directional Product</td>
<td>Recurring Patterns</td>
</tr>
<tr>
<td>Directional Process</td>
<td>Open Structures</td>
</tr>
<tr>
<td>Undefined Product</td>
<td>Sample collection</td>
</tr>
</tbody>
</table>

Part II: Textile Design Perspective

How are the product and process approached?

As has been asserted previously, a textile can be designed with or without knowledge of its future use in products; possession or lack of this knowledge determines if the textile can be designed in relation to that use, but it does not determine to what extent the requirements of the product/process will be given room to influence the development of the textile. When designing textiles for products, the product and the process, along with the requirements and considerations that come with them, can be approached in very different ways, and in relation to this have more or less influence on the development of the textile design. It is what the textile designer considers to be central to the design that will here be given the most room to impact the design. This can, depending on the circumstances or interests of the designers involved, include decisions and considerations that are connected to the product and process, but this may not necessarily be the case. The textile’s design can just as easily be steered by other considerations or intentions, such as creating a fabric with good quality, or innovative construction.

To be able to consider how the product and the process are approached, it is necessary to first look at which design decisions are connected to these two aspects. Product- and process-related decisions can be concerned with defining what the product and the process are, e.g. deciding that the fabric is for home furnishings, or that it should be used in a process in which its design will be developed further by another designer. Moreover, decisions that are made in relation to the product and the process, i.e. those directed towards these two aspects, should also be considered when examining how much influence the product and the process have on the development of the textile. Design decisions that are directed towards the product are intended to create a textile with an appearance, construction, tactility, etc. that will work with or add something to the product or context in which it will be used. In other words, these are decisions that deal with what the textile should contribute to its future application. If a light blue colour were to be selected for a product, the textile designer’s reasoning could be something along the lines of: “This blue colour has been chosen to enhance the product’s visual appearance, and to give it a soft yet bright visual expression. The exact tone of blue was selected to enhance the shape of the product, and to work well with the more intense colours that will be added to the product’s surface in the form of decorative seams and printed details”. Design decisions directed towards the process, on the other hand, are related solely to how the textile will work as a design material in
a product design process. These could consist of e.g. decisions that deal with creating a material that could work as a tool in a process by being especially formable, or that result in the creation of an alterable structure that could be re-designed or further developed by another designer. If the same light blue colour were to be selected in relation to a design process, the textile designer’s reasoning could instead be: “This blue colour has been selected to enhance the textile as a material and tool in the design process. The exact combination of black, white, and a touch of red in the blue tone was chosen so that the textile could be used as a neutral sketching material, with the possibility of adding other colours, patterns, and details without the risk of clashing with the original design”.

The main difference in character between different approaches to the product and the process can be found in the degree to which these issues are allowed to influence the textile design. One way to explore this is to look closely at how and when product- and process-related decisions come into the process, and what type of influence this opens up for. The model based on Jones’s (1992) division of the design process into three phases (divergence, transformation, and convergence) was used in the product design perspective section of the framework to examine the degree of influence textile decisions and materials had over product design processes. This model can also be used to look at what type of influence process- and product-related decisions have when designing textiles; whether the product and process are explored in the divergence phase and become part of the knowledge, ideas, and possible design decisions that form the basis for the development of the textile design, if they are part of the design direction that is developed during the transformation phase, and as such direct what the design will become, or whether they enter the process in the convergence phase, when the rest of the design has been defined and consequently have very little influence over the development of the textile design. Moreover, the degree to which product- and process-related decisions are prioritised when design decisions clash clearly illustrates the relative importance of these issues in the process, and adds to our understanding of how the product and the process are approached in a textile design process. Textile design processes in which such clashes are dealt with by selecting the options that work best with the product’s requirements are as such much more likely to be processes in which the product has a strong influence, as compared to those in which other decisions, e.g. those dealing with producing fabric of a good quality, are prioritised.

