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TEXTILE INFLUENCE:

EXPLORING THE ROLE OF TEXTILES IN THE PRODUCT DESIGN PROCESS

LINNÉA NILSSON

UNIVERSITY OF BORÅS
STUDIES IN ARTISTIC
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ABSTRACT

Textile materials and textile design are a part of countless products in our surroundings, as well as of diverse design fields and industries, with very different material traditions and working methods. Textile materials and industry have undergone many changes during recent decades, in terms of how and where textiles are produced, and what textiles can be and do; in much the same way, the design practices that textiles are involved in have also developed. What these diverse and evolving design contexts in which textiles are involved in have in common is that textile materials and textile design decisions somehow meet the rest of the design during a design process. 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 the roles that textile design plays when designing textile products, the roles they can come to play when textiles become more complex and offer new means of functionality and expressiveness, for example through smart textile technology.

This thesis presents two types of result: Firstly, descriptions of textile product design processes that highlight the wide range of roles that textiles can play in the textile product design processes of today, accentuate how textile materials and design decisions can influence both what can be designed and the design process, and describe some of the additional complexities that come with designing and designing with smart textiles. These examples are presented in the appended papers, and are the outcome of an observation of students who were designing textile products and collaborative, practice-based design research projects. Secondly, this thesis presents a theoretical framework which aims to offer a broad perspective on the relationship between textile design and the product design process, with the intention of opening up for reflection on how we design, and can design, with textiles. The framework focuses on how textile design decisions and textile materials participate in the process, and to what degree they influence the development of the design; this includes methods, questions, etc. that can be used to explore and define this dynamic. One of the main points of the framework is the importance of the textile influence in textile product design processes; the specific qualities of textiles as a design material - the considerations, possibilities, and challenges, which influence both the design of the product and the process of designing it. This includes not only the textiles in the final design, but also the textiles that, in other ways, feature in this process.

CONTENT

INTRODUCTION

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, where textiles, wood, glass, etc., realise the designed object, and through their properties and expressions, and how these contribute to the design process, influence which designs can be created. 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 this understanding 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. Textile materials and 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, e.g. due to increasing digitalisation of the design process, through improved CAD programs (van Bezooyen, 2014). Thus, changes in both the textile and product design field influence what and how we can design with textiles. Moreover, as textile materials, techniques, and industries change, it is important not only to focus on developing new products, but also to re-examine and develop how we design products with textiles to fully realise the potential of both traditional and new materials.

INTRODUCTION

Each material introduces certain aesthetic and functional possibilities (Manzini, 1989) through its visual and tactile expression and material behaviour; these influence what the textile can be used for in a design and open up for possibilities for the material as a medium/tool in the design process. In textile product design processes, design decisions regarding function, form, etc., along with textile design decisions and properties meet and set restrictions, but also open up for possibilities and influence each other and the development of the design. The interaction between the textile and the rest of the product is, from this perspective, a relationship, which is influenced by what the textile can do in the product and process and how the designer approaches the material when designing. These relationships each have their own considerations, opportunities, and challenges; as such, they will influence what types of textile product can be designed, and will be more or less suitable for different types of design contexts. The combination of the wide range of practices in which textile design is involved and the fact that textiles can enter the process as anything from a complete, finished material to something which is designed in great detail as a part of the process, opens up for a broad spectrum of relationships in the design process; here, textile materials and design decisions are given varying influence over the development of the product. The following fictional examples illustrate some ways in which textile materials and textile design can come into the product design process:

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.


WARNING ADVERTENCIA
chicco

INTRODUCTION

Imagine this car seat for a baby, sitting in the back seat of a car. The car seat has a medium 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 first was 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 lot 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. 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.

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, i.e. the textile product design process. 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 licentiate thesis; how does textile design enter into other creative 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?

The research theme / programme

In order to develop the practice of designing with textiles in a direction that can take advantage of the potential of both traditional and new forms of textiles, so that it can encompass both the current diverse roles of textile design and the new relationships which transformable materials such as smart textiles open up for, it is important to reflect on and develop the relationship between textile materials and textile design decisions in the product design process. 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 textile products, 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 a design process, we also need to closely examine the relationship between textile design and the product design process. Here, it is interesting to consider traditional textiles in relation to the product design process, but also new forms of textiles, e.g. smart textiles, as these textiles, through their new properties and considerations in the design process, challenge current practices and have the potential to open up for new ways of designing with textiles. 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). Explorations of this subject, which examine and describe the ways in which textile design and the product design process 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 which, for this licentiate thesis, is formulated as follows:

This research project explores the role which textile design plays and can play when designing products. The aim of the work is to gain a better understanding of the relationship, develop a framework for discussing the subject, and explore what roles textile design could play in product design processes when textile materials become more complex and offer new means of functionality and expressiveness. What the various relationships of today have in common is that textile materials and textile design meet the product during some form of design process. For this reason, the focus of the research is on how textiles and the rest of the product meet in the design process.

BACKGROUND

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 in the design practice of today (Manzini, 1989). The increasing digitalisation of the design process and the development of computer aided design (CAD) tools have opened up for further separation from material in the process (Ahlquist & Menges, 2011; Moles, 1995; van Bezooyen, 2014). Exceptions exist but, in many CAD programs, materials are worked with as 'skins', 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 opening up for more effective design processes and more complex forms, and on the other leading 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 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 (Berlinord, n.d.), Vík Prjónsdóttir (Prjónsdóttir, n.d.), and Periphere (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 three-dimensional 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 homogeneous 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 CAD 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 in regard to materials in the design process relates to viewing materials simply as minor details. Materials are, from this standpoint, a consideration that should be 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: "In the traditional design process, material selection is a process that takes place at the later 'develop' stage where the material selection criteria are defined by context of manufacturing and costs to realize an already mature product concept" (van Bezooyen, 2014, p. 281). 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 in this perspective. As such, material selection has been a large area of interest when looking at materials and design, especially within the field of industrial design; e.g., developing and testing methods and strategies for selecting appropriate materials in the design process (Ashby & Johnson, 2010), looking at designers' information needs when selecting materials (Karana et al., 2008), and stakeholder (clients, manufacturers, users, etc.) influence 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 base 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), and is sometimes described as a path to product innovation (Fischmeister, 1989). Research that relates to this perspective does so by e.g. exploring ways for designers and material experts to collaborate so as to create new uses of 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 explores dynamic patterns in textile design, and Nimkulrat's research 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 (Doordan, 2003), and designing becomes

a form of collaboration with the materials (Mazé, 2007). This is similar 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 (e.g. materials) interact with one another and influence the development of the design (Schön, 1992, p. 3). This perspective relates to several design areas, e.g. the material thinking related to art practice described by Bolt, where materials should be considered as active and equal actors in the creative process (Bolt, 2007), and Oxman's experiments in product design and architecture, where material design and structure play an important role 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 and Morrison's term "design affordances" in its original usage refers to the technology in RFID-tags, 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 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 that are described above illustrate some of the dynamics in the relationship between the designer and the materials that they work with. This relationship has two perspectives: Firstly, that of the designer: how they view, approach, and work with material 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 looking at the relationship and the role of the materials in the process, and are as such 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 designed/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). To what degree and in what way the fabric is designed has an impact on the design process and what can be designed in it, as each way of designing the textile opens up for more or less unique textile solutions and requires more or less time spent on the textile part of the product, textile understanding, and skills.

The textile component of the product can also be given more or less influence in the process by the designer and, as a result, can play very different roles when designing; it may be a material which is selected, specified, or constructed 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 CAD 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 Heimdahl et. al, which describes how textiles were used as prototype materials in three-dimensional model-making in architecture workshops to materialise, illustrate, and develop design concepts (Heimdal, Lenau & O'Mahony, 2012). 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, 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).

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 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 (Ahlquist & Menges, 2011).

Textile properties can differ significantly, depending on the exact design of the material and how it is used in a design. As a result, considering textile behaviour is particularly important to material thinking in the textile product design process. 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 smart textiles and the design process

The development of smart textiles and other transformable textiles, e.g. colour-changing pigments and shrinking yarns, has expanded some of the inherent open qualities of textiles and, in doing so, opened up for new types of textile products, as well as influencing how we can design with (smart) textiles.

Smart textiles are textiles with dynamic/transformable 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 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 areas, smart textiles have primarily been used in fashion and sportswear (Berglin, 2013), e.g. MOON Berlin (MOON Berlin, n.d.) and Numetrex (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 Kobakant'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.

The openness of textiles in relation to the design process means that the same textile can be used in many different products, and that the same product can, in theory, be made with several different textiles. The openness of textiles has opened up for the numerous ways of working that can be found among designers and industries which work with textile products today. Textiles can, as such, be seen as a transformable and flexible design material, which can be used both in the product and the process, and which is open in its expression and properties. Smart textiles, with their even more transformable properties can from this perspective be seen as an expanded form of textiles, as their properties and expressions have the potential to be altered and adapted to suit product and context in even more ways. However, these materials also bring new or more complex considerations and design variables to designing textile products, which can make textiles less flexible and adaptable in relation to the design process. For example, incorporating the dimension of time into the visual expression of a textile require new types of skills, methods, and collaborations when designing and working with textiles (Worbin, 2010). Thus, the design affordances of smart textiles differ from those of traditional textiles, and in order to design with these materials we need to become more familiar with the old and new design affordances and go deeper into textiles and smart textiles as design materials.

METHOD

Design theory and methodology is defined by Cross as ”the study of principles, practices, and procedures of design” (Cross, 1993), and the resulting theories and models can be a bridge between what we know about designing and what we do when designing (Friedman, 2003). Thus, methodology and design theory can help us question and reflect on our practice, and introduce perspectives or methods with which to develop it (Löwgren & Stolterman, 1999; Hallnäs, 2010; Persson, 2013). 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). To develop practice, we also need to understand practice, and an important contribution in design research can therefore be explorations of fundamental elements of design, and presentation of new perspectives and theories for how to view and consider different aspects of design and the design process (Friedman, 2003). This research project is a combination of these two perspectives, and aims to open up a new design space; exploring and defining ways to look at and understand the diverse and developing relationship between textile design and the product design process, and in so doing possibly open up for new directions in which practice could develop.

Design research process

The area of design research is commonly divided into three categories; research into design, where design and designing are the focus; research through design, where the design process is the research method; and research for design, which refers to research that aims to develop design practice (Frayling, 1993). The research project presented here connects all three of these categories, as it explores design and, more specifically, the design process, and uses designing as a research method, in the hopes of opening up the textile product design practice. The research process was initially focused on finding ways to think about, describe, and discuss the roles which textiles play in product design processes. These ideas and ways of looking at the design process became the starting point and basis for explorations. Different research projects were later used to explore different aspects of the relationship, where some focus on understanding the relationship with conventional textiles, while others focus on the new directions in which practice could develop in order to accommodate and take advantage of the possibilities and challenges that come with new forms of textiles. This was done by shifting the focus between defining and exploring - between formulating the research/design programme, developing theory, and creating design experiments/examples (Binder & Redström, 2006). The theoretical part took the form of

the development of a framework for describing the relationship between textiles and the product design process. The design experiments were carried out, and examples of what takes place when designing and designing with textiles were created through the study of and participation in design processes, i.e. practice-based design projects, and the qualitative study of other designers' practices. Using mixed methods (Creswell, 2007) in this way has made it possible to approach the subject from several angles by exposing the initial ideas to different forms of input. The development of theory was, as such, not only an important part of the result, but also an integral part of the process.

Practice-based design research

Practice-based design research methods have in this thesis been used to explore and define the relationship between textile design and the product design process. Knowledge is, in this form of research, generated through constructing/designing something (e.g. objects, services, spaces); "We are dealing with research that imagines and builds new things and describes and explains these constructions" (Koskinen et al., 2011, p. 5). Working in a hands-on manner with a design, e.g. by dealing with real materials and circumstances, provides challenges and experience that can provide a better understanding of the subject (Vallgårda & Bendixen, 2009). Design theory can grow or develop through practice-based design examples/projects—where initial theory is based on early examples, which is then tested and developed through others; moving from specific to general descriptions and definitions (Zimmerman & Forlizzi, 2008). Subsequently, different projects can play different roles in the research process; some projects are selected or created because they may potentially contribute to the understanding of the subject or add to the theoretical foundation, whereas other projects are built on theory, and are used to explore details and definitions in the theory (Landin, 2009), while others create artefacts/prototypes that, through their design, embody our understanding of a subject and/or propose possible futures or developments of practice (Zimmerman & Forlizzi, 2008).

Observation & analysis

Qualitative methods are generally concerned with looking at phenomena in the world and trying to improve our understanding of them by describing and/or interpreting them. The outcomes thus differ in nature, and are related to e.g. which methods are used, and the subjects that are selected for study (Creswell, 2007). Qualitative methods have been used here to explore the relationship between textile design and the product design process, through studying designers' practices. Observing and analysing real-life textile product design processes made it possible to gain insights into how different ways of designing with textiles influenced the textile products that were designed, and what role the textile aspects of the design had in the process. A MA design course, in which a large group of students were given the task of designing textile products, was selected due to it offering a detailed look at a large number of different design processes. A form of participatory observation and the phenomenographic analysis method were used in the observation and analysis:

Participatory observation

Participatory observation is generally used for in-depth studies of specific phenomena in real-life situations. Participatory observation studies are performed through direct observation and experience of the phenomena as it is, and the researcher should during this type of study, not construct the setting and influence it as little as possible. This type of method is useful in the early parts of an inquiry as it explores phenomena without a specific result in mind; "Participant observation is especially appropriate for exploratory studies, descriptive studies, and studies aimed at generating theoretical interpretations" (Jorgensen, 1996, p. 13).

