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Transforming Consumer Experiences: Unveiling Sustainable Innovations from ITMA 2023

Wenna Han,
Textile and Apparel, Technology and Management,
Wilson College of Textiles, NC State University,
Raleigh, NC, USA

Introduction

The textile and apparel industry thrives on constant innovation, driving advancements that enhance product performance, promote sustainability, and improve consumer experiences. Amidst this ever-evolving landscape, the international textile and garment technology exhibition (ITMA) emerges as a global platform, showcasing transformative technologies and unveiling groundbreaking concepts that reshape the future of the textile sector. In 2023, ITMA once again engaged industry professionals across the entire supply chain worldwide, demonstrating the latest breakthroughs in textile and apparel manufacturing and pioneering products and services set to revolutionize the consumer experience.

Sustainability has become a critical consideration in the textile and apparel industry, encompassing three key dimensions: environmental, social, and economic sustainability (Elkington, 1998). Environmental sustainability addresses the industry's impact on the planet, social sustainability aims to mitigate labor exploitation and promote ethical practices, while economic sustainability involves creating economic value and long-term viability for all stakeholders involved in the industry. Today's consumers are increasingly conscious of the environmental and social impact of their purchasing decisions. They seek products that align with their values and demonstrate a commitment to sustainability (Amed et al., 2019).

This paper aims to discuss sustainable innovations exhibited at ITMA 2023, particularly those that directly elevate the consumer experience. Specific areas include blockchain-based digital product passports, 3D-printed shoes and garments, VR and AR-empowered virtual showrooms, and AI-assisted apparel upcycling. Each of these technologies not only addresses the sustainability concerns of the industry but also enhances the consumer experience, fostering a more sustainable and consumer-centric textile future.

By examining these innovative product and service offerings, this paper aims to present a comprehensive understanding of the next frontier in textile and apparel industry advancements, inspire further research, and foster meaningful discussions. In the subsequent sections of this paper, each technology will be presented, exploring its capabilities, benefits, and notable examples observed at ITMA 2023.

Digital product passport

Consumers today are increasingly concerned about the industry's environmental footprint, with issues such as excessive water usage, chemical pollution, and waste generation under scrutiny. Also, consumers are becoming more invested in brands' social

responsibilities, encompassing fair wages, safe working conditions, and ethical treatment of workers. In terms of economic sustainability, counterfeiting is emerging as a critical issue causing economic losses to businesses and arising significant concerns among consumers. It not only undermines brand reputation but also jeopardizes consumer trust. As counterfeiters continually refine their tactics to deceive unsuspecting buyers, consumers face the challenge of distinguishing genuine from counterfeit products.

Given these challenges, consumers expect greater transparency and accountability from brands, pushing for more sustainable practices throughout the supply chain. McKinsey reported that over half of millennials (52%) consistently seek background information before making a purchase. In addition, 42% expressed a desire to understand the components of the products and the production process before buying them (Amed et al., 2019). The apparel industry, with its complex and often opaque supply chains, demands innovations that address these consumer concerns. One such innovation showcased in ITMA 2023 is the digital product passport, exemplified by PaperTale, which promises to provide radical transparency to the textile and apparel industry. PaperTale aims to build a trustworthy and transparent ecosystem that gathers and verifies supply chain data, in real-time through blockchain technology.

Currently, some manufacturers adopted the use of "clean label" components, or ethical certification badges, such as Fairtrade or non-GMO, to indicate their products are procured sustainably. Moreover, brands like H&M's Arket and Reformation are moving towards “radical transparency” in manufacturing, revealing details about product origins and the environmental impacts of their production processes (McKinsey, 2019). Furthermore, brands like Everlane show an even higher level of transparency by specifying costs of material, labor, transport, duties, and mark-ups, along with details about the production (McKinsey, 2019). However, the current methods are facing challenges in gathering and verifying data. PaperTale's blockchain technology provides an immutable and transparent solution, where data cannot be altered once added. The distributed nature and cryptographic security of blockchain make it well-suited for ensuring the integrity and transparency of supply chain information. By leveraging the technology, supply chain participants can securely record and share data, creating an auditable and tamper-proof record of every transaction and movement within the supply chain. This enables real-time visibility into the provenance, authenticity, and movement of products, reducing the risks of counterfeiting, fraud, and unethical practices. From the consumer's perspective, access to supply chain information enables them to discern between products that violate sustainability norms and those valuable ones, thereby facilitating their purchase decision and heightening their appreciation for sustainable goods.