In summary, different ways of approaching the product and the process in the textile design process enable both to have more or less impact on the development of the textile. As such, the choice of approach has a strong impact on how much the textile is designed in relation to its future use in the product and the process, in that it determines how much the requirements of each are considered and allowed to influence the textile’s design. This can provide a picture of which aspects of the textile design are given room to be explored and developed, as well as how well the properties and expressions of the textile will work with the contexts that it will be used in. In the following two examples of a design process, the product and the process are approached in very different ways, which had a clear effect on how the textile design process unfolded as well as what the overall outcome of the design process was:

In the Recurring Patterns project (Nilsson et al., 2011a), the product and the process were present (defined) when designing the transformable interactive textile surface. The requirements and potential that came with the product and the process here worked as a form of reference point for the textile design: They set limitations and frames for what the design could become, but were not one of the main drivers or considerations in the process. Rather, the focus was placed on the potential of the smart materials utilised in the project - specifically how they could be used to create programmable surface expressions and open up for interactions – thus this came to exert the greatest influence over the development of the textile design. The restrictions of the product and the process were initially explored (divergence), which provided an understanding of what they would mean for the textile’s design. However, much more time and effort was spent on exploring and developing the potential of the textile system (divergence), and the ideas that were developed there formed the core of the design (transformation). When defining the specifics of the design (convergence), some of the textile design decisions were adapted to the requirements of the product and the process, but most often they were made based on neither. For example, the details of the printed patterns were adapted to the shape and size of the furniture, but the two types of pattern were selected because they had different degrees of complexity and so made it possible to explore some of the potential of this type of smart textile. The product and process as such influenced the design, but decisions that were made in relation to them were still not part of the central set of decisions. Clashes between decisions, depending on the nature of the clash, sometimes resulted in changes to the textile or to the product- or process-related decisions. This way of approaching the product and the process enabled a functional meeting between the design of the textile on the product and the product itself. However, it also meant that
compromises were made on both the level of experimentation of the transformable smart textiles, and in the meeting between the textile and the product; the connection between the transformable textile’s expression and the product’s form and use was not considered fully, and created a more limited result as compared to if this aspect of the textile design process had been in focus.

In the Open Structures project (Nilsson, 2015), the aim was to develop 3D printed textiles, the properties and expression of which could be adapted in a product design process. The ‘process’ as such became a very significant part of the textile design process, whereas ‘future use in products’ was entirely left out of the textile design process. Exploring ways of combining alterability and 3D printed structures was a very important part of the foundation of the design, and it was here that most of the effort was expended (divergence). Ideas and possible design solutions that were developed through this experimentation became a central element of the textile design’s direction (transformation), and as such had a strong impact on the decisions that were made when defining the structures (convergence). Any clashes with the process-related decisions were, unless they had to do with the ease of production of the textile, handled by retaining the process decisions and changing others. This way of designing a textile meant that it was possible to put time and effort into exploring and developing a structure that could work with the intended type of product design process. How the textile’s design would work in a future product was, however, not considered at all, and as such this had no influence over the development of the product. This type of approach, where the product is excluded to a great extent, relies on the openness and flexibility of the textile design, in that a textile can have many different applications, or can be adapted or altered to accommodate usage in different design contexts. This approach is as such more suitable to textiles with flexible and adaptable qualities, and can be more difficult in relation to textiles that are less so. As regards the latter, this approach could result in textile designs that are incompatible with any product except for those designed specifically for using the qualities of that textile.

The method and questions that were introduced in the product design perspective section above – means of considering how the product and process are approached - can also be used to explore the focus that is placed on product- and process-related decisions when designing textiles for products. The key parts are here repeated, and the examples of textile approaches that are described in this section are introduced into the visual models (figure 16-17).

**Question:** In what phases in the design process do product- or process-related decisions influence the development of the design?

Are product- or process-related decisions present in the divergence, transformation, and convergence phases?

**Method:** In the model, mark the phases in which product/process-related design decisions become part of the textile design process and can influence the development of the textile’s design.

(For further instructions see pp. 16-17)

**Method:** In the model of the gradient circle, mark how central/influential the product/process is in the textile design process.

(For further instructions see pp. 17)

![Figures 16-17. The visual models above demonstrate how product- (blue) and process-related (green) design decisions become part of the textile design process, and how central the product and the process are to the development of the textile’s design. First, the Recurring Patterns design process; second, the Open Structures design process.]
TEXTILE / PROCESS / PRODUCT

part II: textile design perspective

How do the product and the process influence the textile design and the textile design process?