Phenomenographic analysis

The basis for phenomenography is an interest in describing the phenomena of the world, revealing and describing how it can be seen or experienced. The aim of the analysis is therefore to reveal variation in relation to the phenomenon in question, and then to 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).

APPENDED PAPERS

This licentiate thesis includes three appended papers. The first paper relates to the framing of the research theme, and introduces some of the projects that have been a part of the research process. The other two papers introduce and present part of the research results. The main outcome is a theoretical framework; a perspective on the relationship between textile design and the product design process, which has been developed through the work presented in the appended papers. This perspective on how to consider this relationship includes methods, questions, etc. that can be used to reflect on or plan textile product design processes. The main framework is presented in the section on results and ideas (p.44), but several of the methods and questions are introduced and used in their initial forms in the appended paper Designing with textiles (Paper III). Examples of textile product design processes include different ways of thinking, working, etc.; detailed descriptions of the opportunities, considerations, and complexities that come with designing with traditional and smart textiles are also a part of the research results. The appended papers introduce two types of description: examples of how practice works today, i.e. the result of qualitative methods (Paper III), and descriptions of the added complexities that come with designing with smart textiles, which influence textile product design processes that use these materials (Paper II).

Papers I and II, and the practice-based design projects that these papers build on, were undertaken in collaboration with the other authors. Paper I contributed to the framing of the research programme, specifically in terms of the section which deals with how to design with smart textiles, and I also took part in the 'Recurring Patterns' project and the smart textile sample collection, 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 III, I carried out the observation and analysis, and wrote the paper.

PAPER I

Conference paper: Nilsson, L, Vallgårda, A & Worbin, L. Designing with smart textiles: A new research program. In the proceedings of Nordic Design Research Conference, 2011.

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 the 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.

PAPER II

Conference paper: Nilsson, L, Satomi, M, Vallgårda, A & Worbin, L. Understanding the complexity of designing dynamic textile patterns. In the proceedings of Ambience, 2011.

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, thermochromic 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.

PAPER III

Unpublished paper: Nilsson, L. Designing with textiles.

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. An important point here is that textiles are not only something that materialises the final design, but can also play a more influential role in the design process.

- 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.

The methods that were used to analyse and describe the students' experiences of designing with textiles form part of the foundation for the main framework, which is presented in this article in its initial form. It introduces some of the main elements when looking at the relationship between textiles in the product design process—e.g. defining what the textile design is, by defining the type of textile design decisions that are present in the process (construction, alteration, selection, or specification), and examining what influence textile design decisions have over the development of the design, by studying in which phase of the design process they become involved.

RESULTS & IDEAS

The aim of this thesis was to explore the roles which textile design plays and can play when designing textile products, to open up for reflection on how to develop the textile product design practice in relation to both traditional and new, more complex forms of textiles. This has been done through descriptions of textile design processes, which highlight the wide range of roles that textiles can play in the textile product design process and how textile materials and design decisions can influence both what can be designed and the design process itself. A framework for reflecting on the textile product design process has also been developed, and is presented in this chapter:

TEXTILE / PROCESS / PRODUCT

A framework for exploring the relationship between textiles and the product design process

The relationship between the design of textiles and the design of the products they become part of is complex, and is influenced by the specifics of each design context, e.g. which industry the product and textile is part of, what professional groups are involved, whether the product is designed by a team or a single designer. What these diverse textile product design contexts have in common, however, is that the textile somehow meets the product in a design process. Thus, to be able to explore and relate to the diverse relationships and design contexts that can be found in the textile product design practice, the framework focuses on the core of the relationship - the design decisions made during the design process, and how they relate to and influence each other, i.e. how textile design decisions and textile materials take part in the process and influence the development of the design. The framework is, as such, not about the context of the design process, e.g. what type of designers are involved, how labour is divided in the design process, which stakeholders influence the design, etc. Instead, it offers an abstract perspective which focuses on bringing how we design with textiles out into the open; the diverse ways textile can be approached in the process, the impact this choice can have on what can be designed, and how textiles as a design material influence the design process. Thus, the aim of this framework is not to promote a specific way of working, but to provide a broad perspective and open up for reflection on how we design, and can design, with textiles.

TEXTILE / PROCESS / PRODUCT

Exploring the relationship through three perspectives

The design process is, in this framework, seen as a dialogue, where design decisions regarding function, form, etc. meet, set restrictions, open up for possibilities, and influence each other and the development of the design. The interaction between decisions in the process is from this perspective “a conversation between the material of the situation” (Schön, 1992, p. 3), and a relationship in which textile materials and textile design are part of the product design problem and are active partners in the process, (Doordan, 2003, Schön, 1992, Bolt, 2007); the relationship is, however, influenced by how much power over the design the designer gives the material. The following texts, questions, and methods can be used to explore and define the relationship between the textile materials/textile design and the product design process; firstly, by looking at what the textile is in the process; secondly, by examining how the textile is approached/what role it plays in the process; and thirdly, investigating how the textile influences what can be designed and the design process itself. Each section begins by introducing a way to look at 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 using the introductory texts to discuss the relationship in general, to using all of the methods and questions to map out a specific design process from start to finish. Some of the methods and questions in the framework could be used to explore other relationships within a design process; specifically, the methods used to look at how the textile is approached, e.g. the relationship with the product from a textile perspective. The other questions and methods are specific to this relationship, and deal with the aspects that are characteristic for a textile product design process. All parts regarded, the framework highlights important points in the relationship between textile design and the product design process, and could therefore be used for looking back at or planning a textile product design process, or reflecting on textile product design practices in general.

Paper III (ref) describes eight examples of what can take place in a textile product design process. The examples can be seen as a complement to the framework, and could be used to reflect on a specific process or gain a better understanding of the possibilities and challenges that come with different ways of designing with textiles. The examples in Paper III can, as the framework, be read and utilised in varying degrees of detail; one may attain an overview by looking at the introductory texts, the different examples of design processes, and the quotes taken from the observation, or gain a broader understanding by reading the context sections with related research and the discussion, or go into greater detail by looking at the analysis of how textile design decisions feature in the different types of processes.

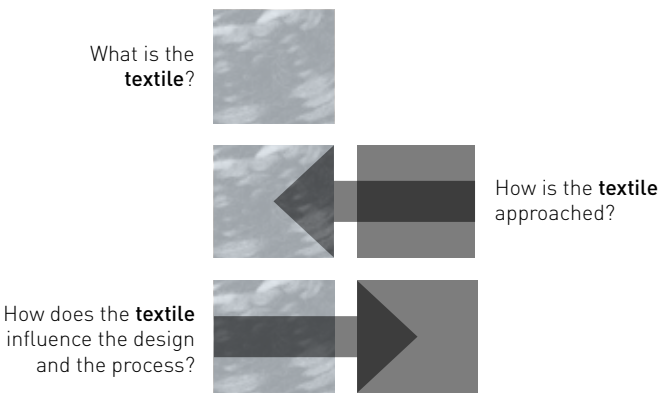


Figure 1: Overview of the framework.

What is the textile?

The textile area is a diverse field which involves numerous techniques and types of materials; this diversity means that textiles enter the textile product design process in an equally diverse range of ways, as anything from a finished material to something which is designed in detail, specifically for that product. Different forms of textile design include different types of considerations, but also opens for different ways of designing and working with them in the design process. It is, for example, more likely that design processes that deal with constructing a new material require more time and effort and more textile knowledge and/or access to or collaboration with textile producers/specialists, than processes where an existing textile is chosen from a collection of samples. The form of textile design also influences what can be designed, as processes that deal with constructing or altering an existing material open up for more unique solutions, whereas working with existing materials can lead to the use of standard materials.

Textile design in this framework is divided into four groups, based on what type of decisions the designer deals with when designing the textile part of the product; construction, alteration, selection, and specification. The answer to the question 'what is the textile in a specific design process?' is thereby reached by defining what form of textile design decision is being utilised in the process. The form of textile design is not necessarily constant through the design process - changes could be the result of textile materials becoming more or less important for the design, or simply a practical consequence of not finding a suitable existing material. Regardless, the form of textile design decisions that are present in the design process, along with how and if this changes, is an important clue when looking at the character of the relationship. The following describes the four types of textile design decisions:

Textile Construction

This form of textile design decision deals with the construction of textiles in the product design process. The construction of the textile can be more or less detailed, 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 that has been designed and produced for that specific product. Weaving, knitting, warp-knitting, and non-woven are examples of textile techniques that are part of this form of textile design.

TEXTILE / PROCESS / PRODUCT

Textile Alteration

This form of textile design decision deals with the alteration of textiles in the product design process. The material is re-designed by changing the surface, 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 are part of this form of textile design.

Textile Selection

This form of textile design decision deals with the selection of existing textiles in the product design process. The designer doesn't design a new material for the product, but instead selects a textile that works with the rest of the product's design; thus, the fabric is designed outside the textile product design process, and is incorporated into the design as a finished material.

Textile Specification

This form of textile design decision deals with specifications of textile materials or properties in the product design process. In this type of process, the designer doesn't design or select a specific textile for their product;thus, the choice of the exact textile is not a part of the design process. Instead, a type of material or a set of properties which the designer believes will work with the rest of the design are specified.

/ Q: What is the textile?

What form of textile design decisions are part of the design process?

-Textile construction?

-Textile alteration?

-Textile selection?

-Textile specification?

/ M: Is the textile constant, or does it change over the course of the process?

The following visual model can be used to describe the form of textile design that is present in the design process, by showing the forms of textile design that have been utilised, as well as the directions in which it has changed. In the first example to the right, the process starts with both textile alteration and selection, and ends with specification.

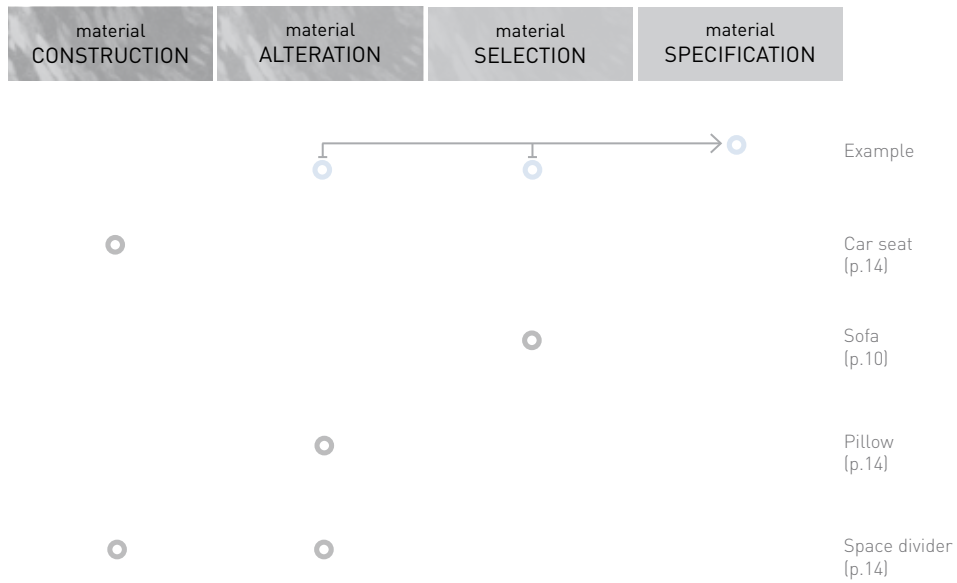


Figure 2:. A visual model for describing the form of textile design decisions that are present in a design process, with the the fictional examples from the introduction placed in it.

How is the textile approached?

The tradition of shape over matter, where materials are selected or designed based on what can best create the intended product, is a common approach within many design industries (Oxman, 2010a). Access to a great 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 detail when designing textile products. The soft and flexible properties of textiles also enable this way of designing, as they make it possible to use the same textile 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 latter stages of the design process. However, this openness in relation to the design, and the fact that it 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. Consequently, different approaches to textiles are more or less suitable for different types of designs, design processes, and designers, as each approach requires a different level of textile knowledge/experience, access to textile equipment, development of new materials, etc. Different approaches to textiles when designing are also more or less compatible with more demanding and complex textile materials and techniques; e.g. smart textiles challenge some of the most common ways of designing with textiles, as some of their properties and requisite considerations can require the rest of the design to adapt more to the textile, rather than the other way around.

The main difference in character between different 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 given room to influence the design, or if it is a consequence of other decisions. This section of the framework explores this part of the relationship: how the textile is approached by the designer during the design process. The following questions and methods look at how and where textile materials and design decisions enter and influence the development of the design, and what role they have. The first method does this in detail by examining which phase in the design process the textile has influence, while the second method is a summary or simplified version of the first method. This latter approach makes it possible to explore and discuss how different types of design decisions are prioritised in relation to each other, and results in a visual representation of the importance a designer places on the textile in the design. Examples of four different ways in which

textile materials and textile design can be approached in the design process (Detail, Starting point, Dialogue, and Tool) can be found in Paper III, along with descriptions of the considerations, challenges, and opportunities that come with them.

/ Q: in which phases in the design process do textile design decisions influence the development of the design?

Design decisions which are central to a design have a greater influence on the development of the design than decisions which come in as relatively minor details at the end of the process. The phase of the design process in which textile design decisions come in therefore provides important clues regarding how much influence these decisions can have over the design, and what role they can play in the process. Jones (1993) divides the design process into three fundamental and logical phases as follows; divergence, transformation, and convergence. These open up for looking at the design process in a detailed way, and therefore form the basis for this part of the framework. The types of decisions that can be made in the three phases play three different roles in the design process, and therefore influence the development of the product in very different ways. The following describes what type of influence divergence, transformation, and convergence have over the design decisions:

Are textile decisions present in the divergence phase?

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 and expands 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 which the designer undertakes during the divergence stage informs the upcoming transformation phase, and gives 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.

Are textile decisions present in the transformation phase?

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, and especially decisions that become part of the direction of the design, have a strong influence on the development of the design.