Figure 1 displays the user interface of the PaperTale app (PaperTale App, 2023). Upon scanning the tag attached to an apparel item, consumers gain insight into the product's entire journey—from raw material sourcing to yarn manufacturing, fabric formation, coloration, exportation, garment production, and even each transit. Both water and carbon footprints for each process are available to consumers. Furthermore, the platform shows the workers/craftsmen involved in each step, providing information about their wages. Simultaneously, PaperTale is working to incorporate an online shopping feature into its app, enabling consumers to make purchases after reviewing product information. Currently, the product tags can be represented in QR code or NFC (Near Field Communication) formats. For NFC, a variety of tag types are available, including those made from woven label, zipper, rubber, leather, cork, ceramic, and silver button. Overall, PaperTale could enhance consumers’ product knowledge, which can subsequently aid in product evaluation and influence purchase decision-making.

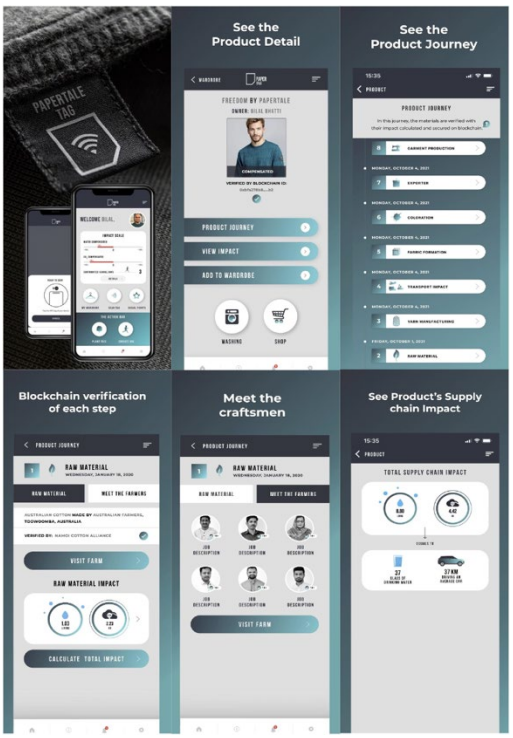

Figure 1. User Interface of PaperTale App

While the primary focus of digital product passport technology has been in the textile and fashion industry, its principles and benefits can be extended to other industries such as pharmaceuticals, sports equipment, shoes, and spare parts. Despite this, the technology remains largely in its early adoption phase and has yet to gain widespread prevalence in the marketplace. Currently, only several brands are engaging in market testing. For example, Gina Tricot, a Swedish apparel brand, is working with PaperTale, aiming to provide consumers with more detailed product information (GinaTricot, 2023). PaperTale's CEO, Mr. Bilal Tufail Bhatti, indicated that the first commercial collection incorporating this technology will be released in August 2023.

Mr. Bilal Tufail Bhatti also indicated a significant challenge associated with the development of the PaperTale platform, that is how to determine the optimal amount of information to disclose. The platform seeks to strike a balance between providing sufficient information to assist consumers in their decision-making process and preventing information overload. Multiple research provides evidence that transparency can enhance price satisfaction, increase trust and brand loyalty, and contribute to sales (Simintiras et al., 2015; Egels-Zandén & Hansson, 2016; Bhaduri & Ha-Brookshire, 2011). However, a study by Kim et al. (2020) investigated the impact of varying levels of product information disclosure on brand equity and consumers' purchase intentions. Interestingly, the findings suggested that differing levels of disclosure did not significantly influence consumer perceptions, which means it is not necessarily the more information disclosure the better. At the same time, the lack of a universally endorsed standard for what defines an ethical or sustainable factory prolongs ongoing debates, and the potential pitfalls of oversharing could jeopardize trade secrets and privacy, which might result in internal conflicts (Amed et al., 2019). The competitive nature of sourcing and pricing in the industry often demands a certain degree of confidentiality, making the path to complete transparency intricate (Amed et al., 2019). Thus, the question of optimal disclosure remains an area of investigation for both industry practitioners and academic researchers.