When designing textiles for products, the textile design and the textile design process are influenced by the fact that the textile is designed for products. Similarly, the product design process that the textile is part of on its way to being incorporated into the product also has an impact; this is especially true with regard to the potential interaction that the textile material brings with it, as it is often here, in the meeting between textile and the product, that the textile design is finalised. Together, the product and the process influence the textile design and the textile design process by creating requirements and setting frames for how the textile design can be designed, but they also influence what type of design the textile design is and, in so doing, bring certain types of consideration to the process. However, as described above, the product and the process, along with their specific criteria, are not always part of the textile design process. When this is the case, the product/process still influences the textile design process, it does so not by providing direct requirements or demands, but instead through the fact that the product/process is unknown and therefore cannot be considered. The following text introduces two perspectives which can be used to look at what the influence of the product and the process can mean when designing textiles for products.

Textile influence

The qualities that come with textiles as design materials, e.g. pliability and context-sensitivity, together with the unique properties and visual and tactile expressions that come with each textile, influence how a textile can be worked with in product design processes and which products can be created with it. The terms ‘textile influence’ and ‘design affordance’, as previously discussed, are used in the product design section of the framework to describe the influence that textiles have in product design processes. However, these terms can also be used to describe what it is that a textile designer is designing when they are designing textiles for products. The textile design is, when designed for products, not simply the design of the material itself but also of the textile’s influence; the effect that the textile will have on the product and product design process, the possibilities and limitations for the product that it creates and the process that it facilitates, ways of sketching that the material introduces, etc. From this perspective, the influence of the product and the product design process expands the textile designer’s task, bringing new questions and considerations to the textile design process that deal with both the textile as a material in a design and as a material/tool that is part of a design process. What the extended textile design can mean in practice can e.g. be seen in ‘Smart textiles as raw materials for design’ (Dumitrescu et al., 2014), where the design of the textiles not only defined the properties and expressions of the material itself but also enabled some, while hindering other ways of working with the textiles as tools, with some of the textiles opening up for fast exploratory sketches while others enabled development of the textile’s design through permanent changes to the structure.

Open design

Another important point to consider when looking at the relationship between textiles and products in the textile design process is that the design that is created by the textile designer is often altered and developed to suit the unique demands of several different products. For example, can a textile that was originally designed to be a woven polyester fabric of one colour be transformed into a highly patterned and expressive textile to suit one product, but just as well be pleated so as to be more textured and have a greater volume to suit another product. Here, the textile designer’s decisions define the material’s original state, but also determine how it could potentially be transformed when placed in another design process. From this perspective, the influence of the product and the process make the potential transformation of the textile design a more central issue, and consequently make considerations that deal with the alterability of the material more important to work with. The fact that textile designs can take on many different forms depending on the product and product design process that the textile is involved in, all while retaining some of the features of its original design, resembles what is done within the field of ‘open design’. The meaning of the term can differ depending on the context; here, it refers to designs that do not have a permanent form, but can be expanded and re-defined by someone else (Lamontagne, 2013). One way to deal with the openness of textiles in relation to their future use in products can as such be to consider the textile design to be a form of open design, and so to utilise some of the thinking of that field. Thus, instead of designing the textile as a static element, one should acknowledge the fact that the material’s properties and expressions can be transformed, and design the textile with this openness in mind. One of the key ideas of open design - to consider the design as a system or a meta-design – is of particular use with regard to this, as such an approach essentially is about creating openings but also restrictions for design decisions and thereby defining how
the design can be developed (Stappers et al., 2011; de Mul, 2011). The designer’s task is then to create a design which retains some of the character of the original design, but still allows the user - in this case a product designer - the freedom to take the design in new directions (Atkinson, 2011). When the design of the textile enters into the product design process in this way, the textile design decisions define the original design, but they also frame the possibilities and limitations for further development of the material. For example, as regards a piece of Jacquard-woven wool fabric with a geometric pattern made from black and white yarns, the surface design (its colour and pattern) can be changed during another design process by dying it, adding additional elements to the prints, etc. The structure of the fabric can also be changed, e.g. by making it denser by felting the fabric. However, the fact that the fabric is woven, constructed with a satin binding, and made from wool yarn cannot be altered, and none of these elements can be removed. As such, this way of looking at the openness of textiles influences the character of the design decisions that the textile designer deals with, but it also opens up for new and interesting considerations: For example, what does the designer, through their textile design decisions, want to define in the original design and in relation to other possible versions? What do they want to leave open for someone else to develop? What directions in the textile design do they want to open up for, and which do they want to restrict? An example of a textile design process in which the open design perspective has been used to actively design the textile in relation to its future alterations in a product design process can be found in the Open Structures project. There, the design task included not only designing the textile’s original properties and expression, but also the range of possible versions that could be created with it. To do this, the design was thought of as a form of textile system, with the textile designer selecting the parts of the textile that should remain as they are, which should be alterable, and to what extent (Nilsson, 2015).

