FUTURE OF FASHION-TECH ALLIANCE

edited by
Daria Casciani, Chiara Colombi

FTalliance

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FTALLIANCE
Weaving Universities and Companies
to Co-create Fashion-Tech Future Talents

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SECTION 1. OVERVIEW

Sustainable futures of Fashion-Tech

Exploring paths of Fashion-Tech transition toward the cultural, social, economic, and environmental sustainability.

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Background

The fashion industry, being both a sociocultural and industrial system, has been affected by the potential of the "Fourth Industrial Revolution". Electronics, information and communication technologies, biotechnological materials, and digital transformation enable the creation of cyber-physical systems that blur the lines between the physical, digital, and biological worlds along the entire supply and value chain (Bertola and Teunissen, 2018). The Internet of Things (IoT), Big Data and Artificial Intelligence (AI), advanced manufacturing and digital fabrication, virtual reality (VR), augmented reality (AR), mixed reality (MR), and collaborative robotics (CR) are just a few examples of the technologies at the core of the implementation of Fashion-Tech systems that are paving their way into the fashion industry and enabling fashion brands to create intelligent and innovative strategies to completely shift fashion paradigms. Fashion-Tech has developed in this setting as a ubiquitous, fragmented, and transdisciplinary industry that includes bio-nano-info technologies and may lead to open-innovation trajectories, activating immediate opportunities and influencing long-term shifts on the industrial, economic, and professional levels. At the same time, Fashion-Tech gives the possibility to broaden the scope of the research from design and technology-oriented issues by raising ethical questions, focusing on sustainable challenges, and possibly driving unexpected outcomes. The COVID-19 pandemic has accelerated current change and reneged on prior agreements. The global fashion system is now under criticism, both in terms of production and consumption as well as focusing on its detrimental impacts at social, cultural, economic, and environmental levels.
Given this scenario, design approaches are particularly interested in facilitating a digital transition of the whole system toward a holistic view of sustainability, associated with the strenght of resilience to envision, shape and develop a better and more responsible future for the fashion system. Therefore in this publication, we aim to address a multi-dimensional perspective on sustainability, whose definition is established on four pillars: economy, environment, society and culture (Ceschin and Gaziulusoy, 2016; UNESCO, 2010; UCLG, 2010).

Fashion-tech influence on a multi-dimensional sustainability

Environmental sustainability refers to our ability to live within biosphere limits, recognising planetary boundaries and limited resources (Rockström et al., 2009). It draws on ecological principles and various practices that recognise people as part of nature and looks for ways to preserve the quality of the natural world on a long-term basis.
Fashion industry´s impact on the environment focuses in particular on design and production processes, as well as on existing materials, their qualities, and their respective environmental footprints.
Economic sustainability aims to ensure a healthy relationship between investment, productivity, employment and economic status and to guarantee that citizens enjoy living conditions that are within agreed boundaries in terms of wage levels relative to costs of living. Fashion industry's should introduce more sustainable and circular business models to support sustainable entrepreneurship and alignment with relevant actions that align with the responsability of the brand. Social sustainability refers to the ability of a community to interact and collaborate in ways that create and exemplify social cohesion, by considering places, communities and organisations, resources, opportunities and challenges. Ethics, wellbeing and quality of life, social inclusion, human beings, child labour laws, and gender equality are the core of the social sustainability scopes. Cultural sustainability aims to recognise and cultivate diversity, to reflect a range of communities, locations, cultural resources and belief systems, safeguarding their integrity. The cultural dimensions of sustainability means to comprehend fashion industry's impact on culture and cultural systems in order to explore how they can be employed in the fields of textile, apparel, and fashion. The fourth pillar of sustainability is aimed at Identifing a recognisable and meaningful relationship between culture and heritage in order to sustain, discover, learn values and knowledge to encode deeper meanings which can be reconfigured into new universal narratives (Martin and Vacca, 2019; Brown and Vacca, 2022).

Aim and structure of the publication

This publication aims to collect, describe and return three different perspectives that approach the sustainable futures of Fashion-Tech alliances among academic researchers and teaching staff, professional designers, researchers, and technicians from Fashion-Tech companies and students, exploring paths of the Fashion-Tech transition toward the cultural, social, economic, and environmental sustainability. The publication reports on these different perspectives in the structure of four sections that cover both emerging topics in the Fashion-Tech scenario and also the results of collaboration among the different stakeholders of the sector. Section 1 provides an overview of the publication providing a precis of topics and opportunities for collaboration among HEIs, Companies, and undergraduate students. Section 2 presents four interesting research works in form of invited academic papers that showcase the most promising research tracks conducted at the HEIs partners of the FTalliance, in particular Politecnico di Milano, Design Department and ESTIA Institute of Technology. Section 3 presents the digest of students' activities and achieved results of 13 Fashion-Tech Residencies, a piloted model of collaboration between HEIs and Fashion-Tech Companies allowing to boost the innovation potential of Companies meanwhile enhancing the professional opportunities

and skills of students working on real-world projects to exploit knowledge, materials, and laboratories from both Academia and the professional fields. The 13 projects has been selected as prototype to be exhibited during the the Biarritz Good Fashion 2022 event (October 2022). Finally, section 4 provides an overview of innovative French Fashion-Tech start-ups working with technologies integration into design-driven processes toward sustainability. These companies have been selected to pitch their business ideas during the Biarritz Good Fashion 2022 event (October 2022).
To this extend, the publication also includes the deliverable D5.3 of the FTalliance project, by providing excerpts of the event "Future Fashion-Tech Alliance" a roundtable about the FTalliance project that took place the 20 October 2022 in Biarritz during the aforementioned event.

Unveiling Fashion-Tech sustainable futures

The publication stems from an open call for paper launched in July 2022 striving to collect original and recent research studies, along with emerging and straightforward findings that explore Fashion-Tech future perspectives with a holistic sustainable impact. As a pervasive, fragmented and transdisciplinary sector, Fashion-tech has shown to expand in multiple directions, due to the complexity and transversality of the field (Casciani and Colombi, 2022). Scientific, academic and industry based research (Bertola & Teunissen, 2018; Noris et al., 2021; Nobile, 2021; CB Insights, 2022; ETP, 2016) has attempted to frame the borders, correlations, and future trends of the research topic of the sector, highlighting limits and opportunities. In addition, through the FTalliance project, we have been investigating how the transformation of the Fashion-Tech sector are changing the skills required by future professional, thus impacting and progressing new educational models (Colombi and Casciani, 2021; Casciani, Colombi, Jansen & Chae, 2021; Teunissen, Miller, Colombi & Casciani, 2021).
According to these previous studies, the following five research directions were presented in the call:

- Fashion Virtual Dimension, focusing on the organizational and sustainability dimensions of digital and virtual fashion systemic transformation
- Sustainable Fashion 4.0, focusing on innovation, sustainability, and digital transformation of fashion manufacturing processes
- Bio-tech Fashion Materials, focusing on circularity and recyclability.
- Eco-phygital retail, focusing on digital and technological acceleration of consumption patterns, and retail experiences.
- Reshaping fashion-tech education, focusing on the sociocultural and pedagogical dimension of fashion-tech education and its transformation towards sustainability.

The invited academic papers under this publication provide a focus specifically on three topics among the suggested ones, giving a instantaneous picture that the future implementation of the Fashion-Tech sector will be extremely interested in:

- the biotech and growing materials for the fashion sector supporting sustainability in terms of circularity and recyclability, through zero-waste and cradle-to-cradle approaches;

- human-centred applications of Industry 5.0 in the fashion field enabling the collaboration among craftspeople and robots in manufacturing activities toward productivity and enhanced working conditions.
- Fashion-tech education evolution in light of emerging new methodologies and pedagogical practices, but also driven from research findings and insights to shape learning objectives and expected outcomes of the learning experiences.

In particular, around the first topic, the article from D'Itria focuses on circular models based on the design and fabrication of bio-based materials and fibers to achieve the sustainable transition of the fashion system against natural resource depletion and the limitation of production of residual waste. In the same context but focusing specifically on bacterial cellulose, the paper of Bolzan and Regaglia investigates the possibilities of integration and contamination between technology and bacterial cellulose by mapping the opportunities arising from the application in the production phase as in the final product outputs.
The second topic is investigated by Bernar, Prevot, Legardeur and Chanal focusing on the collaboration between humans and collaborative robotics within a clothing workshop where it is assessed the improvement in productivity and also the good practices for human management in a human-robotic interaction application.
The third topic is investigated by Rohsig Lopez and Legardeur exploring a design methodology for teaching circular economy concepts to engineering students in a French higher institution and focusing on disassembly solutions to use the material for recycling or repair strategies. This paper includes reflections on materials, circular economy, and educational strategies that allow students to achieve more competencies and skills when dealing with complex matters.