3D-printed footwear and textiles

The textile and apparel industry is actively pursuing sustainability initiatives regarding the environmental impact, particularly in the realm of waste reduction during manufacturing processes. One technology that has gained significant popularity in recent years and holds promise in achieving this goal is additive manufacturing (AM), commonly known as 3D printing. AM involves the creation of three-dimensional objects by adding material layer by layer, guided by a digital 3D model. This technology enables the production of intricate shapes that are often unattainable through conventional manufacturing methods like subtractive manufacturing or formative manufacturing. Additive manufacturing finds applications across various industries, including aerospace,

medical, automotive, construction, and notably, the textile industry, especially in footwear production. AM has the potential to not only reduce waste and enhance recyclability but also deliver new product experiences to consumers that align with the sustainability objectives of the textile and apparel industry.

At ITMA 2023, Decathlon, Lonati Group, and HP presented their latest advancements in 3D printed shoes, showcasing a collaborative project. Decathlon introduced a novel footwear concept featuring a midsole and outsole produced using HP's Multi Jet Fusion (MJF) technology, while Lonati's expertise contributed to the creation of knitted uppers. This partnership allowed Decathlon to demonstrate the possibilities of integrating different technologies into its sports shoe concept. An HP Jet Fusion 5200 system was utilized to 3D print the shoe's sole with Ultrasint TPU01, a highly versatile thermoplastic polyurethane (TPU) powder provided by BASF. The selection of this specific material was based on its exceptional shock absorption capabilities and flexibility, both critical attributes for sports shoes. Lonati's XT-Machine and Double Cylinder E1530XS knitting machines were employed to weave the upper section, creating a lightweight and comfortable fabric "sock." The knitted upper offers a high level of flexibility, breathability, and personalized feel, ultimately enhancing the overall comfort and performance of the shoe. Figure 2 provides a visual representation of the HP MJF printing machine and the 3D-printed shoe components, as well as the final assembled shoes.