Depending on the setting of the textile design process, as well as that of the future product design process, one or a combination of the design affordance and open design perspectives are the best way to describe and/or consider the influence of the product and the process. The open design perspective is most relevant when designing textiles for processes in which the textile’s properties and expression will be developed further, and is less useful when textiles enter the process as a finished element. The design affordance approach is especially relevant when the textile will be used as a tool or medium with which to sketch and develop the product.

The textile influence and open design perspectives both relate to the fact that the textiles are being designed for products, and that product design processes in general influence the design and which considerations are part of the textile design process. However, the specific product and process also influence the textile design and the textile design process. What this influence is can differ from process to process, depending on the character of both the textile design process and the product or process that the textile will be used in (when this is known). The difference in character is often related to whether the product or process is a part of the textile design process, i.e. the form of product/process that the textile is designed in relation to, as well as the specifics of the product or process. In processes in which the product and the process are known, understanding their influence is reasonably straightforward; the textile’s design and the textile design process are influenced by the demands and possibilities that come with that specific product and/or process. Here, the role that the textile will later have in the product design process is an essential element in defining how strong the influence of the product or process will be. Thus, when a textile is designed in relation to a product design process into which it will come as a detail, with little influence over the design of the product, the requirements of the product will have a strong impact on what the textile can be. Contrastingly, when a textile is designed in relation to a process in which the textile has a strong influence on the product (e.g. a process in which the textile is the starting point), the material’s design and physical properties will steer and inform other elements of the design. The textile design is thus less limited by the requirements of the product, and so the ‘product influence’ is weaker.

As is discussed above, the exact details of the textile design process are not always known. When this is the case, the fact that the product and the process are unknown influences the textile design by bringing new and often complex considerations into the textile design process. First and foremost, how does one, as a textile designer, deal with an unforeseen use of one’s design? Here, both the textile influence and open design perspectives are useful: When the product and the process are unknown, the idea of designing the textile influence and design affordances can help the textile designer to relate to the future use of the material. As opposed to working without a connection to the product or the process, this perspective can allow a designer to consider what the textile should add to products and processes that may use the textile in question – e.g. considering which type of properties or tactile or visual expression one’s textile should provide for products and processes. When the product and the process in the textile design process are unknown, thinking about the textile as an open design can also be relevant. These textiles will most likely be applied across a wide range of contexts in different types of design processes, and be adapted or redesigned in terms of their expression and properties. The open design perspective...
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can here help the textile designer to deal with the unforeseen use by helping them to design a textile that can take on different forms, and as such work in many different contexts.

When the textile designer works with a product or process as an imagined direction (directional product/process), it is primarily the intended product or process that determines the form that the influence of the finished product/process will take. Thus, the influence that is present in the textile design process is to a large extent constructed by the textile designer. There will, therefore, most likely be a difference between what influences the textile's design when designing the textile, in the form of e.g. requirements, and what influences the textile's design when it is eventually incorporated into a product or enters a product design process. This difference is not necessarily a critical issue, as the softness of a textile can make it possible to alter some of the decisions that the textile designer has made, thereby accommodating many of the new requirements of the specific contexts that the textile will be used in. However, this difference can also be problematic, particularly if the textile design is strongly adapted for a specific context which has unique requirements, and is then used in a completely different one. One example of this can be found in the textiles developed for the Smart Textile Sample Collection, as these were designed to be examples of smart textile techniques (Nilsson et al., 2011b) but have since been also employed as sketching tools. This latter application was not considered during the initial design of the textiles and, as such, only a part of the process influence that would affect the textile's usage was considered during the textile design process, in turn influencing the suitability of the designs for their new use. This can e.g. be seen in the textiles with patterns printed using thermo chromic inks. They were intended to be examples of textiles that change their expression when exposed to heat, and were designed to showcase this effect, but they also worked reasonably well as sketching tools. The designs would, however, need to be developed much further with a specific process in mind in order to be truly suitable for this use.

