

Fashion Futures Forward: Promises and Perils of Creative Technologies for Sustainable Fashion Design

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ABSTRACT

This paper explores digitalisation as a means for sustainable development within the fashion industry. Through an exploratory qualitative research design, we analyse interview and observation data on fashion industry professionals in Sweden and Finland to further the understanding of the promises but also potential perils of digital transformation in fashion. Our analysis shows that actors within the industry are willing to, and see the value of, digitalisation in order to transform current practices within fashion design. At the same time, lack of resources and understanding for the new types of knowledge required to fully adopt the desired changes leads to a situation where implementing new digital technologies at their full potential is difficult to achieve. Our results point at the importance of understanding the wider need for knowledge development within the fashion industry in order to succeed with the promises of digital technologies for sustainable transition in moving from a reactive to proactive stance on the possibilities of digitalisation.

Keywords: digitalisation, fashion design, sustainability, transitional practices, creative technologies, knowledge intensity

INTRODUCTION

The fashion industry is undergoing a profound transformation driven by the dual forces of digitalisation and sustainability. The two can be seen as heavily interlinked, with on the one hand, the industry being held forward in discussions on unsustainable practices, both regarding production and consumption (Buchel et al. 2022). On the other, technological development is widely discussed as one of the solutions, for example from the perspective of the production of fashion goods through the introduction of Industry 4.0 practices for optimisation (Wang et al., 2017; Bertola & Teunissen, 2018; Ghobakhloo, 2020; Akram et al., 2022; Nouinou et al., 2023).

In relation to this development, legislation at national and international level has recently begun to put a direct pressure on the fashion and textiles industry for advancement in the use of digital technology in their operations, not least in Europe. Through the EU Strategy for Sustainable and Circular Textiles, fashion and textile firms operating within the European Union are facing rapid changes to keep up with the legislative development. For example, the Ecodesign for Sustainable Products Regulation (ESPR), entered into force on 18 July 2024, aims to enhance the sustainability of products in the EU by emphasising durability, recyclability, and repairability, with a particular focus on textiles and fashion (OJ 28.6.2024, p. 33). Replacing the earlier Ecodesign Directive (2009/125/EC), ESPR adopts a more holistic approach to sustainability across the supply and value chains, focusing on the entire product lifecycle (Niinimäki et al. 2024, 45–46; OJ 28.6.2024, p. 26). Setting *performance* and *information* requirements, ESPR introduces a mandatory measure: a Digital Product Passport (DPP) to improve product traceability and transparency, supporting circular practices, lifecycle tracking and social sustainability assessment (Niinimäki et al. 2024, 47–48). However, accurate data on the environmental or social sustainability aspects are broadly missing, inaccessible, unreliable and costly (Niinimäki et al., 2024, 69). There is an urgent need for technologies for data collection and analytics as well as skilful people to operate with the technologies and interpret the data.

From the perspective of the fashion designer, technological advances have been part of design processes for a long time, not least in more experimental settings and research (McQuillan, 2020). The promises of digital tools such as CLO3D have been praised as new means of approaching the design process, the application mainly serving as a tool aiding the design development of physical end products in the conventional fashion paradigm (Baek et al., 2022). In parallel, digital-only fashion companies have emerged that strive to change these conventions, and who solely focus on developing and presenting digital designs through 3D CAD and extended reality technologies. The ambition of these companies is to decentralise the fashion system and to broaden the consumption of fashion from material to immaterial experiences (Särmäkari, 2022).

The promises of digital technology have been widely discussed, with many suggesting that its implementation has the potential to lead to innovation and a paradigm shift within the fashion industry (Colombi & D'Itra, 2023; Tepe & Koohnavard, 2022). However, the realisation of this paradigm shift remains unclear. This highlights the need for further research to critically examine the opportunities and challenges of digital technology and its current impact on design practices.

Therefore, the purpose of our study is to *explore the promises and perils of creative digital practices on fashion design and designers*. We do so from a cross-disciplinary

perspective, merging insights from fashion design research with innovation and entrepreneurship studies, more specifically in relation to knowledge development and implementation. We thereby contribute to the understanding of how digitalisation can be part of pushing fashion forward in this momentum where a paradigm shift is inevitable, aiming at further conceptualising the role of digital technologies for sustainable transition of fashion.

We contrast two different national contexts in the Nordics, namely Sweden and Finland. The region has a vibrant fashion design scene, spanning from fast fashion firms to more experimental fashion, and is home to several renowned fashion schools that are taking an active role in the reshaping of what fashion of the future could be. Examining the implementation of digitalisation in sustainable fashion transitions can provide valuable insights into its potential benefits and risks for the industry. The two countries have had interesting developments regarding digital practices in fashion in recent years and furthermore host industry and research initiatives on the topic respectively (Swedish Fashion Council, 2023; Solita & Gaia Consulting, 2022; Finnish Textile & Fashion, 2023, 2024).