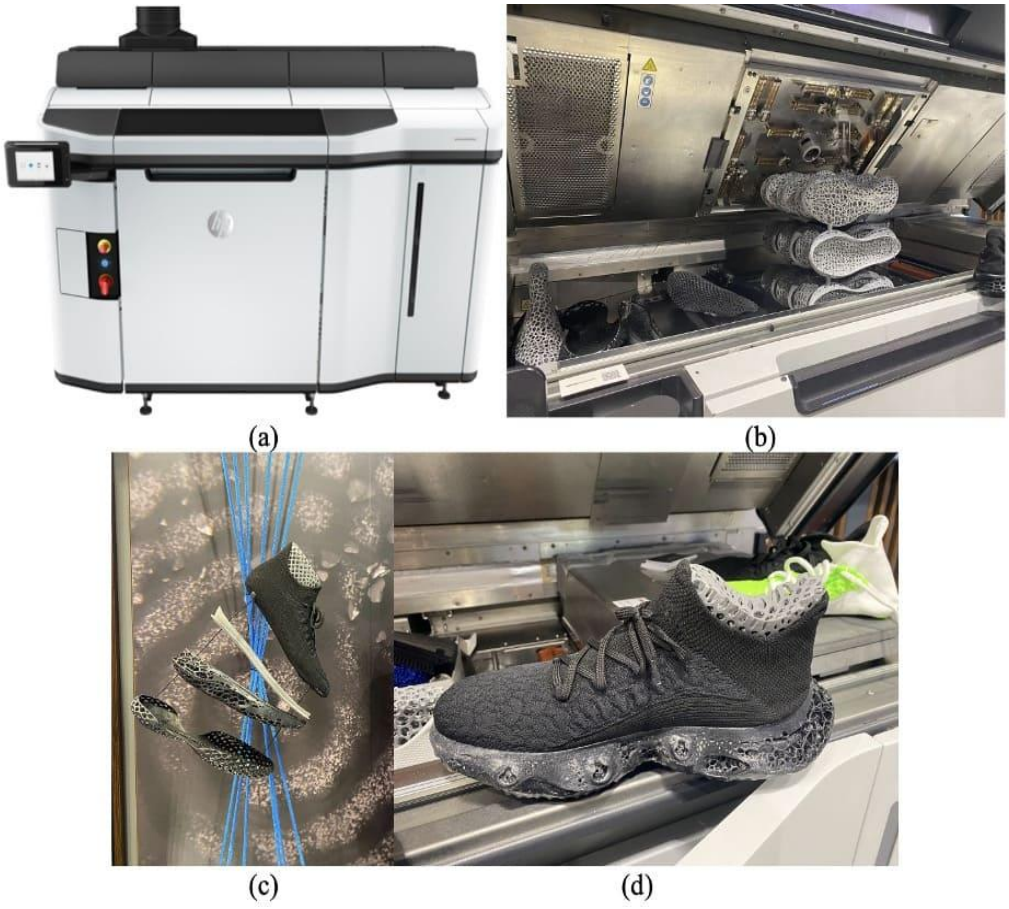

Figure 2. HP Jet Fusion 5200 3D Printer (a-b), 3D printed shoe parts (c), assembled shoes (d).

One significant benefit offered to consumers by 3D-printed shoes is customization. Traditional shoes are typically manufactured in standard sizes, which may pose fit issues. However, with the advent of 3D printing, shoes can be precisely tailored to the exact dimensions of an individual's foot, resulting in an improved fit and enhanced comfort. In addition to size and fit, 3D printing theoretically enables customization in terms of design and aesthetics. Decathlon's staff indicated that although they offered limited color options at the ITMA 2023 due to current technology constraints, it is conceivable that in the future, customers may have the ability to select their own patterns, colors, and styles. This level of personalization is particularly advantageous for consumers seeking unique and customized footwear.

On the other hand, 3D-printed shoes also serve as a means to support sustainability objectives. The made-to-order production model helps optimize inventory management, thereby minimizing waste associated with overproduction. Furthermore, since the shoe parts are not glued together, the recyclability of the shoes is enhanced in that each component can be individually repaired or replaced, prolonging the product's lifespan. The use of a single sustainable material for the grip and cushion parts further enhances the shoe's recyclability. Also, Decathlon has expressed its intention to establish a recycling program aimed at guaranteeing that all shoes sold by the company are able to be recycled. Additionally, 3D printing technology enables local manufacturing, which can decrease energy consumption during transportation and simultaneously support local economies. The environmentally friendly features of 3D printed shoes make them an appealing choice for environmentally conscious consumers in the modern era.

A large driver of the adoption of 3D printing from the industry perspective is speed and efficiency. Traditional shoe manufacturing can be a lengthy and complex process. 3D printing allows for rapid prototyping and production, reducing the time it takes to get a shoe from the design stage to the market (LuxCreo, 2023). Also, it reduces the risk of overproduction and allows for better responsiveness to market trends. A report projected a substantial market potential, with estimated annual revenues approaching $9 billion by 2030 (SmarTech Analysis, 2020). The key manufacturers involved in the current 3D-printed footwear market include Carbon, voxeljet, HP, Voxel8, Kings3D, Formlabs, Stratasys, 3D Systems, EOS, Prodways, BASF, ECCO, German RepRap, Adidas, Nike, Reebok, New Balance, Under Armour, and Timberland (SmarTech Analysis, 2020).

A number of footwear brands have adopted 3D printed technology for making midsoles, such as Adidas, New Balance, and Ecco (Carlota, 2022). While the mass production of 3D-printed midsoles is feasible, the manufacturing of uppers presented more challenges. Some attempts have been made to address this issue by utilizing foam-like materials and exploring the creative possibilities of a single-print aesthetic in fully 3D-printed shoes. For example, ELASTIUM produced the world's first fully 3D-printed shoe using lattice-structured low-density thermoplastic elastomer (TPE) foams (Avery, 2023). However, to achieve optimal comfort level and marketability on a larger scale, a more practical approach to making uppers is demanded. A promising solution lies in the combination of industrial knitting and 3D printing, as demonstrated by the products mentioned above by Decathlon, Lonati Group, and HP. This innovative approach combines the benefits of both technologies, offering the potential for more efficient and cost-effective production of uppers in the 3D printing process.