In summary, the influence of the product or process has an effect on which considerations are central, and what type of design the textile designer is dealing with. Not considering the product/process influence when designing textiles for products can mean that the textile brief is partly ignored. Thinking of the textile as a stable and fixed material in the design process, when in reality it will be used as an open design, means that only a small part of the textile's use is considered. When looking at a textile design process, the question of “how do the product and the process influence the textile design and the textile design process?” is thus very important. The answer to that question can be arrived at by looking more closely at both the general influence that comes with designing textiles for products and product design processes, and the specifics that accompany the product or process, be it known or unknown. The following questions can be used to explore what the influence of the product and the process is, and which perspectives could be used to consider and handle it. Moreover, the following method can be used to investigate whether there are any differences between the influence that steers the design of the textile in the process, and one which is present during the textile's actual use. In addition, the example discussed above is introduced into the model (figure 18).

**Question: What is the nature of the product and the process influence?**

Does the defined or the directional product/process influence the textile design and textile design process? If so, how?

Does the undefined product/process influence the textile design and textile design process? If so, how?

Does the product/process expand the textile design brief to include an interaction with the material in the product design process?

- Is the textile designed as a fixed and complete design, or as a form of open/alterable design?

- Is the textile designed as a material for a product design and/or a tool for the product design process?

Is the influence of the product/process strong?

- Does the future role in the product design process influence the required flexibility of the textile design?

**Question: How is the influence of the product/process considered/handled?**

Should the textile design be considered as a form of textile influence/design affordance? If so; in relation to the product, in relation to the process, or both?

Should the textile be considered as a form of open design?
Method: Compare the influence of the product/process within the textile design process and the influence in the textile’s use.

In the model below place the product- and process-related decisions, and the requirements which influenced the textile’s design, in the phase in which they became part of the process (divergence, transformation, convergence). Additionally, place the requirements that influence the textile in its actual use in the last section of the model.

Discussion

Reflecting on how textiles enter product design practices and how products influence textile design practices is always useful. However, it is when dealing with new forms of textiles that reflecting on the relationship between textiles and products in the design process can perhaps be most useful, in that such an exercise can help both product and textile designers understand, handle, and take advantage of the interesting developments within the textile field. This chapter begins with this reflection by looking at what new materials and techniques, such as smart textiles and additive manufactured textiles, can mean for the product-textile relationship, using the perspectives on the relationship that are introduced in the TEXTILE/PROCESS/PRODUCT framework and by revisiting some of the examples that have been presented in this paper. The chapter ends with a short discussion of the design of the framework itself, as well as how it could be developed further.