The paper is structured as follows: first we give an overview of the theoretical framing for the study, contrasting research on the use and development of digital technologies for adaptation to fashion with literature on the role of varieties of knowledge for further development and implementation of innovation. Second, we present the methodology of the paper. Third, we give an account of the findings from the data collection, leading to the final analysis accounted for in the analysis and conclusion section.

LITERATURE REVIEW

A growing body of literature addresses the potential of the use and development of digital technologies within fashion design. The sustainability aspect has here been central, not least in research addressing the supply chain in fashion and textiles and circular economy, as these in current formats have great environmental impact (Antikainen, Uusitalo & Kivikytö-Reponen, 2018; Pereira et al, 2020; Huynh, 2021; Longo et al., 2021; Heim, 2022; Casciani, Chkanikova & Pal, 2022; Hardabkhadze et al., 2023; Colombi & D'Itria, 2023; Rosato & Calleo, 2023). Digital technologies are here seen as means by which production, through the use of Industry 4.0, can be more efficient and flexible as well as more customised towards the end consumer (Wang et al., 2017; Bertola & Teunissen, 2018; Ghobakhloo, 2020; Akram et al., 2022; Nouinou et al., 2023; Casciani & D'Itria, 2024). Digital-only fashion practices has been regarded as one of the solutions to reduce the use of physical resources and generation of waste (e.g. Särämäkari, 2022). The potential of metaverse technologies, such as virtual and augmented reality, and blockchain technology is argued to reduce the industry's environmental impact and enhance supply chain transparency, custom design

possibilities and smart manufacturing methods (Periyasamy & Periyasamy, 2023; Blazquez, 2024; Heim, 2022; Särmäkari, 2022).

While great promise is held forward in this stream of literature, critical aspects are also addressed, pointing towards potential risks of technological development and adoption. On the one hand, lack of knowledge of how to implement the digital tools could lead to sub optimisation (Longo et al., 2021). On the other, risks of for example mass customisation are brought forward in that the possibilities in fact can have the opposite effect to the desired outcome, leading to an increase rather than a decrease in consumption of fashion goods (Maldini et al., 2019). Metaverse applications and data-driven practices hold serious risks regarding the privacy, data protection, and the lack of skills working with data (Periyasamy & Periyasamy, 2023; Vänskä et al., 2024; Niinimäki et al. 2024). Furthermore, the energy use of data processing and blockchain as well as electronic and data waste and overconsumption of digital products have been raised as concerns around the digitalisation of the fashion industry and beyond (Periyasamy & Periyasamy, 2023). Digital fashion, especially AI-aided design, has been broadly criticized for the risks associated with intellectual property and ownership issues (Park & Kim, 2021; Härkönen, 2023; Boughlala & Smelik, 2024).

From a fashion design studies perspective, exploratory research into the potential of digital technology for changing traditional means and ways of working as a fashion designer have been brought forward, not least with regards to finding new ways for sketching and patternmaking (McQuillan, 2020). Likewise, the digital development and transformation of fashion design as a phenomenon has been held forward as a way by which the democratisation of fashion can continue beyond the paradigm shift imposed through the development of fast fashion from the 1970's onwards to now be a matter of opening up possibilities beyond the actual ownership of physical garments to the digital world (Särmäkari, 2022; Park & Kim, 2022; Sminkle, 2023; Boughlala & Smelik, 2024).

The strive towards digitalisation within the fashion industry also means that an industry that traditionally has been relatively low-tech in its operations pushes towards a state that sets demands for new and more varied forms of knowledge being involved in the operations. Furthermore, these changes mean that new, more knowledge-intensive firms are able to come in place with a strong focus on innovation through the use and development of varied forms of knowledge (Malerba & McKelvey, 2020; Klepper & Thompson, 2010; Baptista et al., 2013). At the same time, a shift towards the adaptation of new varieties of knowledge further calls for a deeper understanding of what knowledge means and how it differs from information, not least in being able to apply the acquired knowledge in the activities (Metcalf, 2002).

METHODOLOGY

As our research focuses on a relatively underexplored topic, not least given the cross-disciplinary point of analysis, we approach the phenomenon of digital practices for new and more sustainable design processes through an exploratory qualitative case study design (Yin, 2018). The main methodology used for data collection was semi-structured interviews, which in turn was complemented with observational studies.

We conducted interviews with fashion industry professionals from Finland and Sweden with expertise in digital technology from a design and systems perspective. A total of seven individuals were interviewed for the study - four from Sweden and three from Finland. The semi-structured interviews allowed the perspectives and experiences of the informants to be explored in detail. Follow-up mapping-questions (Yeo et al., 2014) were asked based on answers given which allowed the informant to address the key aspects of the topic as it pertained to them. This provided nuanced responses and better understanding of challenges and opportunities. An overview of the interviews is given in Table 1 below.