Are textile decisions present in the convergence phase?

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 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 which 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 which the designer places on different decisions, i.e. whether the decisions are seen as a crucial element or a minor detail in the design. Textile design decisions that enter the process in the convergence phase are directed and influenced by previously established decisions. The more it is considered to be a 'detail', the less impact it will have on the overall development of the design.

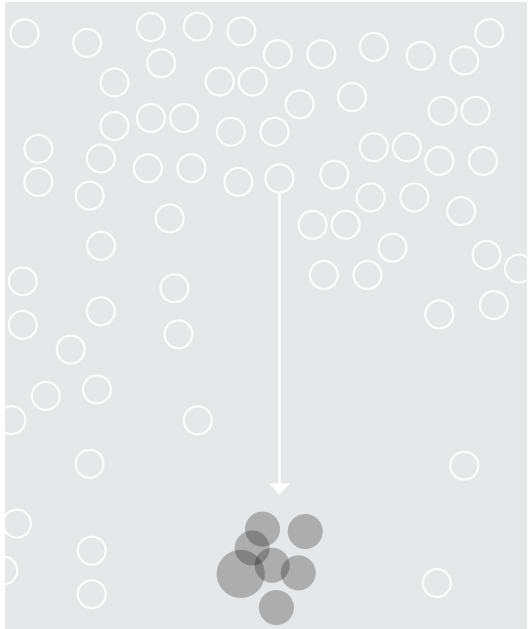
DIVERGENCE

- Are TEXTILE decisions explored in divergence?

- Are TEXTILE decsions transfered into the transformation phase?

Exploration of the design space: Investigating the boundries of possible design decisions.

TRANSFORMATION

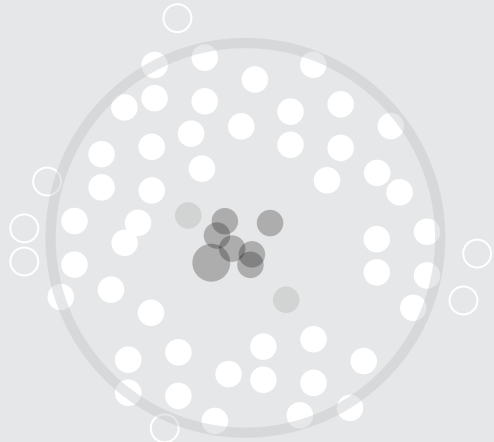


- Are TEXTILE decisions part of the design direction?

Developing a direction for the design: Defining what the essential design decisions are and how they are related.

CONVERGENCE

- Are TEXTILE decisions entering the design process in the convergent phase?



- Where in the convergent phase are TEXTILE decisions taken?

Developing the design from abstract idea to complete design: Gradually defining the design around the directional design decisions.

/ M: place textile design decisions in divergence, transformation, and convergence:

This visual model can be used to place where textile design decisions enter into the design process and influence the development of the design. The small circles in the illustration represent design decisions, and illustrate where decisions of a certain type are present. These decisions float freely in the divergent phase, and combine to form a design direction in the transformation phase, in the manner of an 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 product as a whole. 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 core of the circle, the more important it is, and the more influence it will have on the design.

Figure 3

/ M: What role do textile design decisions have in the design process?
Place textile design decisions in the circle:

The second method is a summary of the first, and describes how the directional design decisions from the transformation phase meet the defining design decisions in the convergence phase. The circle can be used as a tool to visualise and summarise the hierarchy in the design; the role a type of design decision has in the design process in relation to the design direction. It describes the importance which the designer places on design decisions, how much influence they have, and to what extent they have priority over other design decisions. The hierarchy of design decisions in the design process can be thought of as a gradient, radiating out from the centre of the circle, where the most influential decisions have the strongest colour and the least influential decisions are the most diffused.

How are clashes between textile and other design decisions handled?

An important point when examining which role something has in the design process is to look at which decisions are prioritised when design decisions clash. Decisions that are considered to be central to the design are less likely to be changed than decisions that are considered to be an interesting option, but nothing more. An important question, therefore, is how clashes between textile design decisions and other design decisions are handled. 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 created that works with the intended textile, or is a new textile selected or constructed that can create the intended shape? It is not the exact placement in the circle that is important, but approximately which area it is in. The placement in the circle can be seen as a sliding scale, but the four categories that are described in the following can be used as guidelines when defining or reflecting on the role of something in the process:

DOMINANT - Dominant decisions are generally part of the design direction, and are placed at the centre of the circle. These decisions have a strong influence over other design decisions, and are generally prioritised when design decisions clash.

INFLUENTIAL - These decisions are influenced by, and in turn influence, other design decisions in the process. They are controlled by the design direction, and influence decisions that are considered to be details in the design. They can be prioritised when they clash with other design decisions, depending on the role of the other decision. Influential design decisions are placed in between the centre and the edges of the circle.

SOFA
(p.10)

CAR SEAT
(p.14)

SPACE DIVIDER
(p.14)

PILLOW
(p.14)

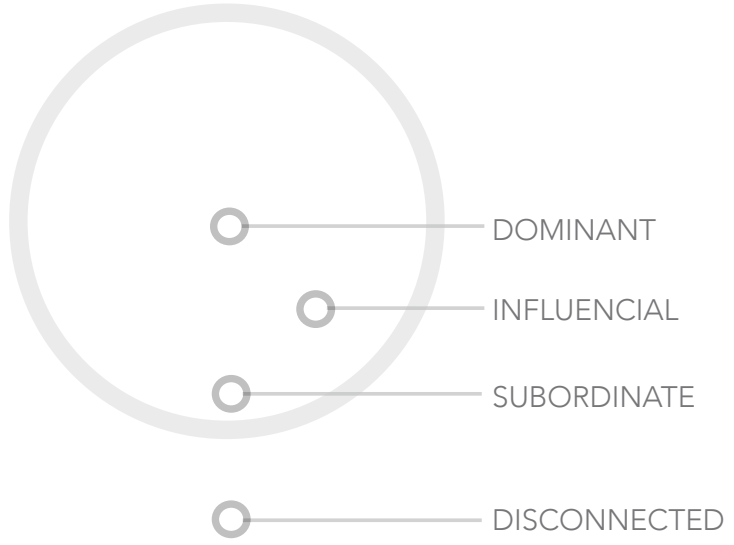


Figure 4. A visual model for describing the role a type of design decision has in the design process in relation to the design direction. The fictional examples from the introduction are above placed in the model.

SUBORDINATE - These decisions have little or no influence over other design decisions, and are generally not prioritised when other design decisions clash with them. Subordinate decisions are considered to be minor details in the design, and are placed at the edge of the circle.

DISCONNECTED - These are decisions that are not considered to be part of the design process. They have no influence over the development of the design, and are placed outside the circle. Textile materials that cover of a piece of furniture can sometimes have a disconnected role in the design process; the choice or design of the textile is in this case not defined by the furniture designer when creating the furniture, but instead left outside of the design process, for the interior designer or customer to decide.

How does the textile influence the design and the 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; as a medium, tool, creative stimulus, etc. In relation to textiles, design affordances (Nordby & Morrison, 2010) could be considered to be what a textile brings to the table when designing; its properties, expressions, the considerations, and the methods of using it in a design process that come with it. When designing with textiles, it is not only the materials that are planned to be part of the final design that should be considered; textiles that are used as e.g. tools, such as sketching/prototype materials, also influence the design and should therefore also be seen as a part of the textile influence in the design process.

Some examples of textile influence/design affordances are general, and should be considered when designing with most textiles. For example, how 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. Production methods often resemble how sketches and prototypes can be made, this also open up for making prototypes or sketches which utilise the final material and therefore have a strong similarity to the final product. The considerations that come with working with textiles can, as such, be very different from the considerations that accompany other materials, textile materials can therefore come to challenge many sketching techniques and design tools. For example, the soft and flexible nature of textile material can influence how a designer can sketch and define a product in the design process, as predicting how a fabric will fall, bend, stretch, etc. can be difficult when sketching on paper or using digital design tools (Ahlquist & Menges, 2011).

When designing with textiles, discrepancies can also easily arise between the textile decisions and materials that influence the design and the ones that influence the function, expression, etc. of the final product. This is related to the fact that the behaviour and expression of a textile can differ depending on what context it is used in, and that design decisions which define a textile material are strongly interdependent, meaning that changing something in the textile or in the product design can change

the unity of the textile and the rest of the product. A lack of awareness regarding this sensitivity to detail and context can make it difficult for a designer to fully consider how textile decisions will, in the final product, influence expression, construction, etc.

There are also examples of textile influence/design affordances that are specific for each process. One example is related to the form of textile design decisions that are present (construction, alteration, selection or specification), another concerns ,the specific combination of materials and techniques that come with a specific textile or material possibility, which influences the design process and design with its unique properties and considerations. The influence of the textile can vary, depending on how the textile material is used in the product. A product in which the textile is added as a surface to 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. of the product. Examples of how textile materials and the considerations that come with designing with them influence the design process can be found in Paper III; here, three examples of how not giving due consideration to different forms of textile influence may result in discrepancies between what influences the development of the design and what influences the design, are discussed. By considering the textile influence/textile design affordances when designing, some of the challenges of designing with textiles can be mitigated and some of the possibilities of designing with textiles can be taken advantage of. For example, an awareness of how the scale of the material influences the behaviour of the textile can lead to the designer altering their design process, and introducing full-scale prototypes/sketches earlier in the process. Paper III provides an example of how some of the textile influences can be handled and used as a possibility in the design process, in this case by incorporating more physical materials and prototyping in the design process and thereby creating a stronger link between textile influences in the product and textile influences in the process, as well as using textiles with diverse properties in prototypes to create a range of possible expressions when exploring the form of a product.

This section of the framework examines how the properties and considerations that come with designing with textiles influence the relationship between textile design and the product design process. The following questions and methods can be used to define/explore what the textile influence is, how this is handled or used in the design process, and how textile influence in the process and textile influence in the final design relate to one another.

/ Q: What is the textile influence/textile design affordance?

Which properties/considerations influence what can be designed with the material?

What general textile influence (textile properties and considerations etc.) affect the design process?

- Context sensitivity?
- Detail sensitivity?
- Soft or elastic properties in relation to design tools and sketching techniques?

What specific textile influences affect the design process?

- What considerations do the form of textile decisions bring? (Construction, alteration, selection, specification)
- What type of considerations and influences does designing with this specific textile bring to the design process?

/ Q: How is the textile design affordance handled/used?

Is this a product/context that is sensitive to textile design affordance?

- Is the textile part of the construction or functionality of the product?
- Are details in the textile important for the final product in other ways?

How is the textile influence considered in the textile product design process?

- Is the textile influence considered, handled, or used when designing?
- Is the design process altered to accommodate the textile influence?

The model for examining where textile decisions enter into and influence the design, which is used to explore how the textile is approached, can also be used to look at which forms of textile input influence the design in the design process and what influences the design in the final product. By comparing the decisions and materials that influence the development of the design process (divergence, transformation, and convergence) and the textiles that influence the final product, it becomes possible to see if there is a difference between which textile materials and decisions have an impact on the development of the design, and which have an impact on the final product. Textiles that are considered for the final design are not all that should be discussed here; textiles that are used when developing ideas, sketching, making prototypes, etc. are also included in the model, as they also have the potential to influence the development of the design.

DIVERGENCE

- Are TEXTILE decisions explored in divergence?

TEXTILE INFLUENCE IN DIVERGENCE?

What textile materials, that are not part of the design, influence the development of the design in divergence?

- Are TEXTILE decsions transfered into the transformation phase?

Exploration of the design space: Investigating the boundries of possible design decisions.

TRANSFORMATION

TEXTILE INFLUENCE IN TRANSFORMATION?

What textile materials, that are not part of the design, influence the development of the design in transformation?

- Are TEXTILE decisions part of the design direction?

Developing a direction for the design: Defining what the essential design decisions are and how they are related.

CONVERGENCE

- Are TEXTILE decisions entering the design process in the convergent phase?

TEXTILE INFLUENCE IN CONVERGENCE?

What textile materials, that are not part of the design, influence the development of the design in convergence?

- Where in the convergent phase are TEXTILE decisions taken?

Developing the design from abstract idea to complete design: Gradually defining the design around the directional design decisions.

FINAL DESIGN

- Which TEXTILE decisions and materials are a part of the final design?

Texile decisions and textile influence meet the real materials in the final design.

Figure 5

FUTURE WORK

The framework and examples of textile product design processes that are presented in this thesis examine the relationship between textiles and the product design process from a product design perspective. This includes the diverse roles which textile materials and decisions can play, and the influence that textiles as design materials can have over both the design and the design process. The next step in exploring the relationship is to continue to work with textiles and smart textiles as a design material, but to shift perspectives and investigate the design of textile products from a textile design perspective.

From the product perspective, the terms ’textile influence’ and ’design affordances’ (Nordby & Morrison, 2010) are used to discuss textiles in terms of how their expression, properties, etc., along with the considerations that are involved in designing with them, influence the development of the design and the design process. When exploring the relationship from a textile perspective, these terms open up for looking at the design of textiles, not only in relation to the products they become part of, but also the design processes they contribute to. To think of textile design as the design of a design material thus has the potential to open up for new and interesting questions to explore in relation to textile design; what do you, through your textile design, want to define? What do you want to leave open for someone else to alter or develop? What directions or ways of working do you want to open up for?