The third section of the publication encompasses short reports of students that have participated in the Fashion-Tech Residencies during the FTalliance project (2019-2022). Fashion-Tech residency aimed to select students through a contest and to generate innovation through a multidisciplinary exchange between young international talents and Companies. During the 2021-2022, 18 Fashion-Tech Residencies has been launched within 4 HEIs and 8 Fashion-Tech Compaines. In this publication, the digest of the 13 Residencies describes the experiences of the students by providing (i) an introduction that states the issue/problem referencing the relevant background of theory and practice; (ii) residency objectives as a short summary of the aim and the contents of the Residency project; (iii) a residency timeline providing information about actors involved in the activities, achieved milestones, and results both intermediate and final; (iv) residency activities by highlighting the exchange process with the Company, the tools, and used resources. (v) project description as a focus on the developed product/service/research highlighting originality, innovation, and relevance; (vi) residency results conceived as the learning outcomes, the knowledge exchange, and the acquired new skills.

The Fashion-Tech Residency experiences have been structured in:
(i) physical prototypes, focusing on zero-waste prototyping techniques for reducing waste materials and using natural bio-based materials and pigments and including sensors for monitoring users' performance and wellbeing:

- Natural dyeing on bio-based material - Zero-waste plants-dyed and biodegradable garments
- Garmentity (noun) - The process of giving a garment an identity
- Hyperfunction - Functional clothing for modern urbanites
- Sensorized twin-set for sportswear - A bio-data monitoring system
- Biomimicry wearable - Smart textile wristband

(ii) Ux and UI prototypes, offering an omnichannel Customer Journey for purchasing better and more comfortable experiences, and offering data related to the company's ecological footprint for more responsible purchase choices:

- Eiréne - Omnichannel Customer Journey for Mass Market brands targeting Gen-Z users
- Optimising impacts - byborre's Online Plaform Create ™

(iii) virtual prototypes, used for reducing samples and materials during the prototyping stage and aiming to achieve the best results in terms of materials aesthetical and performative simulations:

- Modular design and system for disassembly - A Multipurpose Parka
- Digitally empowered fashion design - How digital technologies support the fashion design process

and (iv) models and frameworks, investigating the state of traceability that can enhance sorting and recycling of textiles, the clothing rental business models and the influence of digital platforms and technology on clothing rental, the opinions and discussions spread on the social media platform Twitter relating to fashion rental, and circular economy solutions to achieve a sustained competitive advantage:

- Bridging infrastructural holes - Traceability for circularity in textiles
- Collaborative fashion consumption - Business Model analysis of clothing rental digital platforms
- Developing kpi framework for circular fashion management. A study on circularity initiatives of fashion brands with EU taxonomy
- Discussion topics on fashion rental - An application of Topic Modelling with LDA and Sentiment

The fourth section of this publication is presenting the perspective of young companies in the fashion-tech sector approaching the recyclability and circularity of the fashion, textile and apparel sector by focusing on environmental sustainability at the level of shoes,

materials for collants and threads. The Fashion-Tech Company testimonials have been presented during the pitch session of the BiarritzGood Fashion event held the 20 October 2022.
Three companies have been selected to present their solutions to contribute to the societal, environmental, and economic transition of the fashion industry.
Here, Alex Marquoin presents the project Reshoes developed at CETIA around the topic of automated sorting and dismantling of end-of-life or unsold textile and footwear items thanks to to automation, robotics, and artificial intelligence. Agathe Rouzaud from Ecollant presents the environmental values of the company allowing the recycling processes of tights in a circular loop focusing on the technological aspect and, at the same time, organizing the collection of the raw material, thus implementing bottom-up approaches and customer-based initiative that help the change of behaviours of consumers. Finally, Sonya Manolova presents EcoCycle. a new thread that retains its durability during the life of the garment but dissolves for disassembly when washed in an industrial machine at 95°C, thus allowing a better disassembly of garments and so impacting recyclability and circularity.

Conclusions

This publication provides an overview, on one side of the future Fashion-Tech topics that spontaneously reiterated in academic research, student prototyping activities, and companies' businesses. On the other side, it strives to highlight the importance HEIs and Companies' collaboration for innovation, entrepreneurship, and impact on a scientific, economic, environmental, social, and cultural level. It covers wider scopes of introducing strategies and plans for future research topics and collaboration among different stakeholders of the Fashion-tech system, suggesting that the expertise of different domains of fashion, technology and business management should be combined in alliances working on both theoretical and practical research and development levels in order to develop synergistic changes expected for a more sustainable future.
At the level of Fashion-Tech thematical focus and therefore skills necessary to future fashion-tech professionals, this overview allows expanding of the Fashion-Tech subject-specific skills resulting from the focus groups and learning experiences that were implemented during the FTalliance project (Colombi & Casciani, 2021).
In particular, the focus on eco-material and natural dyes harvested from nature requires the integration of design and engineering with biology and chemistry disciplines toward circularity and recyclability of tech-based fashion products/services and systems. The entanglement of bio-nano-info technologies on garments addresses social sustainability when talking about social acceptance, the influence on human behaviours, and the ethical implications, thus requiring knowledge and expertise from humanistic sciences to predict impacts with a critical attitude and further expand the research questions. In addition to this, the complex architecture of fashion products integrating technologies requires a focus on social, natural, and environmental sciences to understand how to tackle environmental and economic sustainability toward a real change in terms of circularity and recyclability. New business models associated to circular fashion management, fashion reuse, and consumption are of growing interest as service-based fashion activities that

allow the real uptake of circular practices. Collaborative approaches between human and machines, specifically robots are also driving research interests both for companies and HEIs in the manufacturing processes to enhance human work ecosystems and upskill the workforce via non-standard fabrication approaches, thus requiring knowledge on Human-Robot Interaction and a compination of humanistic and engineering disciplines.
The virtualization of fashion design and how this is influencing the design practices, the manufacturing and selling processes along with the new business models is also another topic of growing interest, where technological innovation should not give way to a critical reflection of the social, cultural, environmental and economic implications (Casciani, Chkanikova & Pal, 2022).

Fig.1 Overview of the subject-specific skills more recurrent in the contributions of this publication, compared to the ones emerged from the three focus groups developed and integrated into the three pilot learning experiences of the FTalliance (Colombi & Casciani, 2021; Colombi & Casciani, 2022)

Given the convergence of different disciplinary domains to navigate the complex field of Fashion-Tech, new hybrid pedagogical approaches based on multidisciplinary, interdisciplinary, and transdisciplinary collaborative practices are required to shape future professionals equipped with both soft skills to understand divergent disciplinary glossaries and the specificity of each field through the enhancement of subject-specific skills (Figure 1). All the contributions included in this publication show that the collaboration among HEIs and companies allows achieving excellent results in terms of HEIs scientific impacts, the establishments of new businesses with the development of original and meaningful products, services and systems, along with the enhancement of entrepreneurship of young talents, academic teaching staff, researchers and professionals. Shared vision, relational closeness, collaboration on the same research topics, and knowledge transfer among HEIs and Companies are all very important aspects toward the sustainability and long-lasting future of Fashion-Tech.

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SECTION 2. INVITED ACADEMIC PAPERS

Fostering a Fashion Materials Revolution through Biology

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KEYWORDS
Bio-based materials, Circular fashion, Industrial transformation, Fashion-tech Bioneers

Abstract

As the need for industries to operate according to circular models becomes more and more pressing, the fashion system, one of the most impactful, is shifting from simply synthesizing some natural and finished elements to effectively exploiting the complete properties of environmentally friendly materials and fibers.
Integrating biology into design emerged as one of the possible solutions to natural resource depletion. Through their work together, they mitigate the potential of the industry's environmental footprint at the procurement and production stages and act synergistically on reducing and partially eliminating waste.
This context, favorable to experimentation, allowed the emergence of a new figure, the Bioneer—the biological pioneer. In fashion, they are now focusing on rethinking the system's linearity by developing new lab-grown bio-based materials supported by the digital medium. This paper discusses this innovative approach to sustainable fashion production. It illustrates how it goes beyond the simple engineering of eco-friendly materials because they are sustainable but aspire to close the circle of circularity by avoiding the production of residual waste.