Except for Decathlon, Lonati Group, and HP, Stratasys also presented their 3D printing technology at ITMA 2023, with a specific focus on their latest direct-to-textile printing technology, which expands the applications of AM beyond footwear to include the textile and fashion sectors. Their direct-to-textile printing technology provides support for fashion designers in exploring

boundless creativity and design possibilities, enabling consumers to enjoy textile products with diverse shapes, materials, scales, textures, and colors. The technology has been ready for industry application where it can effectively produce marketable products. Figure 3 displays a direct-to-textile printing machine, namely the J850 TechStyle 3D printer, alongside a collection of 3D printed products showcased at the event, highlighting the capabilities and aesthetic impact of this innovative approach in the fashion industry. The displayed designs in Figure 3(c) and (d) originate from Foraeva studio, while (b), (e), and (f) are attributed to Stratasys.

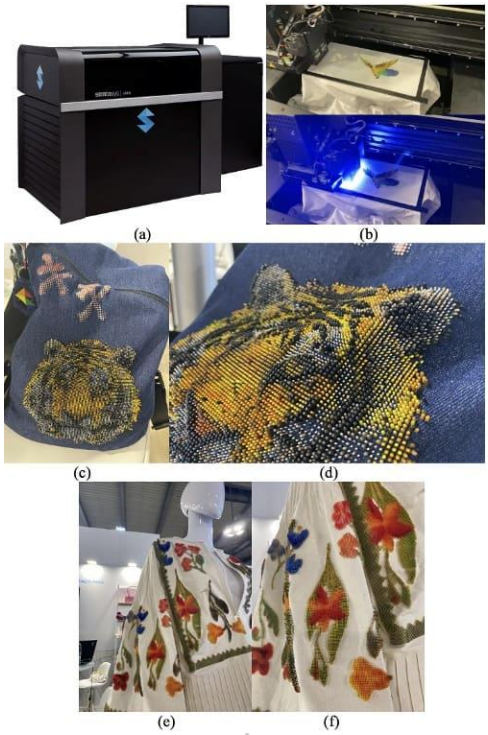

Figure 3. J850 TechStyle 3D printer (a-b) and textile products with 3D printing (c-f)

As evident from the ITMA 2023, the integration of 3D printing technology is poised to revolutionize the consumer product experience in both textiles and footwear industries. With its ability to enable customization, enhance fit, and offer unique design possibilities, 3D printing holds tremendous potential to capture a substantial market share.

Virtual Showroom

The surge of online shopping has triggered the growth in virtual technologies designed to replicate and enhance the in-store shopping experience. More than just a shift in retail strategy, the digitalization of the shopping experience can significantly contribute to sustainability. By reducing the need for physical stores and their associated energy consumption, waste production, and logistical footprints, e-commerce can help lessen the industry's environmental impact. At the same time, virtual technologies offer new possibilities for personalization and interaction, enabling brands to create unique and engaging consumer experiences. This dual potential of digitalization was illustrated at ITMA 2023, particularly through the introduction of the virtual showroom.

A virtual showroom in the fashion industry refers to the digitized environment that replicates the experiential elements of a physical store, showroom, or fashion event. This innovative platform employs technologies such as virtual reality (VR), augmented reality (AR), and high-resolution

3D modeling, enabling customers to interact with clothing and accessory items virtually. Numerous exhibitors at ITMA 2023 demonstrated their virtual showrooms, used either for client presentations or direct consumer engagement.

One noteworthy example was the VR showroom project showcased by Style 3D in partnership with Kimhaie Fashion (Kimhaie, 2023a). Founded in 2015, Style 3D is a leading digital solution provider in the global fashion industry, supporting fabric measurement, simulation design, design review, and online modification to visual effect display. Kimhaie Fashion, founded in 2002, has built a reputation on its robust R&D, consistently offering over 600 unique designs per season for client consideration. This collaborative VR showroom project significantly enhances product demonstration capabilities, eliminating the need for customers to visit physical stores while providing effective and detailed product information.