Smart textiles can challenge some of our current textile product design practices, but they also have the potential, due to their transformable and reactive properties, to open up for new ways of designing with textiles, by design materials that can react and adapt in relation to a developing design (Dumitrescu et al., 2014). Exploring smart textiles in relation to the design process in this way could also add to our understanding of traditional textiles, as these materials exaggerate and contradict some of the main qualities of textiles as design materials; by, for example, being more adaptable, less flexible, or bringing design decisions that influence how textiles function as a design material out into the open. The ’Recurring Patterns’ prototypes (Nilsson et al., 2011a) could be an early example of this, as the behaviour and expression of the textile surface can be altered through programming, both during the design process and in different contexts or scenarios when the prototypes are complete. The possibility to alter the expression of textiles also exists in traditional textiles; here, however, these possibilities were something that we actively defined in the textile system, as we, as designers of the textile, through the making of digital and physical decisions had the chance to define how, when, and where the changes in the surface would take place in the design process and in the final product.

FUTURE WORK

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, including the framework presented here, therefore, struggle to offer a complete picture of what takes place when designing. 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 and Dijkhuis, 1995). The background chapter features several perspectives, frameworks, and methods of describing design processes in relation to materiality. Some of these examples 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 and Goulding, 2011; Pedgley, 2009). Others evaluate specific working methods or promote particular ways of working (e.g. Jacucci and Wagner, 2007; Ashby and Johnson, 2010). The framework and accompanying examples of design processes that are presented in this thesis differ from these examples, in the way 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 with textiles and the impact that this has on the nature of the design process and 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/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 one hand, this makes it possible to go into detail regarding the relationship between textiles and the product design process 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 fictional examples are used in this thesis to illustrate how it could be used by a designer. However, the questions and methods in the framework have yet not been used by designers or design students in real-life processes outside of the observation. Further development of these methods and their presentation would be an interesting next step, and may therefore involve subjecting them to the complexity of real life processes, e.g. by putting them in the hands of designers or design students.

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PAPER 1

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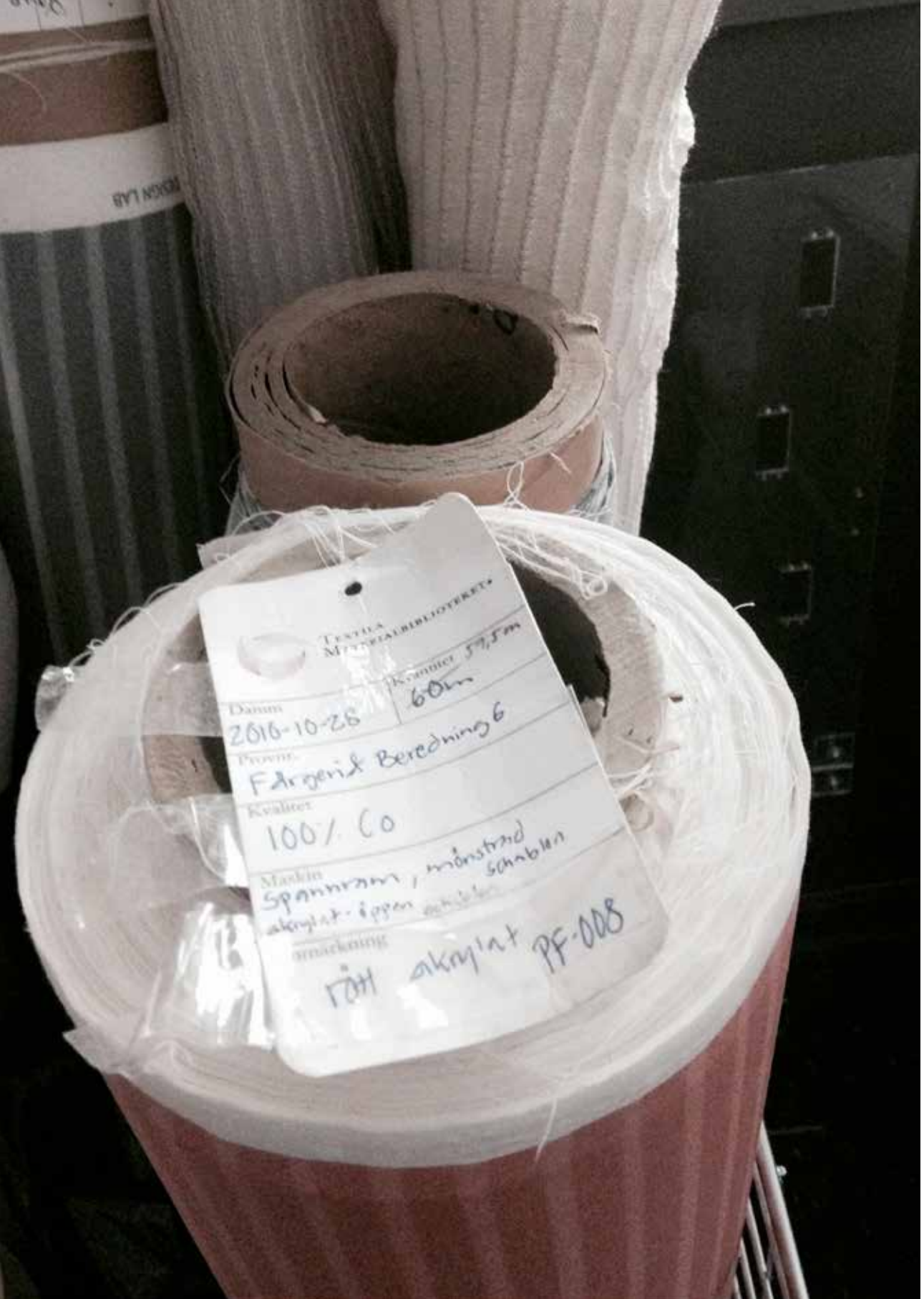

DESIGNING WITH SMART TEXTILES: A NEW RESEARCH PROGRAM

LINNÉA NILSSON ANNA VALLGÅRDA LINDA WORBIN
LINNEA.NILSSON@HB.SE ANNA.VALLGARDA@HB.SE LINDA.WORBIN@HB.SE
THE SWEDISH SCHOOL OF TEXTILES, UNIVERSITY OF BORÅS, 501 90 BORÅS, SWEDEN

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.* 2000; Berzowska and Coelho 2005; Redström *et al.* 2005; Braddock-Clarke and O'Mahony 2006; Seymore 2008; Worbin 2010a).

However, research into smart textiles has gradually surpassed the stage where anything 'smart' in a textile context is new and thus has a research value. Thus, we need to reformulate our research program (cf. Hallnäs and Redström 2006).

The new program is concerned with what it means to design with smart textiles. How the smart textiles can enter existing design practices and production processes and what these new material possibilities will do to them in turn? We will investigate what role smart textiles can play in the design of our physical environment and contexts of use. Before we go on to elaborate on the research program by means of three ongoing projects, we give a brief status of the smart textile research that has led us in this direction.

SMART TEXTILES

We can generally define smart textiles as a material that interacts with its environment in more or less complex ways, including textiles that react and adapt to their environment. The research we summarize here is that which has directly led to the formulation of our new research program.

We have become familiar with what smart textiles can and cannot do with present day technologies. We master the skills of making them, and we have demonstrated a range of expressions (Redström *et al.* 2005; Landin *et al.* 2008; Bondesson *et al.* 2009; 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 (Bergström *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. Ernevi *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 design 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 developing fibers, yarns, and construction, 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 constrains 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.

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

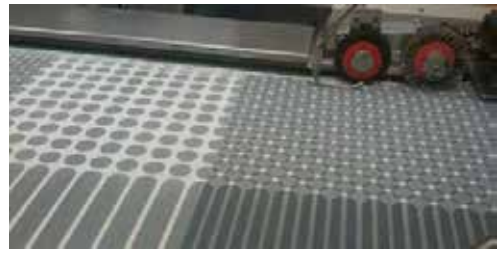

Figure 2 Sample of cotton printed with gray thermo chrome ink that turns white when heated above 27C. Half of this sample is moreover coated with acryl to give a stronger surface for prototyping.

Figure 3 Three samples of textiles knitted with different strength of conductivity. Left: knitted cupper with viscose. Center: knitted blue mohair with brass. Right: knitted turquoise cotton with stainless steel.

DESIGNING DYNAMIC TEXTILE PATTERNS

Dynamic textile patterns, is an ongoing project where we investigate the complexity of designing with smart textiles.

In one experiment we have worked with a Swedish furniture company who wanted some concept furniture to demonstrate possibilities for smart textiles in furniture design. We designed the fabric for two footstools by using the woven conductive fabric (see Figure 1) from the smart textile sample collection and printed it with thermo chromatic ink. The general concept was that sitting on one of the stools would result in a pattern change either in the same stool or in the other.

In this experiment, we have through our own design practice been able to analyze the complexity of designing with state changing materials. In some cases, we can suggest strategies, or tools to deal with the

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 it self 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 at 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.

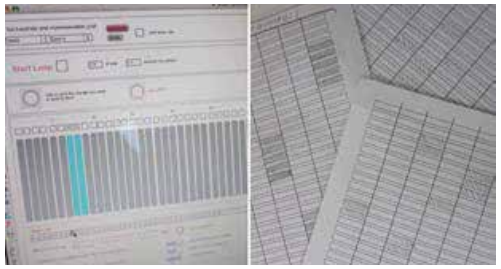

Figure 4 Left: The graphical interface of the software on computer screen. Right: picture of the "note sheets" to visualize the progress of the heating.

Figure 5 An example of the range of colors expressed in the transition between two color states.

BONAD [TAPESTRY]

Bonad [Swedish for tapestry] is a project investigating what it does to the depth, complexity, and quality of the designed textile expressions when one part of the material composition is held stable throughout the design process. Bonad is a platform comprising 1-48 servomotors mounted on a surface controlled by a computer, which in the test setup is controlled either through a graphical interface or through a row of potentiometers. We investigate whether such a platform is a viable way to reduce the complexity of the technological aspects and thus leave room for more advanced textile design.

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.

From 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.

Figure 6 Above shows an example of texture changes for a 3D knitted elastic surface and below shows of movements within a stiff 3D knitted construction. Both designed by Delia Dumitrescu.

AN INVITATION

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 formulate an invitation for others to participate. Participate both in discussing the direction we are taking but also to contribute with own experiments and investigations—perhaps even in collaboration with us.

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PAPER 2

Nilsson, L., Satomi, M., Vallgårda, A. & Worbin, L., 2011.
Understanding the complexity of designing dynamic textile patterns.
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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 creates 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 some extend textile design can be understood parallel to the design composite materials. Every combination of materials, every design choice, enhances or enables something, and suppresses others. In textile design, for instance, the focus can be on the expression and quality of the textile whereas in developing composite materials the focus can be on developing new (combinations of) material properties. When we design smart textiles both cases of interdependencies are at play.

The following section contains a description of the practical project Recurring Patterns that forms the basis for our analyses. The two main sections contain complexity analyses, and methodological suggestions rooted in the temporal dimension and the material interdependencies respectively. The final section contains a discussion of the advantages and challenges of that these complexities entail.

RECURRING PATTERNS: PROJECT DESCRIPTION

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.

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

Figure 1 Weft ribbed cotton fabric with conductive threads

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 chromatic 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 [5] 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 Salon 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 only when someone activated the pressure sensors, i.e. by sitting on it. Other situations and contexts of use may have other demands on the temporal expression and interaction.

Figure 2 Footstool with a textile structure pattern.

Figure 3 Footstool with a geometric pattern

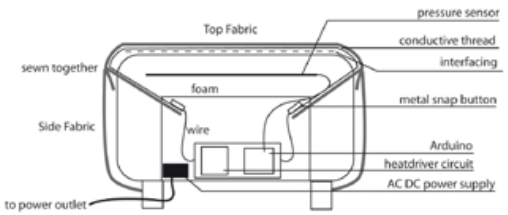

Figure 4 Illustration of the components used in the prototypes.

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 A" [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.

Figure 5 Colour scale that gradually changes from colour A to colour 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 chromic inks are combined. By mixing several thermo chromic 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 chromic magenta to the thermo chromic grey colour.

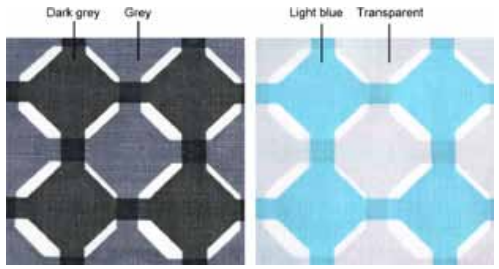

Figure 6 Left: Print sample in ambient temperature. Right: The same print sample in a heated state. Part of the pattern has changed from grey to blue, and the other part from dark grey through magenta to transparent.

The gradual change and combinatorial possibilities with this type of print create a complexity in how colours are combined in a design. Depending on how the heat element is programmed, each part of the print can be in its original state, in a heated state, or gradually changing in-between. This means that each colour added to the colour palette brings a whole range of nuances that can be combined in all possible stages with the other colour scales in the palette. At any point in time, is any combination of these nuances is possible. Figure 7 describes the complexity in a colour palette with three dynamic colours, showing two possible combinations of nuances at two different points in time:

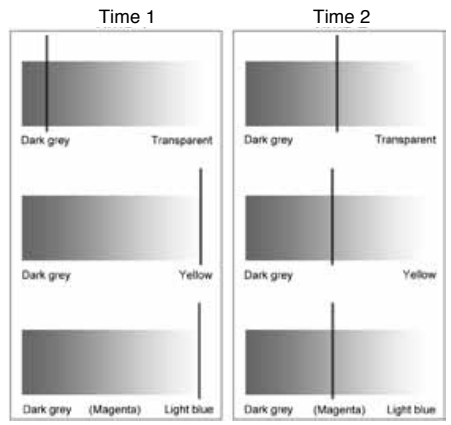

Figure 7 This scema describes the complexity of a three colour palette by showing two possible combinations of nuances at two points in time

In the prototypes constructed for the Recurring Patterns project reaching the transition temperature only took ten to twenty seconds, while the cooling down would take several minutes. Thereby causing the longest period of time the surface was changing to be when it was cooling down. The nuances that are in-between the fully heated and cooled colours therefore provide a significant visual aspect of the overall expression.