1.Introduction

Today, every industry sector is working to reduce its impact on the ecosystem, understood broadly as people, economies, and the planet. The 6th IPCC Climate Report (2021) stated that record-breaking heatwaves, raging wildfires, and unpredictable widespread floods are evidence of climate change. Scientists warn that humanity has dithered for too long and done too little. Since industrialization, human activity has indisputably altered the climate so unprecedentedly that we now face the possibility of breaching the 1.5-degree limit as soon as the 2030s (IPCC, 2021). The report calls upon world leaders, governments, and businesses to take more stringent actions fast and take them now.
In the presented scenario, Fashion contributes to climate change, resource exploitation, and systemic pollution. McKinsey (Berg et al., 2020) reported that the sector was responsible for some 2.1 billion metric tons of greenhouse

gas (GHG) emissions in 2018, about 4 percent of the global total. The fashion industry emits about the same quantity of GHGs per year as the entire economies of France, Germany, and the United Kingdom combined. The fashion industry annually produces and sells between 80 billion and 150 billion garments globally. Of these productions, nearly three-fifths of all clothing produced ends up in incinerators or landfills within years of being made. These clothes are the 4 percent of global waste (WRAP, 2018) and are mainly composed of synthetic fibers. These plastic fibers are, therefore, non-biodegradable and can take up to 200 years to decompose. Synthetic fibers represent 72% of clothing composition.

Furthermore, the fashion industry produces 20 % of global wastewater from manufacturing practices and garments care. The UN (2019) reported that the fashion industry uses 93 billion cubic meters of water, enough for 5 million people to survive. The majority of sold clothes are now polluting the Earth as 551,155 tons of plastic microfibers are estimated to pollute the ocean yearly from washing clothes, which is equivalent to the plastic pollution of more than 50 billion bottles (EMF, 2018; UN Geneva, 2019). Greenpeace (2019) states that untreated toxic wastewater from textile factories is dumped directly into the rivers. This is happening in most of the countries in which garments are produced. Despite efforts to reduce impacts, the industry is on an unsustainable trajectory, and to reach an ecological pathway, fashion would need to change its practices.

In the last years, the fashion industry adopted various strategies and initiatives implemented at different supply chain stages based on resource optimization, circularity, and collaborative networks (Colucci and Vecchi, 2020).

In the context outlined, some of the most pressing challenges are upstream in the supply chain. These challenges are related to the exploitation of raw materials and waste management.

As reported in the State of Fashion 2020 (McKinsey & Bof, 2020), the number of filings for fiber innovation patents is eightfold. Companies are explicitly looking to integrate more innovative materials characterized by biological components that can impact on waste(Macarthur, 2017).

In this context, the figure of the bioneer becomes a fundamental vector of transformation and an enabler of new production paradigms. Born in the early 1990s, bioneers are a hybrid of scientists and designers who work to find practical solutions to environmental problems (Maxwell, 2018). The term bioneer was first coined by Kenny Ausubel, an American author, filmmaker, and ecoactivist. The term is a combination of the words biology and pioneer. Bioneers come from different backgrounds but are united by a shared philosophy that is based on the principle that just as humankind has caused environmental and social issues, humans can, in turn, work with the environment to solve them (Maxwell, 2018).

This paper discusses the work of bioneers and how their knowledge enables the development of design-led solutions to transform the fashion supply chain model toward regenerative, accessible, and abundant process innovations, often facilitated by technological tools.

2. Methodology

According to the author's investigation, a mapping of bioneers' sustainable practices of European Fashion companies is carried out through an iterative process to model the data.
The paper is based on the author's research on the topic. Here, the data pool produced by the author's doctoral thesis (D'Itria, 2022) is analyzed. In addition, further specific data are drawn from the author's contributions to several research projects (DGGROW, Mapping Sustainable Fashion Opportunities for SMEs, 2019; Erasmus+, FashionSEEDS, 2019)
Methodologically, the initial desk research phase was further developed by applying a case study methodology to narrow the selected research field and return to the actual context in which the phenomenon occurs; otherwise challenging to evaluate with other methods (Eisenhardt and Graebner, 2007).
To build knowledge, the study conducted the following three phases: (1) a first phase of desk research on the fashion industry to map the current practices of fashion bioneers and identify best practices; (2) the second phase involved further qualitative and in-depth analysis in helping profiling the emerged best practices; (3) and the last phase combined all the data to codify business directions for implementing sustainability through bioneers' design-driven innovation practices.
The study map 59 companies across Europe. These companies represented a heterogeneous sample. They were companies that invest in materials innovation (61%), textiles companies (36%), and companies that work on implementing new hyper-sustainable technologies (3%). Of the 59 companies mapped, 8 were selected as case studies. All the case studies have reached a mature level in their sustainable performance. The story of maturity was determined by the sophistication of the processes, technologies, tools, and people involved in managing the production process.
Among those that emerged from the research phase, the case studies analyzed are presented here as best practices. This methodological approach aims to focus on these specific cases while considering the whole context that includes many variables and qualities for elaborating new knowledge (Eisenhardt and Graebner, 2007).

3. Case Studies discussion

According to those above, the paper exploits the produced knowledge reservoir to identify possible paths for capitalizing on current bioneer-led practices in the fashion industry's environmental sustainability field. The following sections will discuss the results of the proposed methodology through different case studies that demonstrate the reliability of the trajectories identified by the study. Such trajectories could stimulate the adoption of new behaviors in sustainable fashion-tech design.
From the operative perspective, the study codifies two main paths that the fashion sector is following in embedding the work of bioneers in the production of bio-based materials through a technological medium: (1) Low impact, fostering current industrial practices to capitalize on bio-tech productive process sustainable attributes to generate eco-compatible products, and (2) low waste, exploiting the sustainable intrinsic characteristics of the biotech solutions for enabling systems to lessen waste production or ensure continuous and regenerative use of resources.

3.1. Mitigating the impact of fashion production through biology

The first identified path refers to adopting specific processes that, through the technological medium, lessen the environmental impact of the manufacturing phase.

Companies such as Keel Lab's and Modern Meadow are working on patented solutions for exploiting new technologies that capitalize on the hyper-sustainability of new bio-based processes that generated their products.

Kelsun™ is a yarn developed by Keel Lab from seaweed. This material is characterized by its environmental footprint, which is significantly lower than conventional fibers.

A biopolymer was synthesized in Kelp seaweed to create this innovative solution. This brown seaweed is one of the most regenerative organisms on the planet and absorbs carbon dioxide in the ocean, like trees on the land. Cultivation, necessary to obtain the algae, creates cleaner marine habitats and ecosystems and regulates less carbon in the air and water. The scientists' work combines the seaweed's biopolymers with green chemistry to create original or drop-in solutions for existing yarn and textile manufacturing design infrastructure. The end result is Kelsun, a bio-based material based on using and creating clean, non-toxic inputs and outputs used throughout the textile industry. Modern Meadow is an American biotechnology company that uses biofabrication to create sustainable materials. In 2014, the company began working with Suzanne Lee's first bioneer as Creative Manager. They developed a way to brew leather in a lab without harming animals: Zoa™ They engineered a strain of yeast that produces collagen through fermentation. Collagen is the main biological building block of leather. They assemble collagen into a range of materials that become Zoa bio leather. Modern Meadow has refined its technology, and now its leathers can be brewed in large commercial fermentation facilities that make food and medical-grade products for the masses. Suzanne leads the designers who work closely with the dedicated materials science team to create new materials through biotechnology. In 2017, Zoa™ was launched with a revolutionary t-shirt presented at MoMA as part of the exhibition, 'Items: Is Fashion Modern?

Both the presented cases are developing cutting-edge biotechnologies to create new materials to enable sustainable processes to lessen the impact of their practices and products.

3.2. Ecologizing waste

The second direction addresses the issues of waste production concerning the specific family of materials involved, the biodegradable materials. This direction aims to recover the biological resources that fashion companies exploit through biotech materials by returning them to the natural cycles to which they belong.

Companies such as Pangaia and Vollebak work on developing materials by exploiting technologies for producing new resources characterized by bio-compatible degradation attributes that guarantee a minimum impact by acting on the production of pre and post-consumer waste. Pangaia has created an innovative material called Flwrdwn, an alternative to animal feathers for the padding made from a combination of wildflowers, a biopolymer, and air gel. This innovation is the first of its kind. Wildflowers are grown without pesticides or artificial irrigation, avoiding pollution and reducing water consumption.

Toward the end of the growing season, when the flowers are almost dry, the pods are harvested and sown again to preserve local biodiversity. The flowers are combined with a fully compostable biopolymer and a patented cellulosic air gel that enhances their thermal heating properties, creating an innovative blend. This solution that mixes science and design is entirely biodegradable and a sustainable alternative to the traditional feather industry. Flwrdwn can decay naturally and in a way that is not harmful but impacts a very positive manner on the residual waste production.