Product design perspective

Different approaches to textiles are more or less suitable for different types of designs, design processes, and designers; each approach requires a different level of textile knowledge/experience, access to textile equipment, development of new materials, etc. One of the most common ways of designing products with textiles involves textile materials and design decisions entering the process as a minor detail, often designed separately from the product and introduced as a surface material at the end of the process. This way of working relies to a great extent on the openness and flexibility of textiles as design materials, e.g. the fact that it is easy to find and replace suitable materials and to alter the textile element in the design. The openness of the material is as such one of the core qualities of textiles as design materials in this type of design process, and changes in this aspect can have interesting effects on how these textiles enter the product design process. Developments in the textile field have opened up for new functions in textile products, with the textile being far more than a surface and also offering complex functionalities. However, with these properties and possibilities come components that are not ordinarily associated with textiles, e.g. conductive threads, electronics, and micro-processors. One of the consequences of these components becoming part of textiles is that some of the flexibility, adaptability, etc. that enable textiles to be worked with freely is reduced. In the Recurring Patterns project (Nilsson et al., 2011a), the programmable textile surface was incorporated into an existing furniture design in collaboration with the furniture producer IRE. The common practice within IRE is to not design or select a specific surface material for a product, but to instead leave that part of the product open for the customers to decide upon, and to provide general guidelines to assist this choice. This way of working, however, relies on textile suppliers etc. to provide customers with a wide range of textiles that are flexible, easy to sew, and that can be placed on various shapes. The composite textile that the Recurring Patterns introduced into their furniture, however, contained conductive threads, microprocessors, colour-changing inks, etc., meaning that it could not be cut, sewn, or freely placed on the product, as would normally be the case. To deal with this, the design of the furniture, as well as how it was produced, was to some extent adapted to accommodate the requirements of the textile. This way of
working with the textile in relation to a product also meant that there were limitations in place regarding what could be achieved with the textile, and only some of the potential of that form of smart textile could be realised. To fully take advantage of the possibilities of the smart textile technique, the design process and more particularly the way that the textile and the product were combined had to be different. With this type of textile, as well as with other, new types, it is as such relevant to consider not only how to incorporate these more demanding materials into products, but also how this incorporation should take place within the product design process. One interesting option is to move away from practices where textiles come in as details, and to instead let these materials play a more dominant role in the product design process. For example, working with the textile as a starting point, or as a component which is developed in dialogue with the product, and giving the textile a strong presence in all of the phases of the process, means that the less flexible properties of the textile are able to strongly influence the product’s design (figure 19). To open up for new and more innovative or unique textile solutions in products, the form of textile design decision in the product design process also needs to be altered so as to include the design of these textiles within the product design process, e.g. moving from a process which deals with specification of textile properties- as is the case with IRE - to a process in which textile decisions are made in the form of constructions or alterations.

New textile technologies can also have a very different effect on the textile product design process, by making the textile as a design material even more open and alterable in relation to the product as compared to conventional textiles. For example, many smart textile techniques and other transformable textiles make it possible to change the textile’s properties and visual expression, either permanently or temporarily, through interaction with the material. The textile structures that can be created using 3D modelling and additive manufacturing also have the potential to be changed in their design and adapted to products, particularly if the alteration of the textile’s design is performed using a CAD program. Thus, these new techniques, as well as opening up for interactive textile products, also open up for new ways of interacting with the textile material’s design during the product design process. In doing so, they e.g. open up for processes where the textile, to a higher degree than with conventional textiles, is adapted in its design to the product’s specific requirements, where the product and the textile inform each other and develop in dialogue. With 3D modelling of textiles this dialogue could become very detailed, as the design of the textile is not limited by any specific textile technique and therefore can be altered right down to the details of its construction (Nilsson, 2015). Moreover, the new forms of alterability that come with some smart textiles also open up for using textiles in new ways as design tools in the product design process, e.g. by making it possible to explore many options in the same piece of material, and to re-design the textile permanently by manipulating it using both analogue tools and digital interfaces. This use of transformable textiles in the product design process was initially explored by Dumitrescu et. al (2014), but could and indeed should be explored much further.

In summary, these new textiles have the potential to influence how we design with textiles by altering the character of textiles as design materials. In many cases this is achieved by bringing a different type of textile influence to the process as compared to conventional textiles, thereby going against what one would normally expect with textiles that are less open and flexible; in other scenarios, this is done by exaggerating what the textile is as a design material by making them even more flexible and so introducing new ways for other designers to interact with the textile in the design process. Thus, to take advantage of what these new forms of textiles can do in products and in relation to the design process, an awareness of the relationship between textiles and products in the design process is central. The framework and the examples presented here from previously published papers can help to paint part of the picture, but further exploration of what type of textile influence these new forms of textile bring to the design process, along with which ways of working with them that best handles and takes advantage of this influence is also needed.

Figure 19. A common practice when designing products is for textile decisions and textile materials to enter the process as a detail, selected or designed based on other design decisions. How textile design decisions participate in this type of process is illustrated by the placement of the orange circles in the diagram above. In scenarios in which new technologies make textiles more demanding, knowledge about the materials’ potential and requirements is essential, as well as letting the textile part of the product influence the development of the design. This means that textile materials and decisions need to be elements of all three of the phases of the design process, as illustrated by the placement of the black circles.
Textile design perspective