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.

Figure 8 Left: Colour palette sketch, with TC colours in various stages between heated and cooled. Right: Notes describing colour-mixing tests.

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 forms and patterns, but they are multiplied. It is no longer just about building up one composition of forms but about building up compositions of compositions of forms.

Figures 9-11 are prints made in the Recurring Patterns project, which illustrate how the relationship between the shapes in the design can change when the surface is heated. Figure 9 and 10 show how the same combination of forms changes in different ways depending on how the thermo chromic ink and pigment colours are placed in the composition of the pattern.

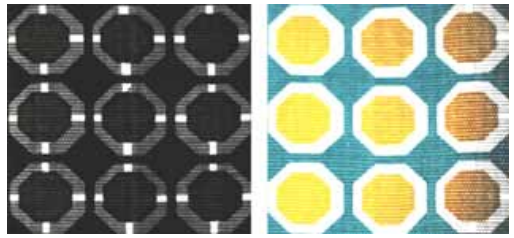

Figure 9 The first version of the same combination of forms. Left: shows the pattern in ambient temperature. Right: shows the pattern has been heated.

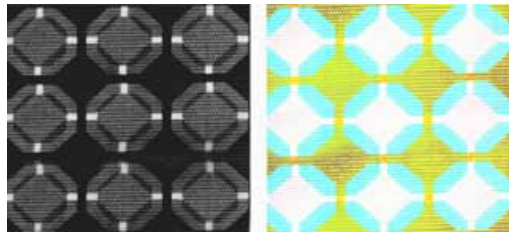

Figure 10 This is the second version of the composition in an ambient and heated state. (The forms are the same in both prints but print colours are different, the two versions are therefore slightly dissimilar in ambient temperature.)

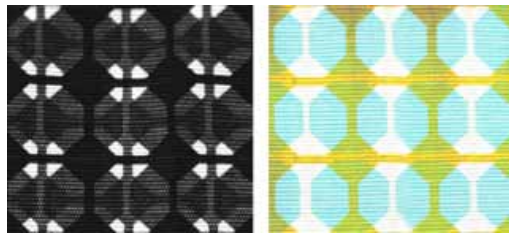

Figure 11 Left: Print sample in ambient temperature. Right: Heated print sample.

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 behind the textile are programmed.

To design a composition of compositions can obviously be difficult to do without the right tools. The design of the geometrical pattern for one of the footstools (See Figure 12), was the done by extensive sketching with simple CAD

programs but primarily by sketching directly in the printing lab. Nonetheless, the complete expression was not really understood until the printed fabric was put together with a heating sequence in the final prototype. The lack of overview and the numerous combinations of changes meant that it was close to impossible to actively design every expression with the tools at hand.

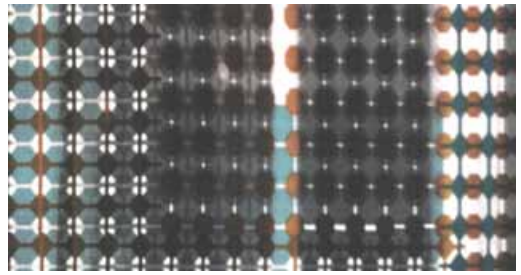

Figure 12 Geometric pattern, showing several types of form-changes occurring on the same print.

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/msp 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 se 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 ads 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.

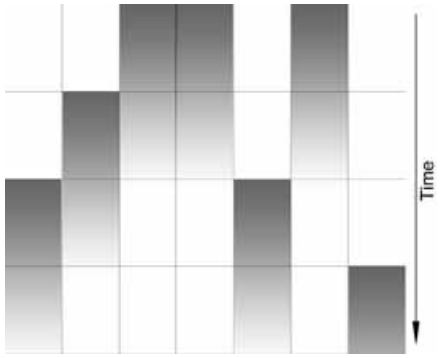

Figure 15 illustration of how the layout of the heating overlap in a composite with 7 individually controlled heat elements.

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 temporal patterns we needed a way 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 forms.

Figure 16 Left: the graphical interface to the computer programme. 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 also inherits this interdependency in its design.

In this case, the main components of the composite are a woven cotton textile embedded with steel yearn, 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 chromic 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 chromic ink. Furthermore, the material, which constitutes the primary part of the fabric, should be susceptible to the thermo chromic ink as well as be resistive to the concentrated heat produced in the threads. The material

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.

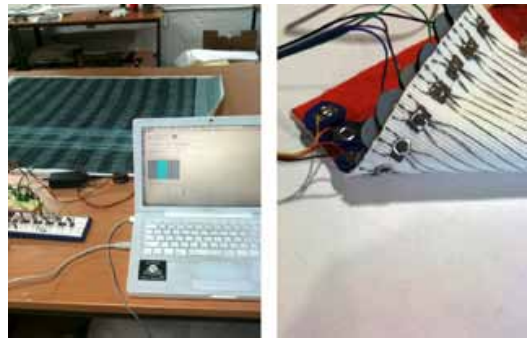

Figure 17 Images from the composite design process.

Designing the textile print

The design of the textile composite combined with the complexity within each of the dynamic design variables also increases the complexity when composing the overall expression. Here demonstrated through two examples.

Traditionally, the design of form and colour consists of a series of interdependent choices at least when the form is expressed through the colours, for instance, some colours appear to be in the foreground when combined with their contrast colour. When designing with dynamic colours, and through those dynamic forms, makes it is possible not only to change the forms and colours, but also to change the relation between the forms. For example, where one form may appear in the foreground before the colour-change it may have shifted to the background after the change. More generally, the colour palette will simply regulate the forms and their transformations and vice versa.

Another example is about how the layout of the heating elements will have a significant impact on the way each form can change. In the textile composite for Recurring Patterns, the heat elements can warm up sections of 20mm wide stripes over the width of the fabric. Obviously, this places some constraints on how the forms can change. We could either use it as an element in the pattern or find ways to hide it through the composition of the forms. Another challenge was in the distribution of a pattern over more than one heat element. When, for instance, a form was placed over two different heat elements it could also be transformed by both. This meant that the same form could either be completely changed, half changed, or remain unchanged depending on the temporal pattern. Thus, the form compositions are also dependent on the temporal forms and vice versa.

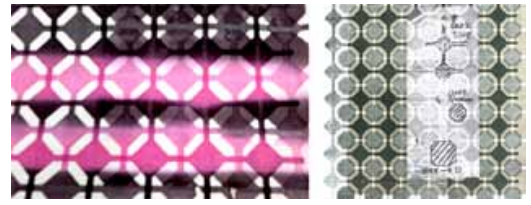

Figure 18 Left: A printed sample placed on the sketching tool with two heat elements activated, the line shape of the heat element has a strong effect on the expression of the change. Right: A printed sketch of how form and colour could be combined. The notes on the sketch describe how the different forms react to heat.

When designing textiles, sketches are often done on paper, with CAD programs or directly on fabric. In this case, such techniques only took us so far, partly due how the interdependencies among the design variables was difficult sketch. When designing the dynamic print, doing test directly on the materials and evaluating them on the sketching tool became a way to better grasp how the combinations of colour and form worked in relation to the layout of the heating elements. The sketching tool became a way to see how the dynamic variables influenced each other already in the process of designing the pattern.

Discussion

Through this project we have identified a series of practical as well as conceptual complexities that arise when designing with such state-changing materials. Moreover, these materials are interdependent compositions of several material elements.

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 haven not yet addressed, namely, the fact that most of these smart textiles are made for a specific project and thus to a large extend 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.

ACKNOWLEDGMENTS

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PAPER 3

[redacted]

Unpublished paper: Nilsson, L. Designing with textiles.

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 on six different occasions; three tutoring sessions and three presentations, spread 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

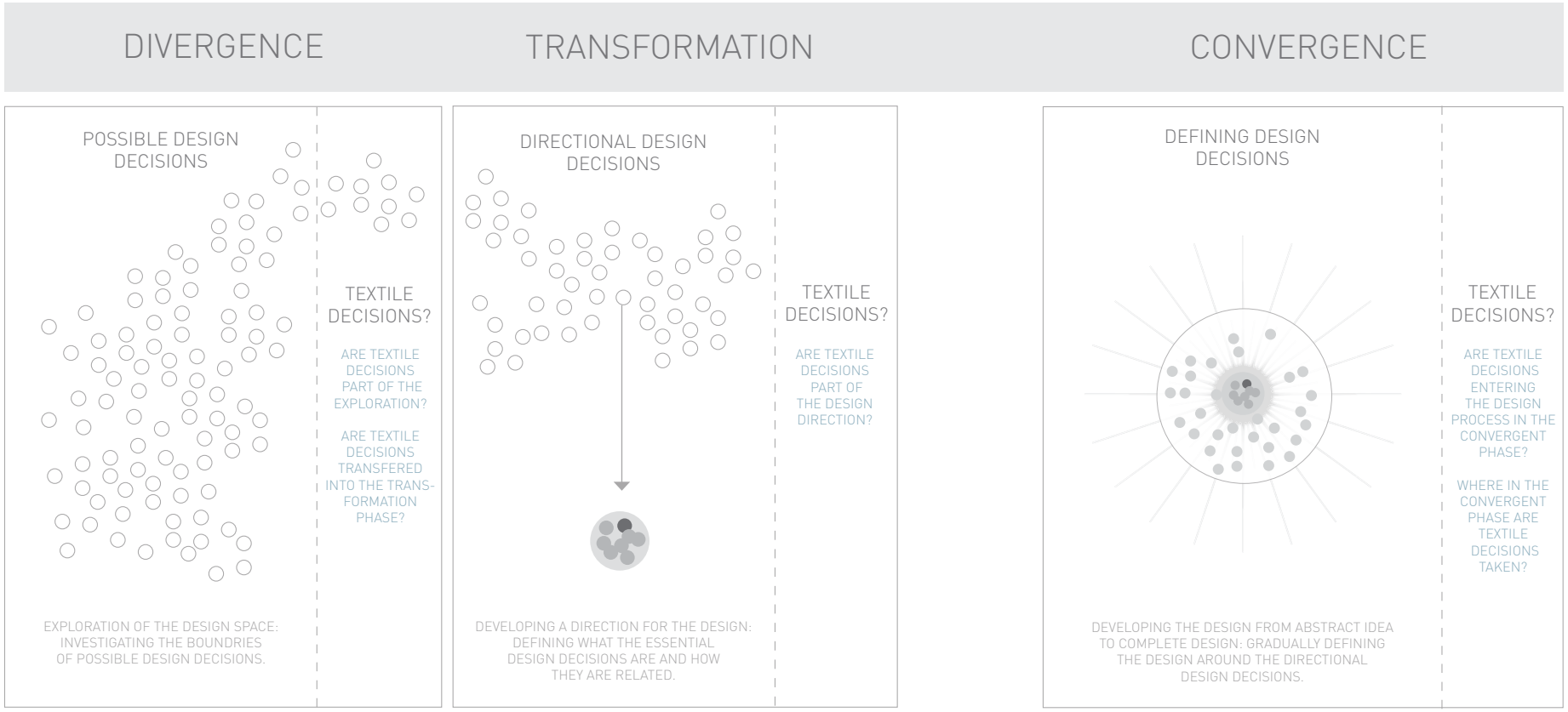
Jones divides the design process into three phases; divergence, transformation, and convergence. These phases represent three fundamental, logical phases of the design process, each with its own type of design decisions. Divergence is the initial phase of the design process, and is described by Jones 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 experimentations 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
Figure 1.

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:

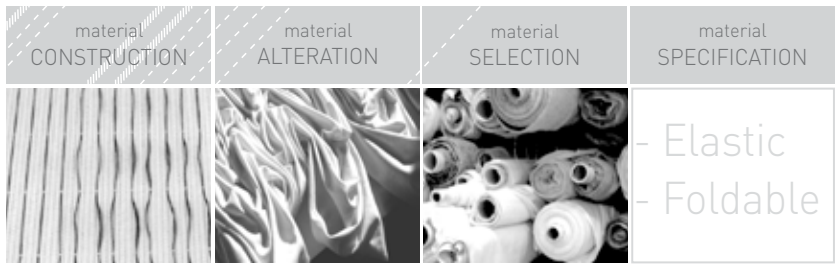


Figure 2. This illustration visually describes what forms of textile design decisions are present in a textile product design process. In this article, it is used to describe in what form textile design decisions come into the categories of experience, and whether this changes over the course of the process.

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

textiles in the product are highlighted. 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.

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 loose it's 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).