All interviews were conducted digitally and subsequently transcribed. The transcriptions were analysed using thematic analysis in relation to the topic at hand (Saldaña, 2021). The interviews were conducted by one researcher per interview, with the consequent analysis being performed by the research group as a whole. Common denominators were found concerning promises and perils of the current and future use of digital technology within fashion industry practices.

Table 1. Overview of informants

	Profession	Area	Country	Length
<u>#1</u>	Freelance designer, founder of digital fashion magazine, and educator	Digital fashion and games	Sweden	44 min
<u>#2</u>	Digital apparel and fashion creator	CGI company	Sweden	1h 4 min
<u>#3</u>	Project leader	Sustainability and circular economy	Sweden	48 min
<u>#4</u>	Fashion designer & founder of digital fashion studio	Digital fashion	Sweden	42 min
<u>#5</u>	Shoe designer, 3D design specialist, and educator	Digital fashion	Finland	1h 2 min
<u>#6</u>	Head of digitalisation	Fashion industry expert	Finland	59 min
<u>#7</u>	Fashion designer working with 3D tools	Sportswear company	Finland	1h 11 min

As a complement to the interviews with fashion industry professionals, observational studies (Yin, 2018) were made at an industry conference focused on digital technologies in design processes within fashion retail. The observations were further used to contrast and compare the findings from the interviews in terms of promises and perils of the use of digital technologies with how these are portrayed in actual industry settings dealing with implementation of digital technologies in fashion design practices and processes.

RESULTS AND DISCUSSIONS

The data collected for the study gave various interesting insights into the perceptions of digitalisation in fashion, its impact and potential for sustainable development, as well as indications on both promises and perils of this shift. An overview of the results

of our study is given in Table 2 below, showcasing the main themes that crystallised from analysing the data.

Table 2. Identified common denominators based on interviews and observations

Common Denominators: Promises	Common Denominators: Perils
Efficiency and optimisation of design and production processes	Conservatism toward change
Upskilling and reskilling	Resistance among colleagues and management
Strengthening consumer relations and engagement	Difficulties measuring benefits and uncertain about ROI
Transparency	Overflow of goods
Facilitating communication	Lack of competence and limited understanding of possibilities
Sharing culture	Insecurity about future, awaiting others' Proof-of-Concept

Unpacking the promises of digital technology for sustainable transition

According to the informants' experiences, digital technologies were seen as tools for reducing physical samples and accelerating the speed of the design process. Furthermore, AI technology was seen as a valuable tool to enhance these processes, improving precision in product decision-making and market analysis, thereby contributing to savings in time and resources.

From the interviews and observations, we could further observe that the implementation of digital technology has the potential to strengthen design teams' competencies and technical knowledge. According to the informants, that knowledge could be used to train other teams within the company and thus create ambassadors within the organisation that could assist in the change management that comes with the implementation of, for example, 3D CAD software packages and their working methods.

Moreover, the data suggested that companies that invested in sustainability and transparency would gain more trust through knowledgeable consumers. These consumers would subsequently strengthen the company's position and relevance on

the market. In addition to this, it was believed that innovative digital solutions could create competition benefits that would attract new consumer groups, particularly among younger generations and that digital platforms would offer increased opportunities to reach new consumer segments and thereby create new types of products.

All informants agreed that the use of 3D CAD software in design processes facilitated communication within design and manufacturing teams. Advanced digital tools such as CLO3D and Cinema 4D would make it possible to create realistic visualisations which could increase the standards of designs and their presentations. This would allow fashion companies to better communicate their products to consumers and production partners.

The observational data from the industry conference pointed towards a shift in how companies presented themselves and their design philosophies. They showcased how and where digital technology was implemented in their design processes, demonstrating transparency regarding various challenges faced such as efficiency, reliability and durability of technology, competence development of staff, and consumer loyalty and satisfaction. The conference revealed that many companies required mutual support and input to navigate the transformative changes they were all confronted with. This emphasised their shared challenges and highlighted a shift from a previously secretive and guarded nature to a more open approach that welcomed competitors' feedback and suggestions on potential paths forward.

Unpacking the perils of digital technology in fashion design practices

Six key factors were identified as significant challenges. These were resistance towards change, conservatism, insufficient knowledge, time, financial constraints, and insecurity about what the future holds with regards to technical advancement and EU legislations. These factors were considered to hinder both the current and future implementation and advancement of digital technologies within fashion design practices. In terms of conservatism, the informants believed that management within large fashion companies lack knowledge regarding digital technology and its potential. This makes them hesitant toward investing in it. Furthermore, companies demand quick turnover when it comes to investments in digital technology even though the measurable benefits of its implementation, such as less prototypes and more sustainable workflows, take years to come to realisation.