One of the key facets of the textile perspective presented in the framework is that the product design process that the textile influences is an important part of the textile-product relationship. Thus, to obtain a complete picture of how the product and the textile meet, the product design process needs to be considered. An important part of considering the product design process relates to acknowledging the openness of one’s textile design, that the design is not fixed when it leaves the textile design process but can take on many other forms. Most textiles can be altered quite dramatically in terms of both their properties and expression when they enter another design process; for this reason, giving due consideration to the process and the openness of the textile that comes with it is important when designing most textiles. However, this perspective on textile design becomes even more essential in relation to some of the developments that have been made in the textile field, as these techniques and raw materials in many ways expand the openness and alterability of textiles by introducing new and more dramatic transformations, and make it possible for textile designers to define how and where these changes in properties and expression should take place. These developments thus, in addition to enabling transformable and interactive textile products, have the potential to open up for more fully designing the interaction with the material that takes place in the product design process. For this type of textile to be created, the process side of the relationship cannot be ignored; instead, the textile designer needs to reflect on how to include the process and its considerations within the textile design practice (figure 21). An example of a textile design process in which the product design process was a central consideration can be found in the previously discussed Open Structures project (Nilsson, 2015). Here, instead of working with a static textile, the focus was on how to ensure the alterability and openness of the textile. An important aspect of achieving this was to give the process, and more specifically the interaction that takes place in it, a central role in the process. Designing textiles with a great transformability can as such open up for transforming the textile design brief: Making the product design process, the textile’s design affordances, and the openness of the textile design more important when designing textiles for products.

However, the raw materials, components, and techniques that enable new expressions and interactivity in the material also bring with them the need for new skills and considerations. For example, knowledge of electronics and programming is often needed in order to design smart textiles, and knowledge of 3D modelling and additive manufacturing is needed to work with 3D printed structures. Moreover, the increased emphasis on the process that these materials can open up for also requires the textile designer to become more familiar with this side of the relationship. To really work with and consider the product design process requires an understanding of that type of process, and how the textile’s design influence and interact with it. In order to develop the textile design practice in relation to these new types of textiles, it therefore becomes important to not just focus on the material itself, but to explore and obtain a better understanding of how these textiles can influence the product design practice.

Figure 21. When designing textiles for products, the textile designer often does not consider the product design process. However, new textile technologies open up for designing the alterability of textiles; in doing so, several of these techniques could make the product design process a much more central consideration within the textile design process.

Reflection on the framework:

All design processes are unique, and all descriptions of them are simplified versions of what are often messy, complicated series of actions; these descriptions can therefore struggle to offer a complete picture of what takes place when designing - and this extends to the framework presented here. What we look at in a process and how this is done has a great impact on the version of the process that will be portrayed, and so the numerous ways in which design processes can be described and analysed with what has been created up to this point have different strengths and weaknesses in relation to different design contexts, areas of interest, etc. (Dorst & Dijkhuis, 1995). Within the extensive research area of material and design, there are many perspectives on and frameworks and methods for describing design processes in relation to materiality. Some of these focus on the design process in a specific context, or in relation to a way
of approaching materials, and thus provide a way of looking at a material in a specific setting (e.g. Townsend & Goulding, 2011; Pedgley, 2009). Others evaluate specific working methods or promote particular ways of working (e.g. Jacucci & Wagner, 2007; Ashby & Johnson, 2010). The framework and accompanying examples of design processes that are presented in this paper differ from these, in that they do not focus on a specific approach to materials in the design process or a specific type of product or context and, moreover, do not directly suggest a specific way of working. Instead, it is hoped that this framework will open up the subject and highlight the importance of reflecting on how to design products with textiles and textiles for products, and to consider the impact that the nature of these design processes has on the resulting designs. The choice not to focus on a specific working method or context does, however, afford the designers or other practitioners using the framework less direct answers as compared to many other frameworks and perspectives. As a result, the questions that are raised are potentially more challenging, and require more of the person who is using the framework. In addition, the framework in its current form is quite complex, with multiple perspectives, questions, and methods; on the other hand, this makes it possible to go into detail regarding the relationship between textile design and product design but, on the other, could make the framework less accessible and more difficult to grasp. The framework is built on real-life examples of textile product design processes, and some of these examples are here also used to illustrate how it could be used. However, other designers have as yet not used the questions and methods in the framework in order to analyse real-life design processes. Further development of the framework would be an important next step, and this development should involve in some way subjecting the framework to the complexity of such real-life processes, e.g. by putting them in the hands of designers or design students.

References