The virtual showroom created by Style 3D for Kimhaie is accessible on Kimhair's website for consumers to experience without the necessity of a VR device (Kimhaie, 2023a). The virtual showroom mirrors the display layout of the brand's physical stores, thereby offering a comprehensive, immersive virtual shopping experience. Upon entering the virtual showroom online, customers are able to virtually navigate around the store and access detailed information about each garment. By clicking on specific apparel items, customers will be directed to a new webpage that displays the product from all angles. This feature allows consumers to closely observe the products, even enlarging them to scrutinize fabric or trimming details. Furthermore, the model's background can be altered to display the product in varying environments. Figure 4(a)-(c) features screenshots from this innovative VR showroom, showcasing the 2023 Autumn/Winter collection of Kimhaie (Kimhaie, 2023a). In addition to the virtual showroom, the collaboration introduced a 3D fashion show in which simulated models exhibited new products in a virtual environment. The high-level realism of the 3D fashion show is noteworthy, as the models' motions and apparel effects are vivid to reality. This innovative depiction of runway shows provides further evidence of the transformative potential of virtual technologies in the fashion industry. Figure 4(d) offers a glimpse of the 3D fashion show video (Kimhaie, 2023b).

Figure 4. VR showroom (a-c) and virtual fashion show (d) provided by Style 3D and Kimhaie.

Another significant example of virtual showroom revealed at ITMA 2023 is provided by Shima Seiki, developed in collaboration with the Telecoms firm KDDI Corporation. Distinct from Style 3D and Kimhaie's project, Shima Seiki's virtual space does not replicate a physical store but instead focuses on a model-centered try-on effect. Each product is showcased by an individual model, and viewers are able to pan around the entire virtual space, offering a complete 360-degree perspective. Consumers are able to access the virtual space online. As illustrated in Figure 5 (a) & (b) (Shima Seiki, 2023), by clicking on the "i" button located above the 3D model, viewers can access detailed information about the product. Another feature that makes Shima Seiki's virtual showroom stand out is its integration of AR, which allows viewers to virtually place the model within specific real-world environments, such as their homes, offices, and gardens. Figure 5(c) illustrates the use of the AR feature on a mobile device, where the author places a model wearing the clothing product in a real-life lounge room captured by the device's camera. By bridging the digital and physical domains, AR technology introduces an additional layer of interactivity and authenticity to the virtual shopping experience.

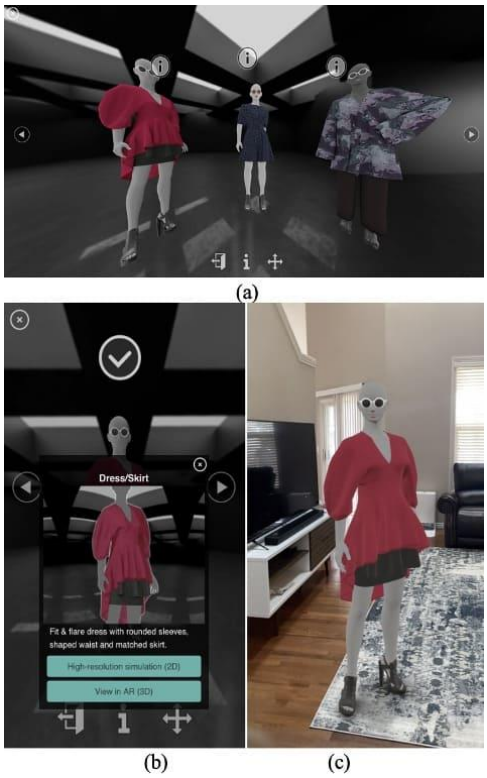

Figure 5. Virtual showroom by Shima Seiki.

While the majority of virtual showrooms displayed at ITMA 2023 primarily serve B2B applications, all exhibitors agreed that these innovations could extend to B2C retail as well. Several fashion brands such as Gucci, Balenciaga, and Louis Vuitton have already embraced virtual showrooms, which offer an improved product showcase, extend their reach to global customers, reduce costs associated with physical showrooms, and provide valuable data for personalized marketing strategies. Moreover, these digital platforms emerge as a sustainable alternative to traditional fashion shows and events, thereby aligning with the industry's commitment to

sustainability. From a consumer standpoint, virtual showrooms offer an advanced level of engagement and customization, allowing consumers to explore and experiment with fashion items without leaving their homes. This expansive interaction with products greatly enhances the decision-making process and potentially leads to heightened consumer satisfaction. Overall, virtual showrooms mark a noteworthy convergence of technology and fashion, responding to shifting consumer demands and sustainability-oriented industry trends.