Vollebak, a tech-based clothing startup, launched a t-shirt made entirely from wood pulp and algae, which breaks down in soil or a composter within three months. This material is produced from eucalyptus pulp and seaweed powder. The productive technology for obtaining such material uses significantly less water than cotton since seaweed is grown underwater, and eucalyptus proliferates on arid land without irrigation. But beyond the sustainability attributes of the production process, what characterizes this resulting soft and silky fabric is being completely biodegradable in water, landfills, and composting environments. When the user decides that the garment has reached the end of its life, he or she can put it in compost, or dig a hole in the ground and bury it. Nature will do the rest breaking it down and turning it into nutrients for the soil. The speed of biodegradation depends on the environment in which it is placed. Heat speeds up the process, because of the greater amount of bacteria and fungi it is exposed to. So while industrial composting is the fastest, in the ground, the company estimates about 12 weeks. This material minimizes waste production equally at the pre and post-consumer stages.

Both cases presented developed advanced materials to create new solutions to enable sustainable processes to reduce impacts. Science and design have collaborated to minimize waste by proposing environmentally friendly solutions.

4. Conclusion

From what has been illustrated, bioneers practices can foster sustainability and guide the approach of fashion companies toward sustainable development through continuous investment in tech and materials capital. The cases discuss how the development of new materials made through biotech input becomes a means of bringing sustainable innovation to very impactful steps of the fashion supply chain, such as the sourcing and manufacturing raw materials. The presented companies hold, through the interaction of science and design, the necessary knowledge and acquire the skills needed to implement such knowledge as a means of sustainable production practices.

The study indicates the opportunities that have emerged, for fashion companies, to trigger innovative processes that favor the production of alternatives. These processes can enable practices between the holders of knowledge, the bioneers, and designers to reach the goal of sustainability.

The two directions discussed are interpretations of the same goal, promoting sustainable materials production as an engine of sustainable development, focusing on what happens when fashion capitalizes on this knowledge. Both aim to enable new green paradigms and strategically invest in enhancing technological know-how and product sustainability.

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Fashion-tech and growing materials: challenges and opportunities facing bacterial cellulose

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KEYWORDS
Fashion-Tech, growing materials, bacterial cellulose, technological integration

Abstract

The technological integration in the fashion industry is an issue that is gaining increasing relevance driven by the renewed demands for sustainability, transparency and ethical worthiness of consumers. Fabric is the raw material that has the priority role in the environmental impact of the textile sector, and in this context, growing materials - in particular bacterial cellulose - can act as substitutes to enable the achievement of sustainability, both in terms of resources and methodological approach to fashion production, with a holistic circularity perspective. Therefore, this contribution aims to investigate the possibilities of integration and contamination between technology and bacterial cellulose by mapping the opportunities arising from application in the fashion industry. Following an analysis of the reference context and the most relevant examples of biomaterial application in relation to both fashion and technological inclusion, the research focused on experimentation regarding the integration of the technology as much in the production phase as in the final product output. The contribution presents the development path and outcomes of three applications of bacterial cellulose for the creation of an accessory for the fashion world following an optimization approach to resources and production processes. Starting from the evidence gathered, the conclusions outline development strategies for the realization of other effective and functional demonstrators.

1. Introduction

The fashion industry represents one of the most influential sectors globally, its business alone contributes to the creation of value chains that are crucial to the global economy (Jacometti, 2019). In recent years, fashion companies, increasingly driven by consumers' growing search for business models characterized by transparency (Bertola & Teunissen, 2018), ethics and sustainability (Pine & Gilmore, 2007), have shown a tendency to integrate digital technologies within their business models, products, services and processes (Kozlowski et al., 2016). This is with the aim of maintaining competitiveness in the sector, even renewing themselves through

the added value of Tech in approaching a new sustainability on an ecological, economic, social and cultural level (Ceschin & Gaziulusoy, 2016).
In this context, it becomes crucial to incorporate the concept of enabling fashion through technology to that of circular economy, aiming at the shift towards a more sustainable and less wasteful fashion industry (Brydges, 2021).
A major factor within the sustainability landscape of the fashion industry is textiles, which have undergone significant growth over the past 50 years, reaching a threefold increase in production volumes (EEA, 2021). This phenomenon, driven by the advent of realities such as fast-fashion, has led to the overproduction of more than 30 million tonnes of textile waste globally each year (Chen & Burns, 2006).
Within this landscape, it is therefore of paramount importance to rethink the fashion system through more sustainable and circular materials and production strategies.
One opportunity in this direction is represented by the fashion-oriented technological integration of new biofabricated materials: in particular, this contribution explores some application potentials of Kombucha-derived Bacterial Cellulose (BC) for the production of fashion-tech accessories. The synergy between experimentation with biofabricated materials and the use of technology, in relation to the BC material, is demonstrated according to two strategies: through the creation of (i) outputs containing technological actuators, and through (ii) artefacts constructed using an advanced supply chain supported by digital technologies. The results of this experimentation, conducted at the Design Department of the Politecnico di Milano, are aimed at empirically defining possible application trajectories in the contamination between the world of growing materials and Fashion-Tech for the development of innovation scenarios aimed at promoting the holistic dimension of sustainability and circularity for fashion.

2. Literature review

In the contemporary landscape, research and design are moving to explore new paths that can overcome the linearity of production, embracing increasingly holistic and circular practices (Moreno et al., 2016). The contamination between the worlds of design and biology, through biofabrication techniques (Fritz et al., 1994), which exploit forms of design hybridisation of nature and its growth processes to incorporate living organisms for the creation of biomaterials and growing materials (Myers, 2012; Camere & Karana, 2017), appears to be an emerging theme on which the interest of researchers and designers is converging.
All the characteristics of growing materials show substantial affinity with sustainable, circular and low environmental impact production logics. In particular, BC deriving from the fermentation of Kombucha tea with Symbiotic Colony of Bacteria and Yeast (SCOBY) additives, is widely applied in the fashion sector, showing itself as a sustainable alternative to traditional production processes and materials.
In particular, the possibility of treating the material both as a fabric layer and as BC tartare (Bolzan et al., 2022) resulting from the chopping and subsequent recompacting of the SCOBY allows complex shapes to be obtained from an initial piece size and the reuse of biomaterial waste and/or layers with production defects, placing the material in a circularity-oriented zero-waste production model.
The application potential of this material in