Another example of a peril was the resistance and unwillingness to change existing workflows. The informants stated that employees could be unwilling to learn new working methods, especially when the benefits or purposes behind them are not clearly expressed. Another hindering factor was the redistribution of tasks as a way to create more time for employees to learn digital technologies. This redistribution would

often fail because of lack of structure, leading to frustrated and overworked design teams.

Digital technologies also require cross-disciplinary collaboration between design, production, and IT, which, according to many, is not in place. This results in departments working in different ways without collaboration or an overview, making design processes inefficient. In the cases where working structures are in place, many companies lack internal competence and technical knowledge to fully make use of the technology.

The inefficiency is also due to a lack of concrete ways to show progress and value, for example in terms of costs and shorter production cycles. This makes it difficult to motivate further investment. Companies are hesitant and indecisive in their processes because new working methods require time and financial support. For this reason, and in relation to EU legislations, the informants describe that companies are interested in fast returns of investment and await results from competitors' proof-of-concept.

Informants describe efficiency as a double-sided coin where digital technology can facilitate design and production processes while it can also be misused. This is especially addressed when discussing the implementation of AI technology, where it can fuel ultra-fast fashion production cycles by making production easier and faster and thereby lead to increased overflow of goods.

The interviews further showed that the introduction of ESPR has effects on design processes, supply chain management, technological tools and business strategies. Designers would need to consider the entire lifecycle and durability of a garment, from material sourcing and production to multiple ownership and end-of-life, exploring e.g. zero-waste, modular and multi-functional garment design. Here digital 3D modelling could be a good tool. Design must consider care, repair, recycling and upcycling practices as well as physical and aesthetic durability (longevity), where also traceability and transparency are crucial. With the introduction of DPPs, designers may need to integrate digital elements into their designs (data carriers) that provide the required information to all the stakeholders in different forms. To provide reliable information, data must be collected, managed and analysed, which would require quite a lot of extra effort from the company. Current technology-based data analytics are not enough, as extensive research also on the use phase of the products is needed (Niinimäki et al. 2024, 54). Designers would need to work more closely with consumers, suppliers, manufacturers, and other stakeholders.

To sum up, extant literature addressing digital transformation in fashion design has showcased many promises, and some perils, of this development for pushing fashion design forward (e.g. Park et al., 2021; Akram et al. 2022; Casciani et al., 2022;

Periyasamy & Periyasamy, 2023; Boughala & Smelik, 2024). Our study confirms these previous results through interviews with industry professionals. At the same time, our initial studies further crystallise many perils still being present in the industry in terms of digitalisation, not least when it comes to development of varieties of knowledge (Malerba & McKelvey, 2020; Metcalfe, 2002). We propose that part of the explanation for the slow adaptation of digital tools and techniques on greater scale in fashion design can be accounted towards not necessarily the lack of knowledge per se, but rather how the varieties of knowledge are able to interact in moving the business forward.

Fashion design as a concept can traditionally be considered to be more focused around the idea of development and adaptation of creative and aesthetic knowledge (Thornquist, 2015). What we propose is that in order to move forward also in a digital era and thereby to tap into the potential of digital knowledge, we need to account for this knowledge-intensity in relation to one another, that is, how creative knowledge and aesthetic knowledge can communicate with, and thereby be strengthened by, the acquired digital knowledge. Likewise, these varieties of knowledge need to be set in relation to the more generic components of business knowledge and market knowledge that are crucial in succeeding with business making (Malerba & McKelvey, 2020).

CONCLUSION

The results from our preliminary, ongoing research shed interesting light on the current discussions of the potential use of digital technologies for sustainable transition of the fashion industry. Furthermore, it showed that the promises, and especially perils, of Swedish and Finnish contexts are similar. Therefore, differences between the two are not specified in the results.

We propose that the promises of digitalisation of fashion needs to be set more in relation to the development and use of varieties of knowledge in general as to meet its potential, in combination with freeing up the resources needed for this transition to build the infrastructure necessary for such a change. This falls in line with results from our data pointing to the general conservatism within the industry in terms of actions taken in the actual business making that is fashion design, leading to a lack of investments that could further enhance the implementation of the digital knowledge acquired and developed. Failing to do so risks putting the efforts into a perpetual mode of perils that are never turned into the potential promises underlying the efforts. Hence, we propose that the importance of understanding the wider need for knowledge development in relation to necessary resources and infrastructures within the fashion industry needs to be stressed further in order to succeed with the promises of digital technologies for sustainable transition in moving from a reactive to proactive stance on the possibilities of digitalisation.

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