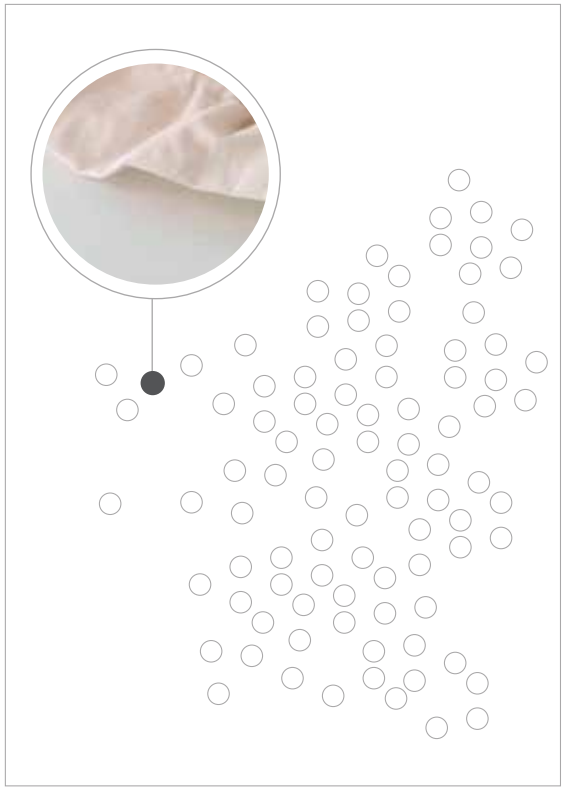
DISCUSSION

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

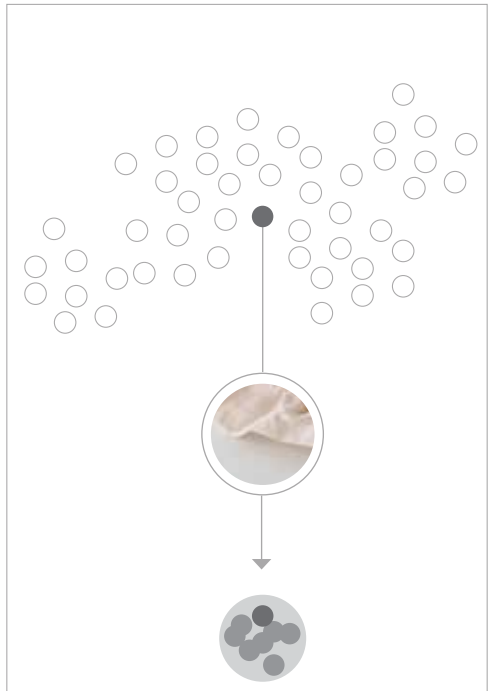
DIVERGENCE



POSSIBLE TEXTILE DECISIONS

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.

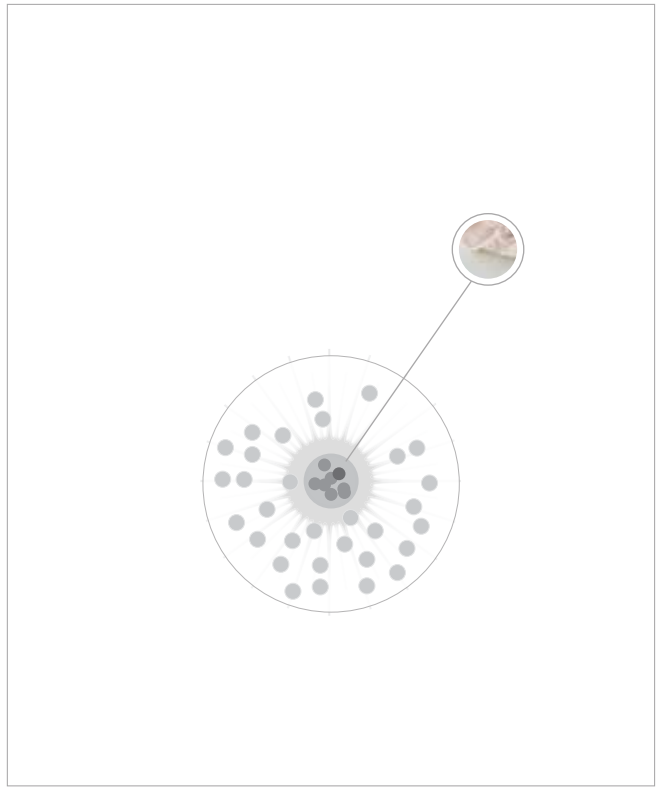
TRANSFORMATION



DIRECTIONAL TEXTILE DECISIONS

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

CONVERGENCE

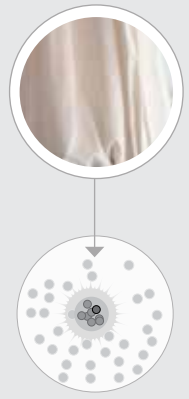


DEFINING DECISIONS

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

EXAMINING THE DESIGN

TEXTILE MATERIAL



?

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?

Figure 3. SCALE

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.

Figure 4

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.

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

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, then, 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.

Figure 5.

It is possible that the students were influenced by the freedom and flexibility of the CAD programs, where surfaces can easily be exchanged and altered without affecting other design decisions. If the physical materials are not present in the design process to outline what is possible in reality, it may be easy to consider the material to be just as mouldable as the form of the product. It is also possible that the students were influenced by the finished appearance of sketches and renderings produced in this type of program. These images, with their realistic depictions of material surfaces, can give the illusion of the materials being included in the design, while in reality they are not

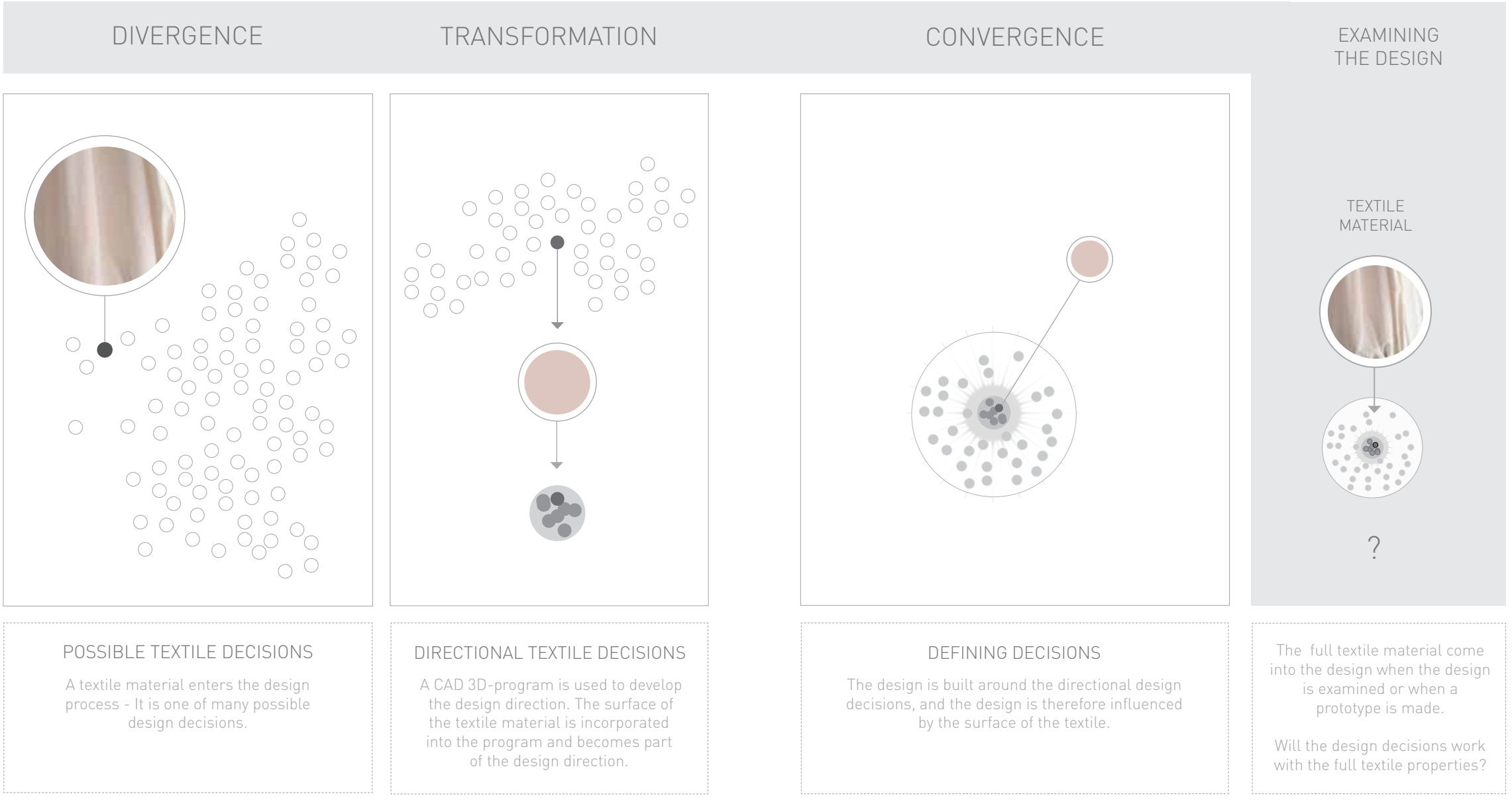


Figure 6. CAD-MODELLING

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 misguiding 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, over-estimated, 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 absorbent.
- 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).

Material research becomes a more and more challenging task for designers as the world of materials becomes increasingly complex and difficult to grasp. Material research no longer deals with clearly defined material such as textiles and wood, but instead with an ”expanding continuum of possibilities”(Manzini, 1989, p. 38), in which new materials can be created to suit almost any requirement. Designers work in a world where materials can be manipulated in extreme detail, and where most things are theoretically possible. But they also work in a world where their designs are strongly influenced by what is feasible, realistic, accessible, and where it is challenging to grasp and communicate complex material issues (Manzini, 1989). When working with textiles, both worlds exist; textiles can be custom-made in minute detail, but accessing and researching this type of material can be difficult for independent or inexperienced designers, small producers, etc.

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

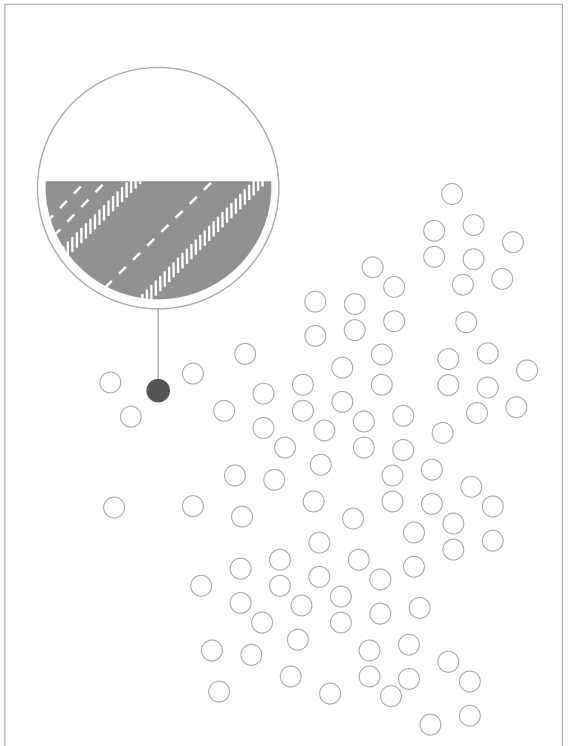
In this category, the students came to experience the effects of partial or misleading material research when designing textile products. The material research, which was mainly done at the beginning of the process, provided the students with an unreliable foundation for the design, and was not updated 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

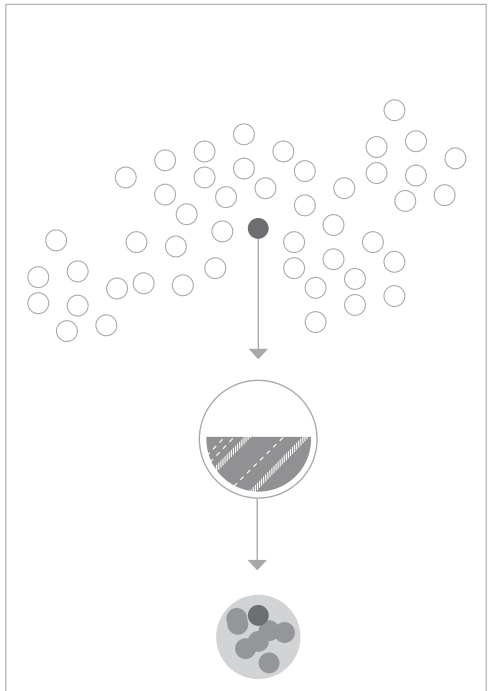
DIVERGENCE



POSSIBLE TEXTILE DECISIONS

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

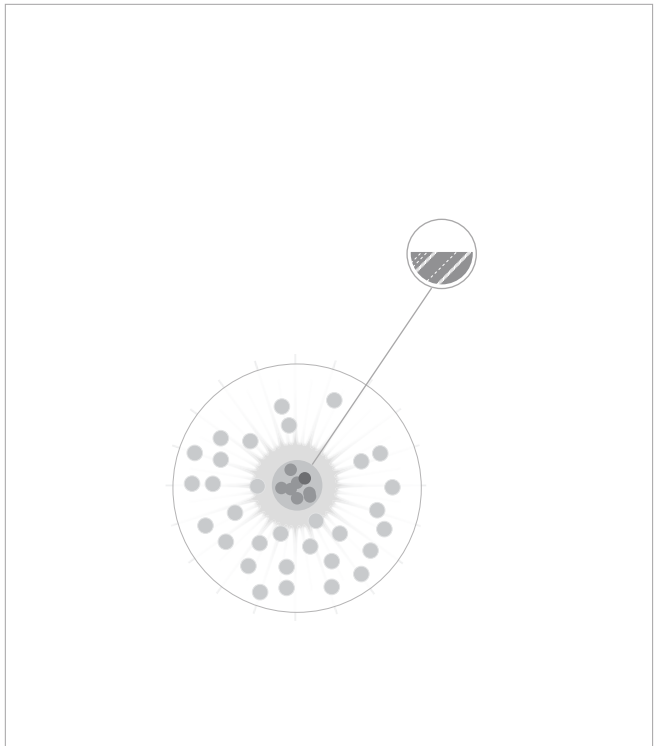
TRANSFORMATION



DIRECTIONAL TEXTILE DECISIONS

The textile material, or specifically the designer's limited understanding of the material, becomes part of the design direction.

CONVERGENCE

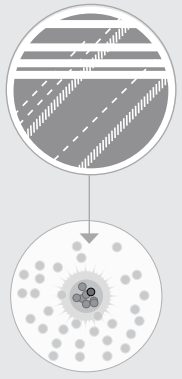


DEFINING DECISIONS

The design is built around the directional design decions - the design is influenced by the designer's limited understanding of the textile.