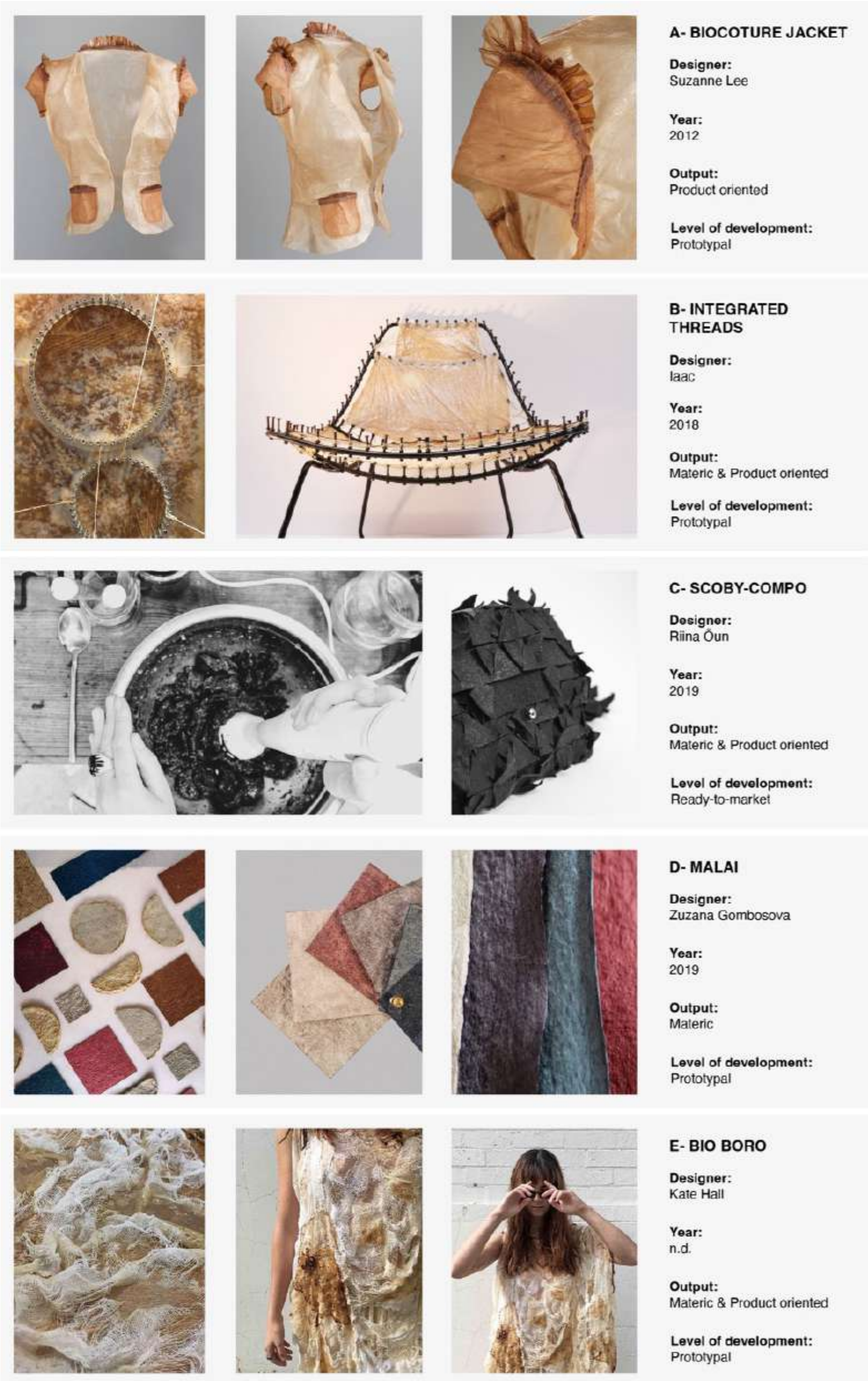

Fig.1 BioCoture jacket (A), Integrated threads (B), SCOBY-compo (C), Malai (D), Bio Boro (E).

the fashion field is expressed in the selection of seven explanatory case studies (Blatter & Haverland, 2012), the first five, shown in the first image below (fig. 1), where BC was used for the production of garments and accessories, and two others in fig. 2, where electronic circuits and actuators were integrated into the material.

In detail, the BioCouture Jacket (Fig. 1, row A) represents one of the first examples in which BC was used to construct an entire garment. The BC layer, after drying, was cut into the pieces necessary to construct the jacket, which was subsequently assembled using traditional tailoring techniques (Lee, 2012).

In the second case study (fig.1, row B), the Institute of Advanced Architecture of Catalonia (IAAC) investigated textile integration within the BC by using a yarn support structure that was inserted into the growing culture (IAAC, 2018).

Designer Riina Õun explores the potential of waste from the kombucha industry by using discarded SCOBY to produce a new material (fig.1, row C) that is sustainable, vegan and leather-like. The fabric developed by combining chopped waste material, natural oils, waxes and organic compounds is water-resistant and flexible and can be produced on a large scale, providing a viable alternative to the materials traditionally used within the fashion industry (Õun, 2020).

Another case study focused on the construction of a material is Malai (Fig. 1, row D). It is a material created from BC grown in substrates using agricultural waste from the coconut industry in southern India (Malai, 2021).

In the last row of the image (fig.1, row E), Kate Hall exploits the growth of BC to join, mend or patch together broken fabrics, drawing inspiration from the traditional Japanese Boro technique (Li, 2021).

As introduced earlier, there are also experiments on the integration of BC in electronics. Among these, it is possible to distinguish two different types of approach to contamination: a strongly engineering orientation and a more experimental and laboratory orientation.

In the former case, electrically conductive filler materials are usually added to BC nanocomposites to enable the fabrication of modern electrical and electronic equipment, such as biosensors, flexible electronics, electromagnetic interference (EMI) shielding and energy storage (Poddar & Dikshit, 2021).

On the other hand, within the second approach, the experimental and artisanal dimension for the integration of electronic components into the material is more present. This dimension, which is also the focus of the experimentation conducted by the authors of the contribution, in which the designers have the role of approaching and devoting themselves to a production process (Bolzan et al., 2022) intended to understand and verify the possibilities offered by the union of the world of growing materials with that of digital fabrication.

Existing application experiments are mainly unstructured, and are at an embryonic stage in which most outputs do not go beyond the laboratory/academic dimension. Among the most significant applications are those of Reinout Van der Hauwert (fig. 2, row A), in which the integration of electronic components into the BC occurs in the growth phase (Van der Hauwert, 2019).

In contrast, the Biker Vest (fig.2, row B) is a garment made of bacterial nano-cellulose (ScobyTec BNC) and equipped with LED lighting, powered by Teensy micro-computers (Giebichenstein, 2014). The electronic components are in this product inserted between different layers during the drying process.

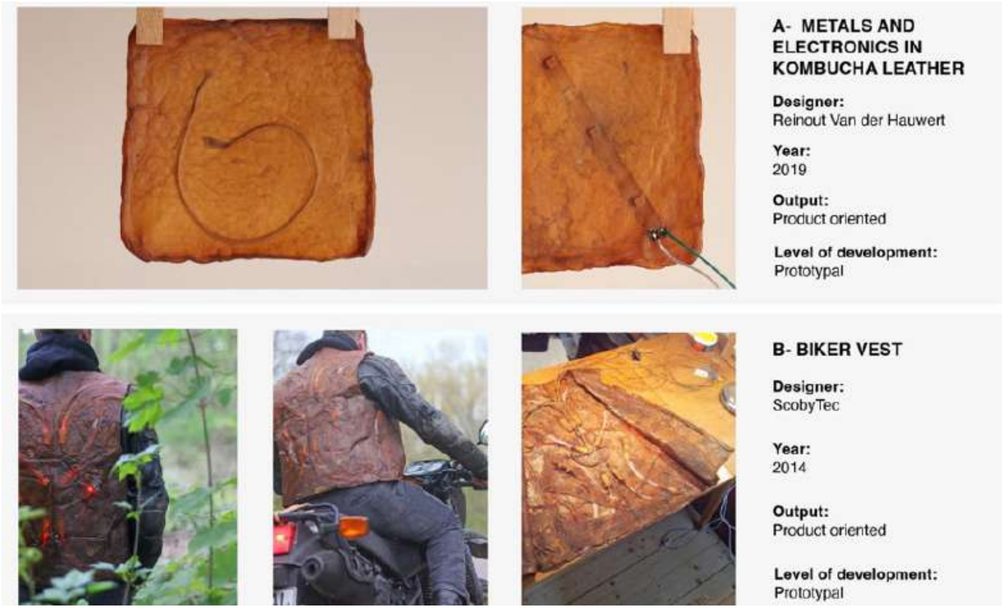

Fig. 2 Metals and electronics in kombucha leather (A), Biker vest (B).

3. Methodology

Aware of the existing experiments on BC-based materials and the possible integration of electronic components in them, this contribution aims to explore the potential of such technological synergy when addressed to the fashion design panorama. To this purpose are presented three possible applicative interpretations of the same fashion accessory, the collar, in which the technology is used in the production phases thanks to digital fabrication and/or becomes explicit in the final output, through the insertion of basic electronic circuits and actuators.

These experiments materialise from the authors' in-depth knowledge of BC as a material (Bolzan et al., 2022; D'Itria et al., 2021) with respect to production and cultivation management processes, as well as raw material treatment. The investigation was conducted as part of the De_Forma (Design Explorations on bio- Fabricated ORganic MAterials) project financed by the basic research fund of the Department of Design of the Politecnico di Milano, and took place in the laboratory spaces of Polifactory, an interdepartmental makerspace and Fab Lab. Following the acquisition of an accurate knowledge of the bacterial material, as well as the definition of the optimal growth conditions and replicability of the cultures (Bolzan et al., 2022), the phase of the De_Forma project described herein focused on the perimeter of the possibilities and ways of combining materials and technologies for the generation of added value in fashion field applications.

With this objective in mind, three possible declinations of the same type of accessory were identified in order to investigate the following opportunities:

1. The creation of a shape in BC material characterised by variable thicknesses and reliefs obtainable through the use of ad hoc moulds, created with digital

fabrication technologies; this approach requires that the technological dimension plays a decisive role in the preparation and production phases of the artefact, but that the final result does not contain any visible trace of its use.

2. The realisation of an output in which the BC acts as a base for the integration of electronic components in order to facilitate the subsequent wiring of the electronics, without the need for stitching or complex electronic circuits to which the actuators can be attached; the final output of this type of production involves an object with a visible technological part.

3. The combination of the two strategies illustrated above for the creation of a fashion-tech product through the use of advanced manufacturing; the latter involves an output in which part of the technology is visible and part remains limited to the production stages of the object.

Specifically, the experimentation envisaged the realisation of three collars characterised by: 1) structure made of chopped BC with variable and controlled thickness texture (collar 1); 2) structure made of textile material with the addition of parts made of BC for the containment of back-led (collar 2); 3) structure made of BC foil with the integration of additional elements made of BC chopped for the integration and wiring in position of LEDs and electronic circuits (collar 3). Below is a representation that better summarises the strategy for the use of technology for the realisation of the three collars. The next section describes the experiments and their strengths and weaknesses.