AI apparel upcycling

Another significant avenue where sustainability and technological innovation intersect lies in artificial intelligence (AI) facilitated apparel upcycling. An estimated 30% of all clothing produced is categorized as overproduction, causing significant waste within the textile and apparel industry (Science Park Borås, 2022). With the growing consumer desire for variety, sustainability, and affordability, the lifespan of fashion products is being stretched as pre-owned, refurbished, and repaired (Amed et al., 2019). Apparel upcycling is the process of transforming discarded or used clothing items into new products with a higher value or improved quality. Not only does upcycling require less energy than traditional recycling methods, but it also presents a solution to divert textile waste, providing garments with a renewed life cycle (Bhatt et al., 2019). While apparel upcycling benefits sustainability, it also comes with some challenges. Sorting through diverse textile types, sizes, and conditions can be time-consuming and labor-intensive. Also, the need to disassemble, clean, and prepare the source materials for upcycling adds complexity to the production process. Moreover, upcycling often necessitates designer involvement for each individual piece, posing challenges in terms of scalability. However, incorporating AI into upcycling processes can significantly enhance efficiency and reduce labor costs, which ultimately increases the accessibility of upcycled products for consumers. One AI-empowered apparel upcycling project exhibited at ITMA 20203 is the AI remake project, a sub-project of the Microfactories project by Science Park Borås and the University of Borås, in Borås, Sweden.

Microfactories, a project focused on sustainable fashion, developed an AI remake machine, incorporating robotics, AI, and sensor technology, to allow an automated process to transform discarded garments into valuable items. The project combines Eton Systems' overhead conveyor technology with advanced AI to detect garment defects and generate design recommendations. Figure 6 shows three examples of upcycled products by the AI remake project. In Figure 6(a), the AI system identifies a food stain on the front of a white shirt, prompting the recommendation of a transfer print to obscure the imperfection. In Figure 6(b), small holes were detected on the left chest and arm of a shirt, and the AI suggested the use of embroidery to address these defects. In Figure 6(c), stains found on the collar and cuffs of a shirt lead the AI to propose using print to upcycle it. This innovative process introduces design components that repair and artfully conceal flaws, albeit the human designer is still required to make the final decision regarding the upcycling method. According to the communications officer of Science Park Borås, the aim is for using AI to assist rather than replace human input. By effectively sharing the workload, AI can enhance the efficiency of apparel upcycling.

(a) (b) (c)

Figure 6. Upcycled apparel products by the AI remake project.

While enhancing industry efficiency and bolstering sustainability, upcycling also delivers a host of benefits from the consumer perspective. Foremost, environmentally conscious consumers can actively participate in sustainable practices and reduce their carbon footprint by endorsing upcycled products. Moreover, upcycled apparel offers consumers the opportunity to own unique garments or accessories that have been creatively repurposed rather than mass-produced, which assists with consumers' self-expression. In addition, upcycled items or the services offered by AI-aided upcycling should be more affordable, which makes sustainable fashion more attainable for a wider range of consumers. However, several barriers have been identified in the literature concerning consumers' acceptance of clothes made from recycled materials, including performance concerns, contamination risks, fears about style obsolescence, unsupportive social norms, and ethical issues (Harris et al., 2016; Yoo et al., 2021; Polyportis et al., 2022). The integration of AI in upcycling manufacturing has the potential to address these consumer concerns and elevate purchase intention. However, the actual market response remains for the industry and researchers to examine. The role of AI in promoting sustainable fashion is worth exploring for consumer researchers. For the industry, effective marketing strategies and storytelling are essential to promote the benefits and appeal of upcycled apparel.

Conclusion

This paper delved into the transformative power of technology in redefining consumer experiences in the textile and apparel industry, with a spotlight on sustainable innovations exhibited at ITMA 2023. The industry's increasing commitment to sustainability, alongside growing consumer demand for environmental and social responsibility, has fostered the emergence of groundbreaking developments, notably digital product passports, 3D-printed footwear and clothing, virtual showrooms, and AI-aided apparel upcycling. These innovations are presented as an indicator of the significant progress being made and the potential that technology holds. However, it's crucial to recognize that the adoption and integration of these innovations pose challenges and require concerted efforts from all stakeholders, from manufacturers and brands to consumers and policymakers. This paper serves as an exploration of the opportunities presented by these advancements, and it is hoped that it will inspire further research and discussions that drive the industry toward a more sustainable and consumer-focused future.

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