EXAMINING THE DESIGN

TEXTILE MATERIAL



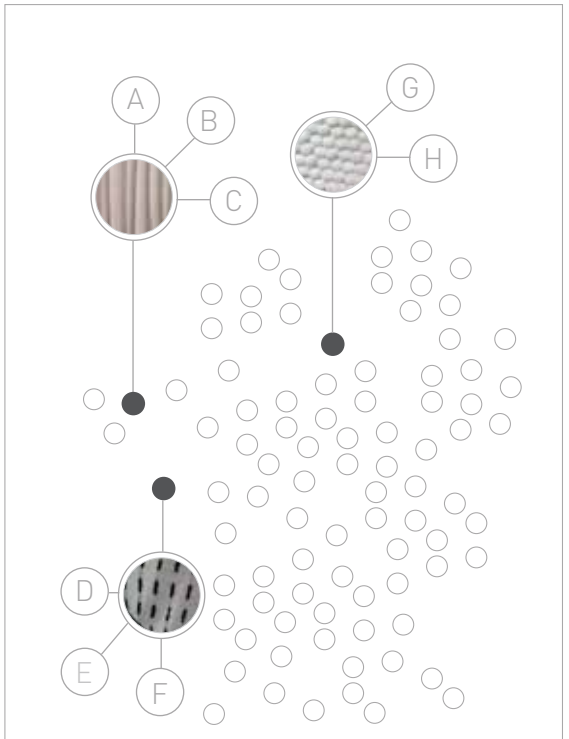
?

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 7. MATERIAL RESEARCH 1

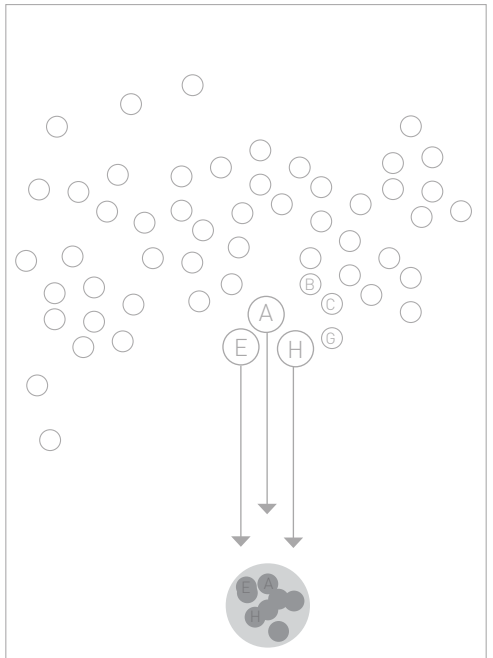
DIVERGENCE



POSSIBLE TEXTILE DECISIONS

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.

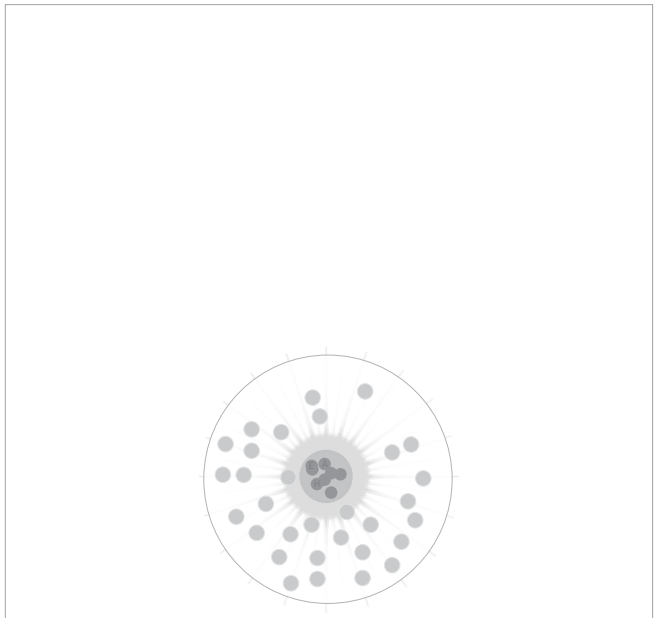
TRANSFORMATION



DIRECTIONAL TEXTILE DECISIONS

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

CONVERGENCE

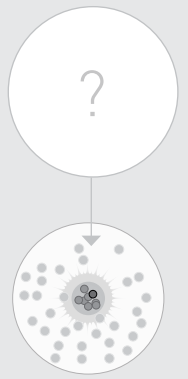


DEFINING DECISIONS

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

EXAMINING THE DESIGN

MATERIAL SPECIFICATION



?

The design is presented with a material specification.

Can a material that fulfil these requirments be found or created?

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

Figure 8. MATERIAL RESEARCH 2

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.

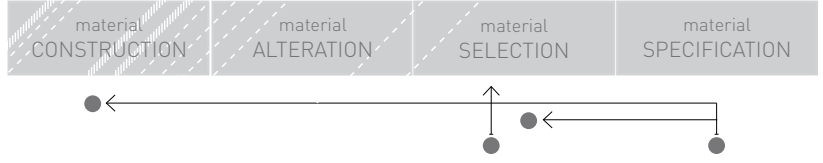


Figure 9

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 in 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 become 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.

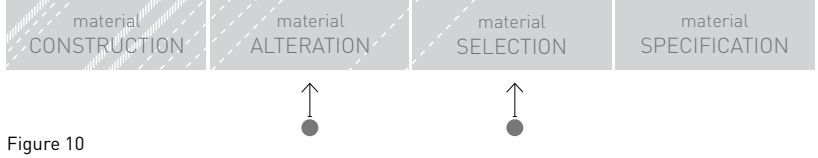
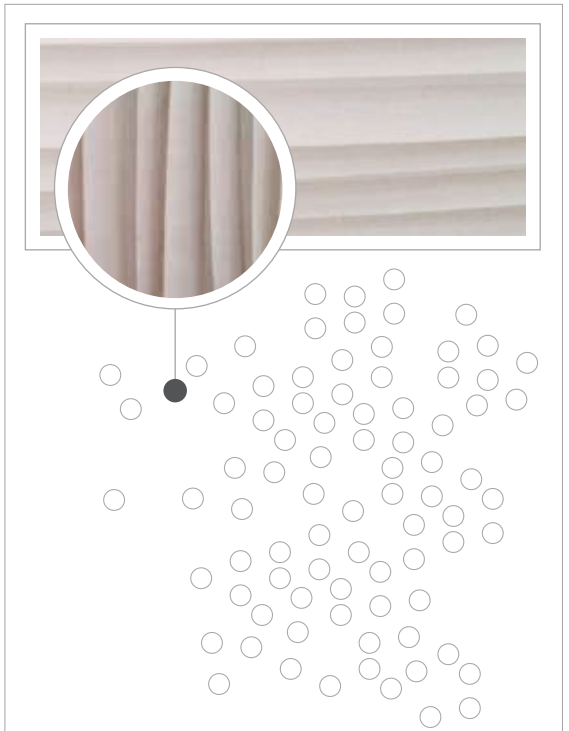


Figure 10

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

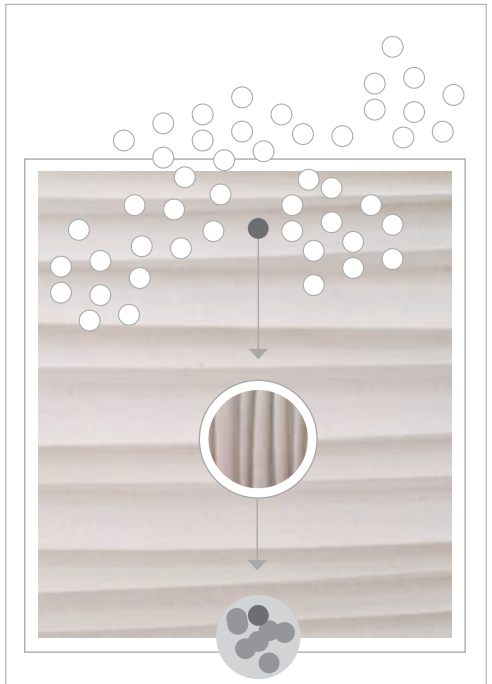
DIVERGENCE



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.

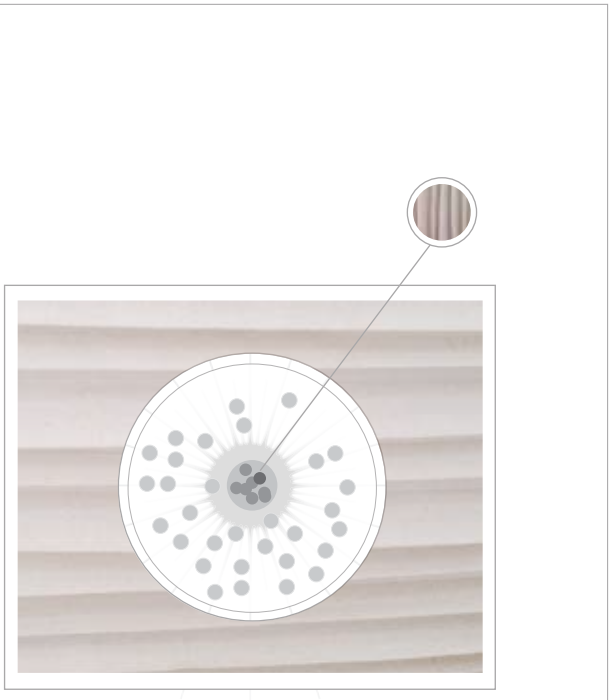
TRANSFORMATION



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.

CONVERGENCE

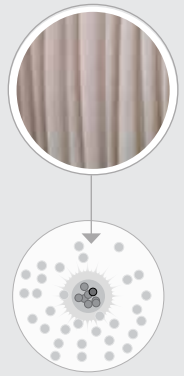


DEFINING DECISIONS

The design is built around the directional design decions, 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.

EXAMINING THE DESIGN

TEXTILE MATERIAL



?

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?

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 Haglöfs. To have top quality in details and material.

CONTEXT

Before the Industrial Revolution, man-made objects were generally created by craftsmen, 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 material (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 in some way 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 how 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”.

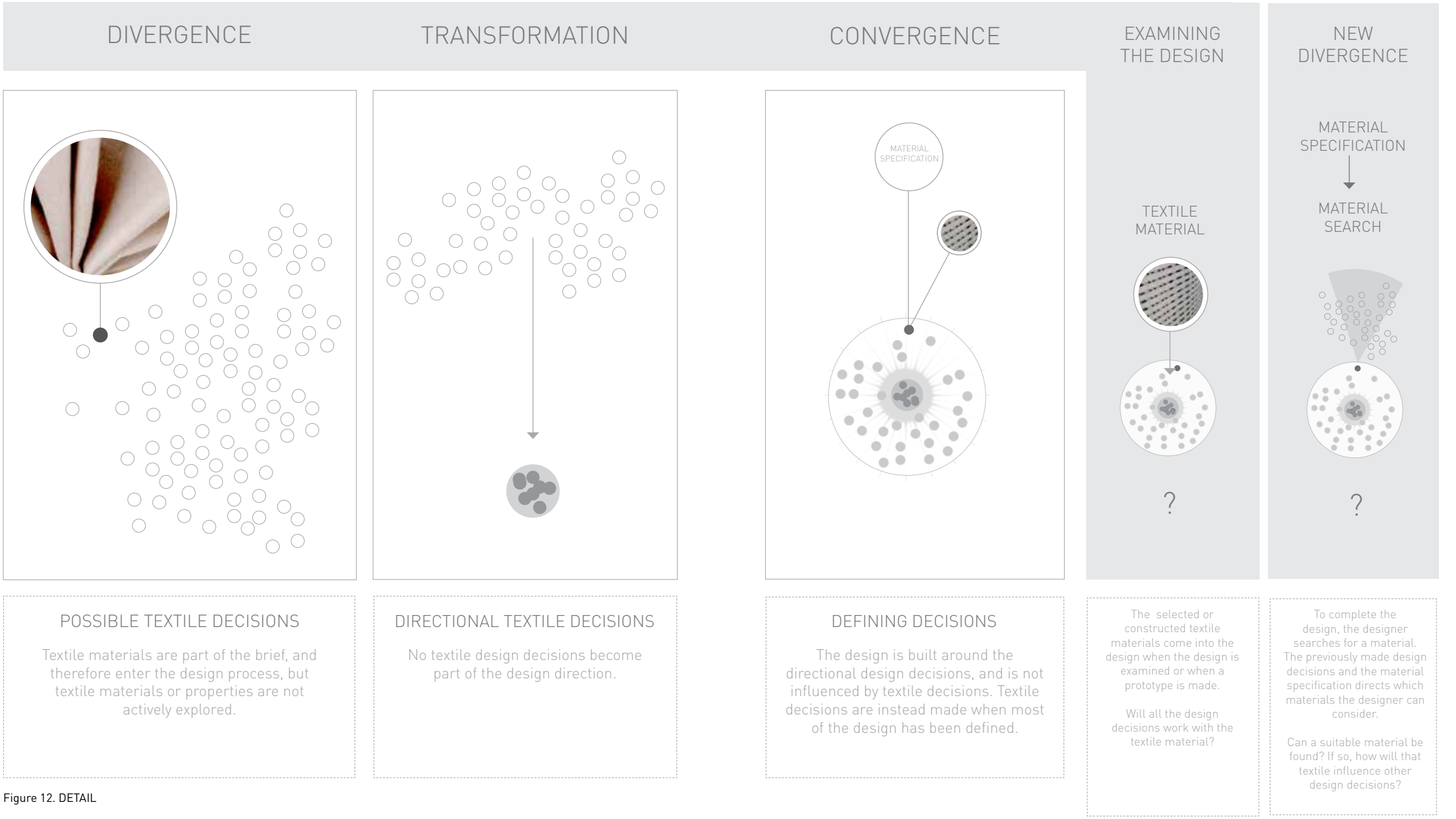


Figure 12. DETAIL

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.