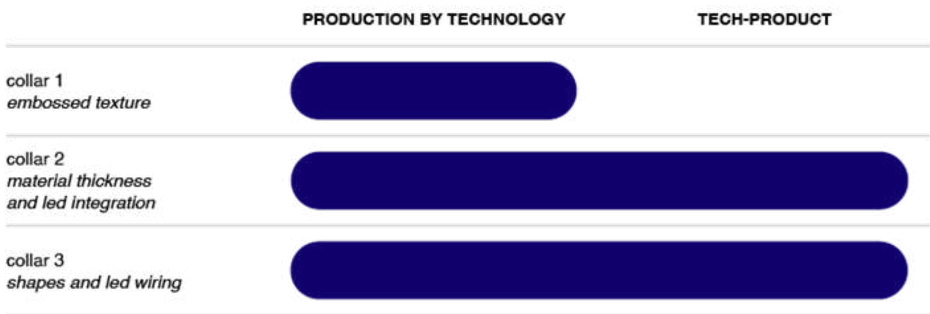

Fig. 3 Strategies employed in the different experiments

4. Results

A. Collar 1 - embossed texture

The first application case involves the use of digital technology to shape material based on BC and textile scraps. Through the use of 3D printing, a mold of variable thickness was produced having the shape of the pattern of a collar. Some finely shredded fabric scraps were combined and amalgamated with a tartare of BC. This material, obtained from scraps of further experimentation, was smeared on top of the 3D printed geometry. During the drying phase, some refills of the deeper areas of the model, in which the material showed a tendency to have more shrinkage, were made to obtain a collar of varying thickness. Once dried, the collar was finished by laser cutting along the edges. Finally, a hook-

and-loop closure was applied to the back of the accessory, via an additional amount of BC tartare, due to the self-fixing property of the material.
The technique used, resulted in a collar with a controlled and highly variable thickness, and with an embossed visual pattern.

B. Collar 2 - material thickness and led integration

The second application proposes a collar with the integration of backled and BC parts in synergy with textile material. Through the use of 3D printing, molds were created that could: a) shape the chopped bacterial cellulose, b) contain high thicknesses of material, and c) hold the pair of backled used in place. The 3D printed molds were filled with a compound formed from chopped BC and inert waste powders to provide more structure to the material. When removed from the molds, the two parts supporting the backleds result solid and at the same time lightweight to provide more stability for the actuators. In addition, the exposed outer surface was aesthetically treated and coated with a thin layer of BC tartare with threads, remaining from previous experimentation.

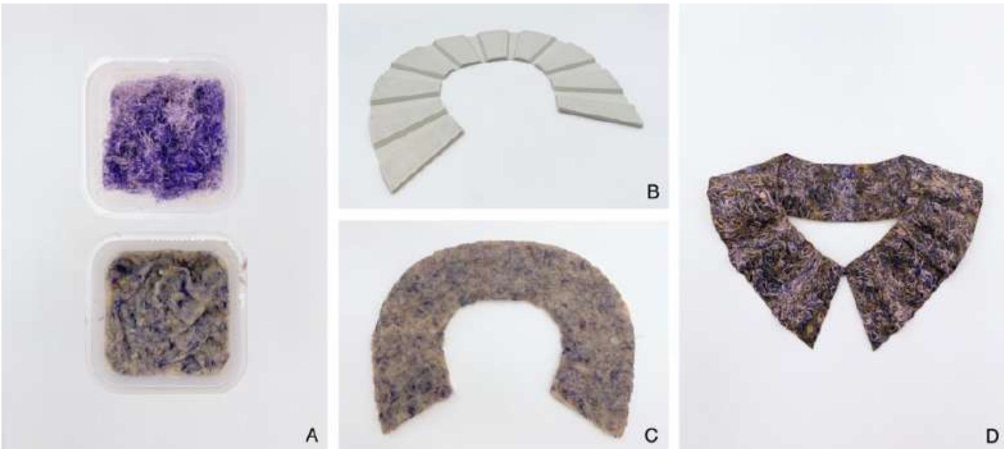

Fig. 4 Chopped bacterial cellulose with textile integration (A), 3D printed stamp (B), material placed over the stamp to dry (C), final output (D).

Fig. 5 Worn end product

The parts were then assembled to the laser-cut textile component by following the shape of the pattern through a layer of chopped BC. Finally, electronic connections were created using a copper tape, and the whole circuit was powered by a button battery placed in battery holder printed with FDM 3D printing technology.

Several tests following the assembly of all components proved the actual functionality of the circuit and consequently of the accessory, which creates a bright accent on the wearer's decolletage.

C. Collar 3 - shapes and led wiring

The latest proposal is that of a collar made from a layer of BC, with parts of BC tartare to hold 6 LEDs for decorative purposes. Through the use of 3D printing and a laser-cut PMMA base, triangular molds were created to shape bacterial cellulose. The molds, with the LEDs inserted inside them, were filled with a mixture of shredded bacterial cellulose and inert waste powders for the purpose of giving more rigidity to the material. When completely dried, it was

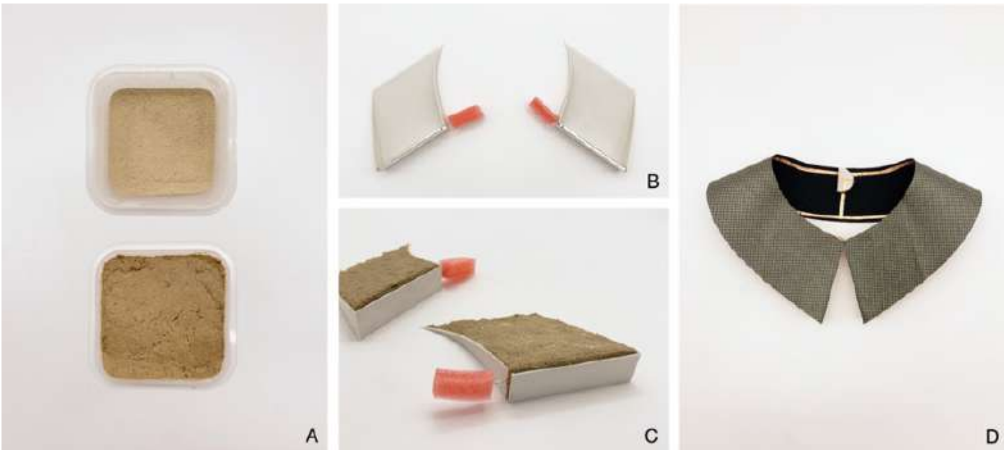

Fig. 6 Chopped bacterial cellulose with dust integration (A), 3D printed stamp (B), filling with the composite material (C), final output (D).

Fig. 7 Lighted worn end product

possible to obtain triangles with material texture having precise shapes.
The main body of the collar consists of a layer of BC, laser cut with the shape of the paper pattern of a collar. The scrap material formed was used to create the BC tartare used in the experiments presented earlier. The electronic components were again connected through a copper tape and powered by a button battery placed in a special housing printed with FDM technology (Fig. 8). Again, a hook-and-loop closure was applied to the back of the accessory, partially rehydrating the affected location and using a bit of chopped BC. Following assembly of the components, the circuit was effective and the accessory functional. The nature of the material emphasizes the presence of the cambage, which itself becomes a decorative element, albeit placed on the back of the piece.

5. Discussion and conclusions

This paper provides an overview of the potential related to the integration of

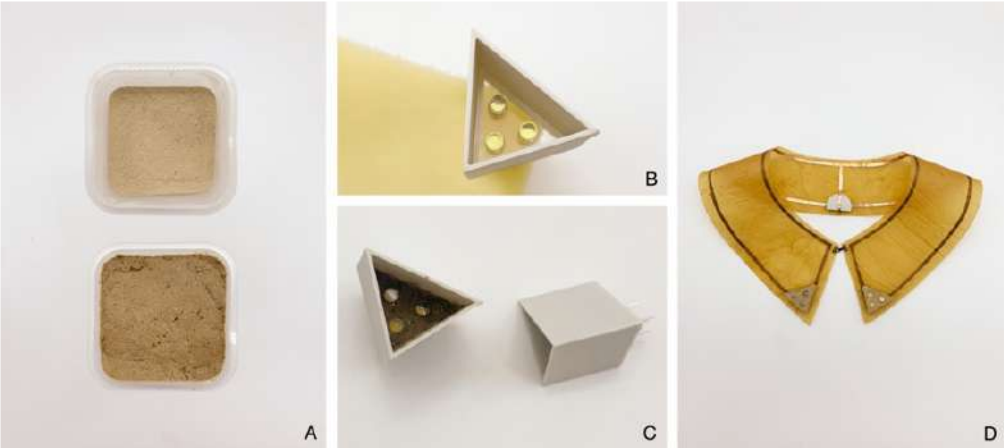

Fig. 8 Chopped bacterial cellulose with dust integration (A), 3D printed stamp and led holder (B), filling with the composite material (C), final output (D).

Fig. 9 Lighted worn end product

the technological component to BC manufacturing, production and processing processes within the fashion field focusing on the application possibilities arising from such synergy.
The possible advantages of using BC in fashion, which had already emerged during the reconnaissance of the case studies, were also further confirmed regarding the encounter between fashion and tech. In fact, the characteristics of sustainability, characterization in the growing phase, reduction of post-production activities as well as waste material, already intrinsic in the bacterial growing material, are successfully transferred into the fashion-tech product output.
In particular, through the three experiments presented, reflections emerge to further refine this encounter between BC and the technological dimension.
From the point of view of technological applications, the use of a BC base makes it possible to anticipate in the design and production phase the possible problems that may arise in the product at the end of its life: the separation of circuits and connective elements from the biofabricated material, in fact, turns out to be particularly efficient and effective, creating new possible supply chains for the disposal of sensorized wearables. Moreover, once the functioning of a prototype has been consolidated and verified, it is already possible to envision the integration of circuits equipped with sensors and actuators into BC's already growing layers, overcoming the limitations and complexities given by the realization of connective traces sewn directly onto garments or accessories.
Equally interesting is the use of this material also from the point of view of the production of artifacts and accessories that are not smart, but take advantage of the use of digital fabrication, as in the first experiment presented. The choice of using BC in all its possible forms allows for the use of alternative assembly systems to stitching, but above all it allows for finished products that have characteristics that are difficult to achieve with other production systems, such as geometries with highly variable thicknesses.
The use of BC in the fashion-tech field, therefore, can be said to be very promising, and the authors plan to continue developing current research to understand the possibilities offered in this area, also checking the possible integration of other technological elements in accessories and finished garments, as well as extending the fleet of digital machines used.

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Using problem-based learning to engage engineering students in circular economy

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KEYWORDS
Circular economy, Fashion and sports industry, problem-based learning, students workshop

Abstract

In this paper, we explored a design methodology for teaching circular economy concepts to 52 engineering students in a French higher institution. Considering the collaboration between fashion and sports industries, students explored disassembly solutions for diving masks and swimming goggles in order to use the material for recycling or recuperate spare parts for repair strategies. The methodology was based on the Double Diamond diagram for innovation, starting from a general problem to get to a specific solution. Deliverables include machinery and tool prototypes, as well as service design. Finally, students evaluated the course, presenting promising results regarding support materials, interest in the course and comprehension of circular economy.

1. Introduction

Sports are a significant source of inspiration for fashion designers (Lee & Park, 2012)). Considering collaborations within the fashion industry, sports and casual clothing manufacturers and distributors may have synergy and win-win effects (Jang, 2006). Also, once we combine fashion and sports technology, sports lines can get more refined and fashion can be displayed more vividly (Jang, 2006).

Parallelly, circular economy (CE) emerges as an alternative to our current linear logic of extracting, producing, consuming and throwing away, as it proposes a restorative system that relies on renewable energy, minimising tracks and eliminating the use of toxic chemicals; and eradicating waste by careful design (Ellen MacArthur Foundation, 2013). Educating engineers for CE is an important action towards circularity, once they will shape the industry's future (Kirchherr & Piscicelli, 2019).

In the sustainability and CE context, the fashion industry plays an essential role considering its strategic areas of innovation, especially in the textile sector, and its environmental impact (Jacometti, 2019). Considering these factors, in this paper, we analyse the results of a workshop based on a methodology for teaching CE to engineering students, focusing on diving masks and swimming goggles from a partner sports company, responsible for developing and distributing its products.

2. Literature review

CE is defined as "an industrial economy that is restorative by intention; aims to rely on renewable energy; minimises tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design" (Ellen MacArthur Foundation, 2013). Singh and Ordonez (2016) add that it is a strategy that uses innovation to transform the current linear system of consumption into a circular one that leads to economic sustainability combined with material savings. CE is usually seen as a condition for sustainability, in which human activity happens in a way that does not harm Earth's ecosystems (Geissdoerfer et al., 2017). Putting CE into practice demands the transformation of businesses, especially in the manufacturing industry, which calls for the re-thinking of design and engineering education in order to develop new proficiencies related to material science, engineering technics, operational processes, service design and human behaviour (De los Rios & Charnley, 2017). Higher education can play a significant role when grounded in five principles: interactivity, non-dogmatism, reciprocity, constructive alignment and problem-based learning (Kirchherr & Piscicelli, 2019). In this context, active learning is defined as "any instructional method that engages students in the learning process. In short, it requires students to do meaningful learning activities and think about what they are doing" (M. Prince, 2004). Active learning methods focus on involving the students in activities that promote manipulating, applying, analysing, and evaluating ideas (Crawley et al., 2007). As part of active learning, problem-based learning confronts students with "an open-ended, ill-structured, authentic (real-world) problem and fosters them to work in teams to identify learning needs and develop a viable solution, with instructors acting as facilitators rather than primary sources of information" (M. J. Prince & Felder, 2006). In sustainability and CE courses using problem-based learning, engineering students recognise the project as a stimulating challenge that enables reflection and learning on sustainability issues (Alves et al., 2017). It resulted in deliverables based on the choice of raw materials, digital and physical projects, and the production systems design and product prototypes (Alves et al., 2017).

3. Methodology

In this section, we will explain each step of this course, focusing on active learning practices for CE. Also, we present how students evaluated the course.

3.1. Course methodology

We gave this course to 52 students from the first year of engineering studies in a higher education institution in France. We planned each class (2 hours long) to be focused on a phase of the Double Diamond framework for innovation : (1) discover, (2) define, (3) develop, and (4) deliver. The objective is to pass from a general problem to a specific solution.

3.1.1 Discover

We invited a designer from the sports company who explained the circularity challenge for swimming goggles and diving masks. These products are composed of glass, buckle, and frame in polycarbonate; textile straps; metal screws; and silicone skirt. Based on internal research, the company found that 57.0% of sold goggles and 81.4% of sold masks are products from the cheapest range. Analysing the customers' reasons for switching products, most of it is due to fog (22%), scratches

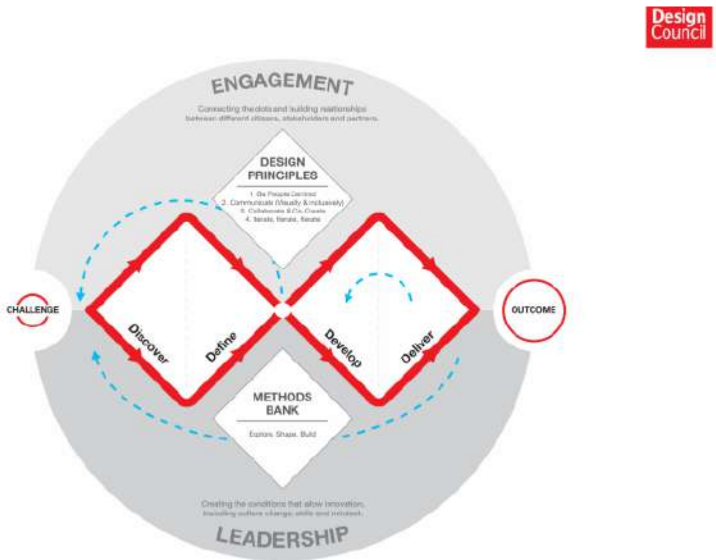

Fig. 1 Double Diamond Framework (Framework for Innovation, s. d.)

(14%), mould (16%), broken glass or buckle (12%) or torn strap (11%). Masks and goggles are considered products of individual protection, so repairing them in workshops can be difficult once it demands re-homologation through a destructive test. Thus, the company explores do-it-yourself (DIY) solutions. Their research shows the percentage of customers that said that they would repair their own masks (Figure 2). In addition, we can think of recycling solutions for polycarbonate and metal and reintroducing crushed silicone with virgin material. Thus, the generic problem was: what are the circularity solutions for masks and goggles at the end of life?

The designer brought two products of two mask models (M1 and M2) and two goggles modes (G1 and G2): one product for each one of the eight groups. Then; the students dismantled them and classified each component and assembly type, following the Unlinear Methodology (Demarcq et al., 2022).