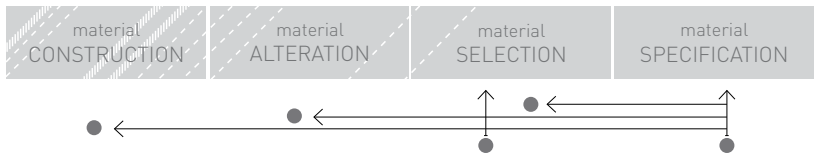


Figure 13

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.

DESIGNING WITH TEXTILES

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

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 Aschby 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.

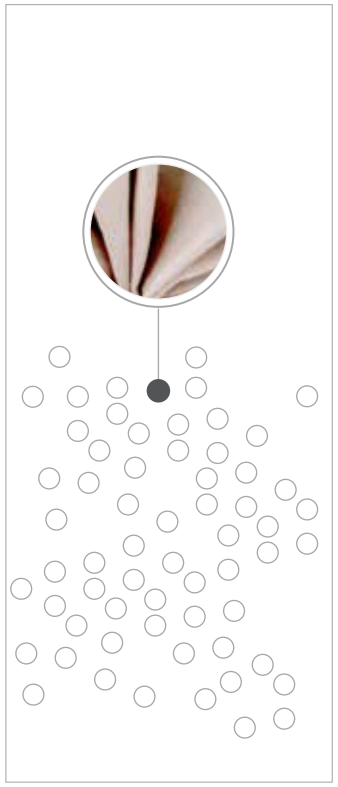
Several students in the observation used this approach and worked with the same textile material as their starting point. Due to the fact that each person became interested in different aspects of the material, and let that aspect of the textile strongly influence the design, one textile came to result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

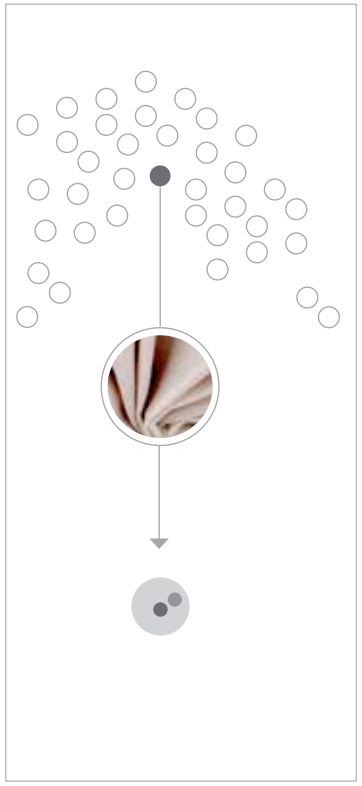
DIVERGENCE



POSSIBLE TEXTILE DECISIONS

A textile material is the starting point for the design. The divergent exploration is focused on the material and its potential.

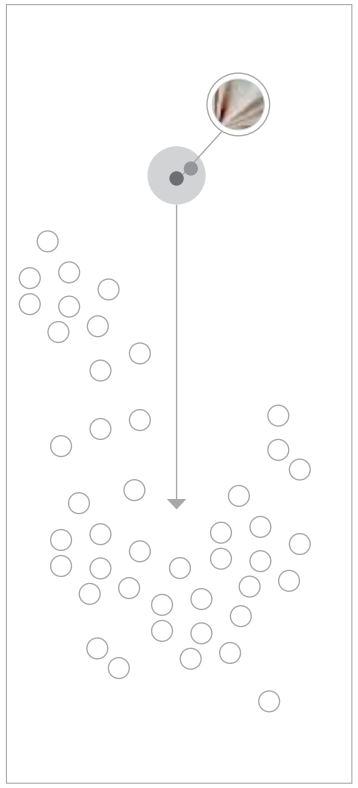
TRANSFORMATION



DIRECTIONAL TEXTILE DECISIONS

The first design direction is to use the material and the potential found in it to create a product.

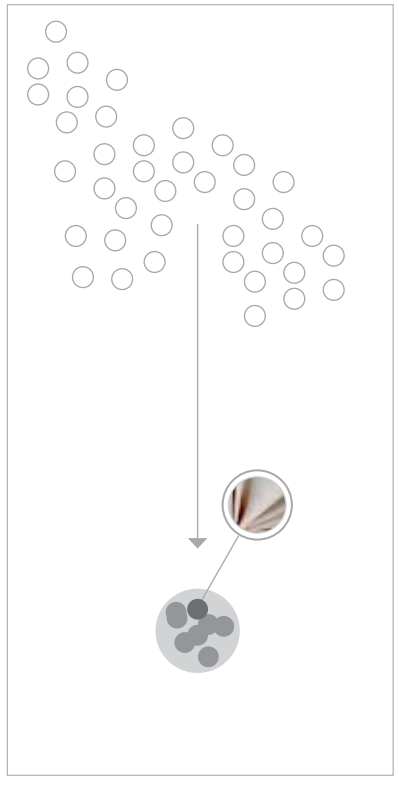
DIVERGENCE



POSSIBLE TEXTILE DECISIONS

The design direction is the foundation for a new divergent phase, where the designer explores what the textile could be used for.

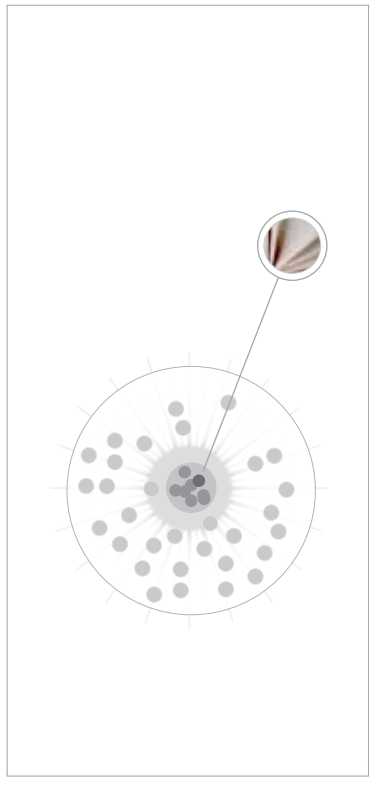
TRANSFORMATION



DIRECTIONAL TEXTILE DECISIONS

The textile material and other design decisions form a new design direction.

CONVERGENCE

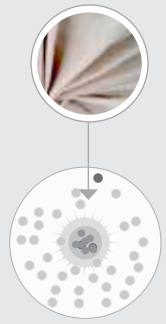


DEFINING DECISIONS

The design is built around the directional design decions. The design is therefore influenced by the textile material that started the process.

EXAMINING THE DESIGN

TEXTILE MATERIAL



?

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.

Figure 15

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

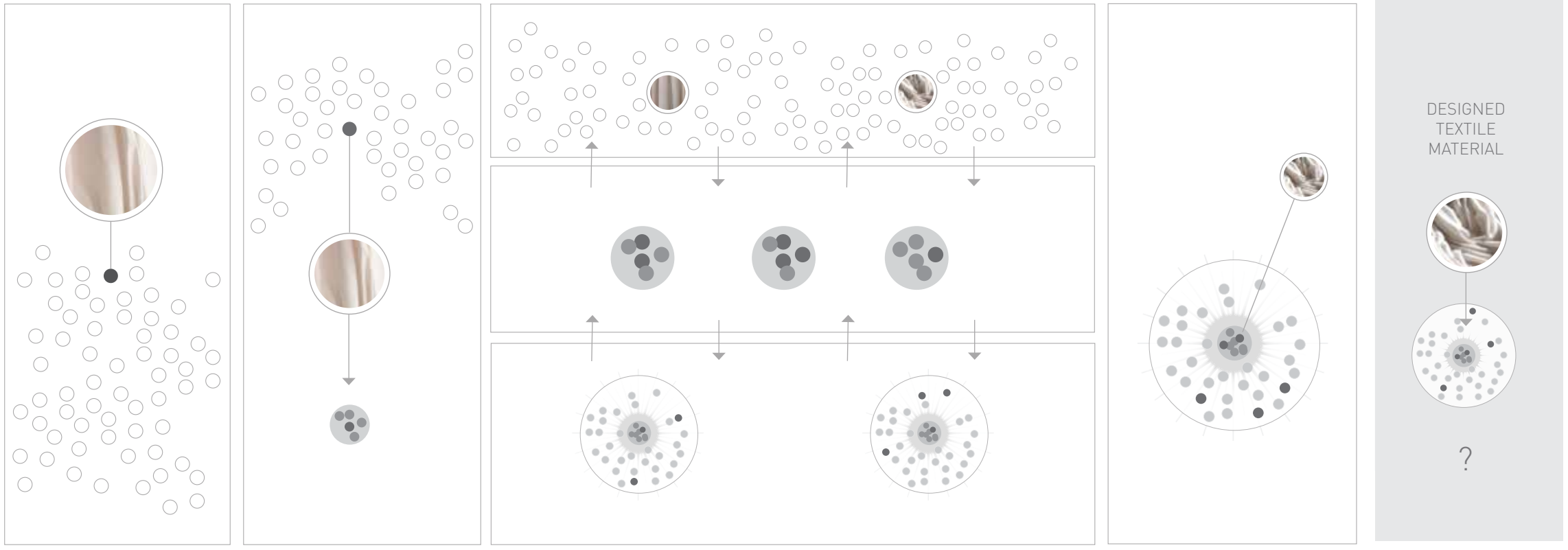
DIVERGENCE

TRANSFORMATION

DIVERGENCE / TRANSFORMATION / CONVERGENCE

CONVERGENCE

EXAMINING THE DESIGN



POSSIBLE TEXTILE 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.

DIRECTIONAL TEXTILE DECISIONS

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

POSSIBLE TEXTILE DECISIONS

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.

DEFINING DECISIONS

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.

DIRECTIONAL TEXTILE DECISIONS

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.

DEFINING DECISIONS

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

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?

Figure 16. DIALOGUE

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 be 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.

Figure 17

The students in this category developed their understanding of the material, and how it could be used in their product, by designing with it. In the course of the process, they obtained increasingly detailed knowledge, as well as more detailed definitions of the material design. The students' increased understanding of the material affected the development of the material as well as the whole design, which over time became more realistic; in some groups, this resulted in the design becoming smaller or less advanced as it developed.

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.

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.

- 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.

- 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.

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 sandpit 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 it 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.

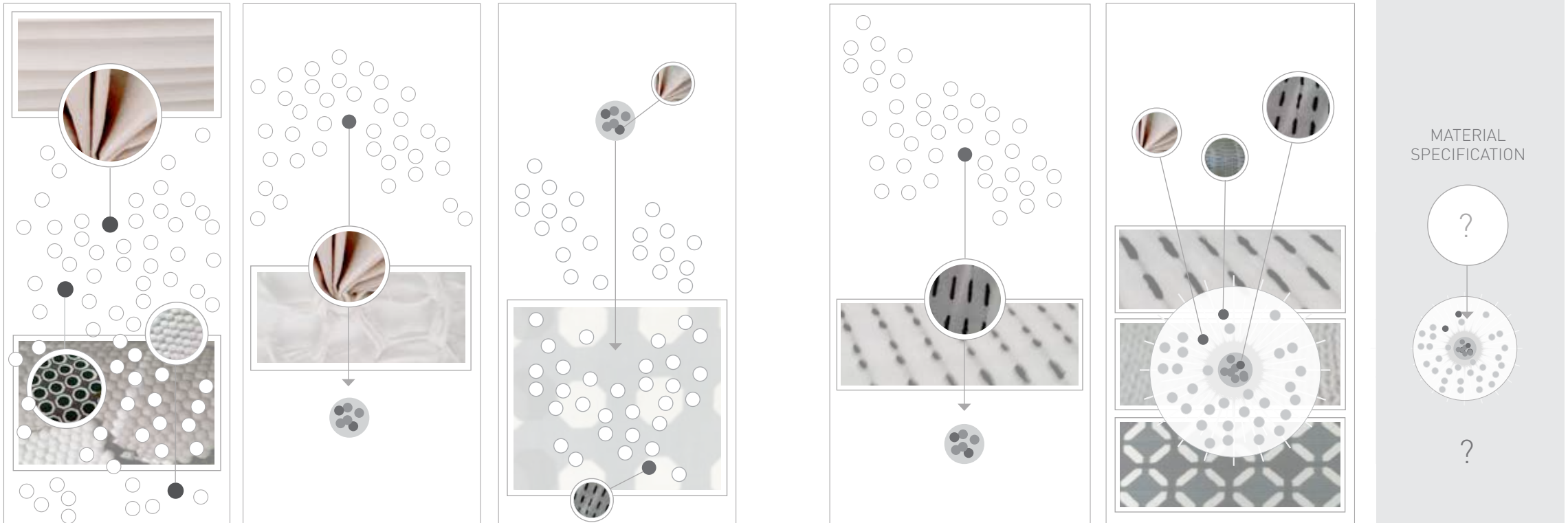
The students in the observation used textiles as a tool in two ways: Firstly, as a sketching or prototype material when developing, defining, and visualising the design; secondly, as a creative stimulus with which to better understand or develop the design. Textiles can be used as a tool throughout the 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.

DIVERGENCE | TRANSFORMATION | DIVERGENCE | TRANSFORMATION | CONVERGENCE | EXAMINING 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 possiblities 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.

The design contains decisions from a number of textiles. The final design is therefore presented with a material specification.

Can a material that fulfil these requirments be found or created? If a suitable material can be found, how will the full properties of this material work with the design?

Figure 18. TOOL

Figure 19

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.

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