3.1.2. Define

We started the class with the question: "What is CE for you ?" Afterwards,

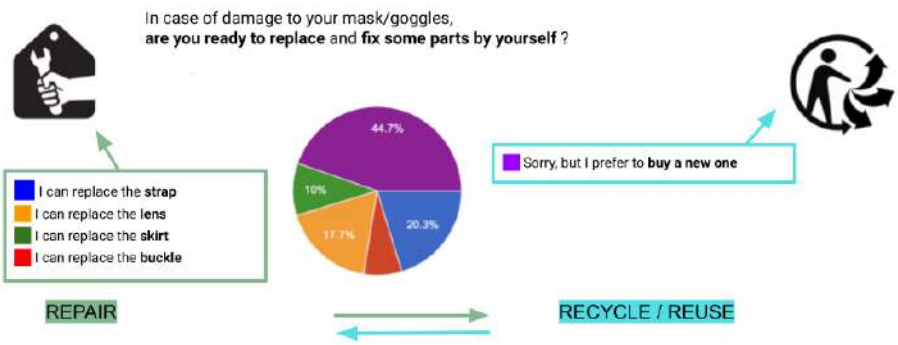

Fig. 2 Customer positioning towards DIY repair solutions

we presented CE concepts that were developed by Ellen MacArthur Foundation (2013), focusing on the technical loops and the analysis by shape degradation (Menu et al., 2019). Based on it, we showed them the framework from Figure 3, which combines the previous studies. Next, the students had a practical activity. Considering the information they had in the last classes, they had to create a mindmap describing the possibilities of disassembly for their group's end-of-life product and reflect on the circular loops related to it. Then, they should synthesize their discussions following the framework below (Figure 4). The goal was to pinpoint a specific problem when dismantling masks and goggles at the end of life, so that they can fit certain circularity loops, such as reparability and recycling.

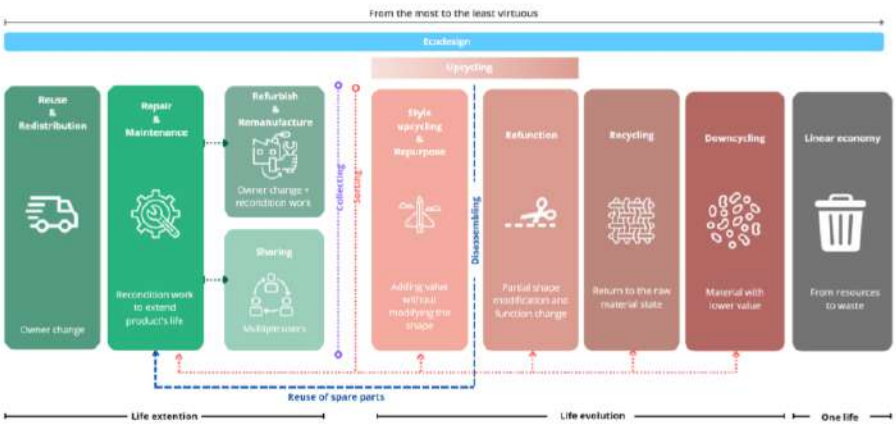

Fig. 3 Circular Loops Framework by Shape Degradation (by the author)

3.1.3 Develop

The students should explore different solutions to enable end-of-life solutions for the masks and goggles. We incentivized them to explore and experiment with possibilities regarding the technical process, service storyboards and scenarios, and creating through computer-aided design.

3.1.4 Deliver

Finally, the students selected one of the proposed solutions. In order to give more structure, we asked them to make a business model canvas (BMC) to explain their solutions. It pushes them to go further into their thinking, once they need to define users, the value proposition, resources, partners, client relationships, distribution channels, costs, and revenues.

3.2. Course evaluation

After finishing the course, we assessed it with a questionnaire. It was composed of the following affirmatives that should be evaluated using a Likert Scale from 1 to 4, in which 1 meant "I do not agree at all" and 4 meant "I agree a lot".

i. The support material was clear, and it helped me to understand the subject.
ii. The activities were interesting to me.
iii. The project helped me to comprehend CE.

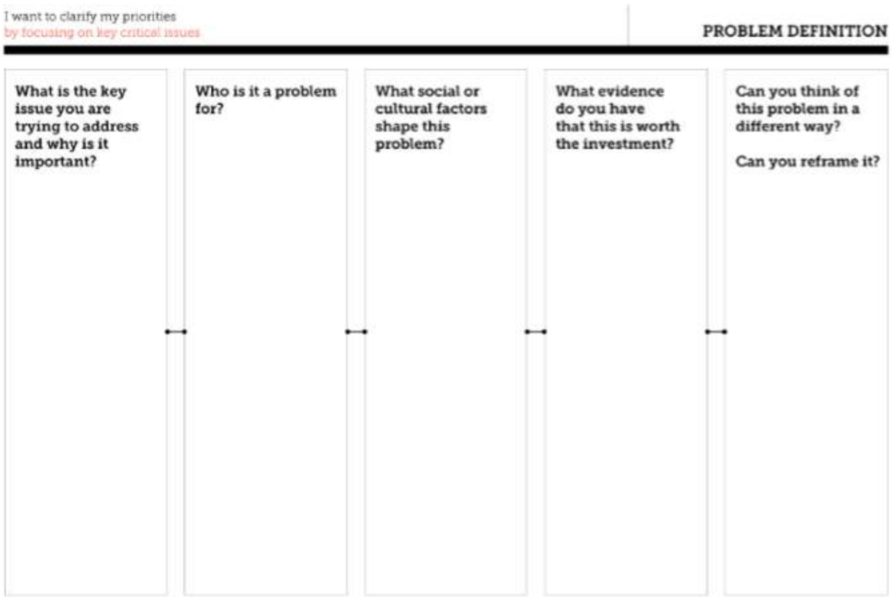

Fig. 4 Problem Definition Framework

iv. The activities had a good duration. In the end, there was also a space where the students could make free comments regarding the course.

4. Results

In this section, we present the results of each step of the course methodology. Additionally, we show the responses from the students' questionnaire evaluating the course.

4.1. Course methodology: results

In this subsection, we describe how the activities were conducted, and the student's project development from discovering the problem to delivering solutions, using prototypes, service design and industrial operations.

4.1.1 Discover: results

The students disassembled the masks and goggles, taking pictures of the final result: the separated components (Figure 5). Next, using the Unlinear Method, they made a scheme (Figure 6) in which each hexagon represented a component, describing its function and material. The hexagons were connected by lines, in which they described how the components were assembled. We noted that the cheapest the products, the fewer components the product had.

4.1.2. Define: results

With the knowledge that was acquired in the previous class, students had to imagine different kinds of disassembly processes. Next, in another level of the mindmap, they described the resulting components, and what kind of circular strategy they could apply to it. For example, if they decided to crush the product, they could envision downcycling all materials together or recycling certain materials (e.g. polycarbonate) after sorting. On the other hand, if they disassembled the product without degrading it, they could reuse the spare parts in a repair strategy. In Figure 7, we show part of a translated mindmap that was created by a group.

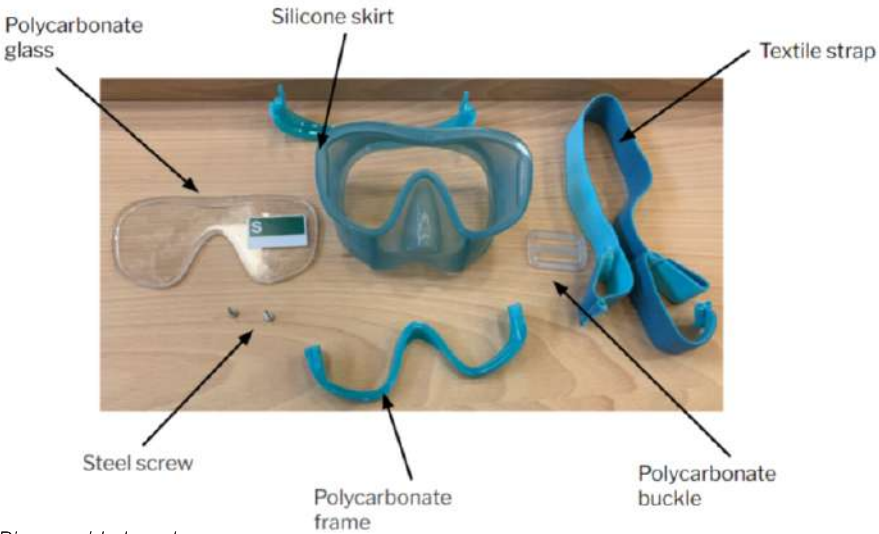

Fig. 5. Disassembled mask

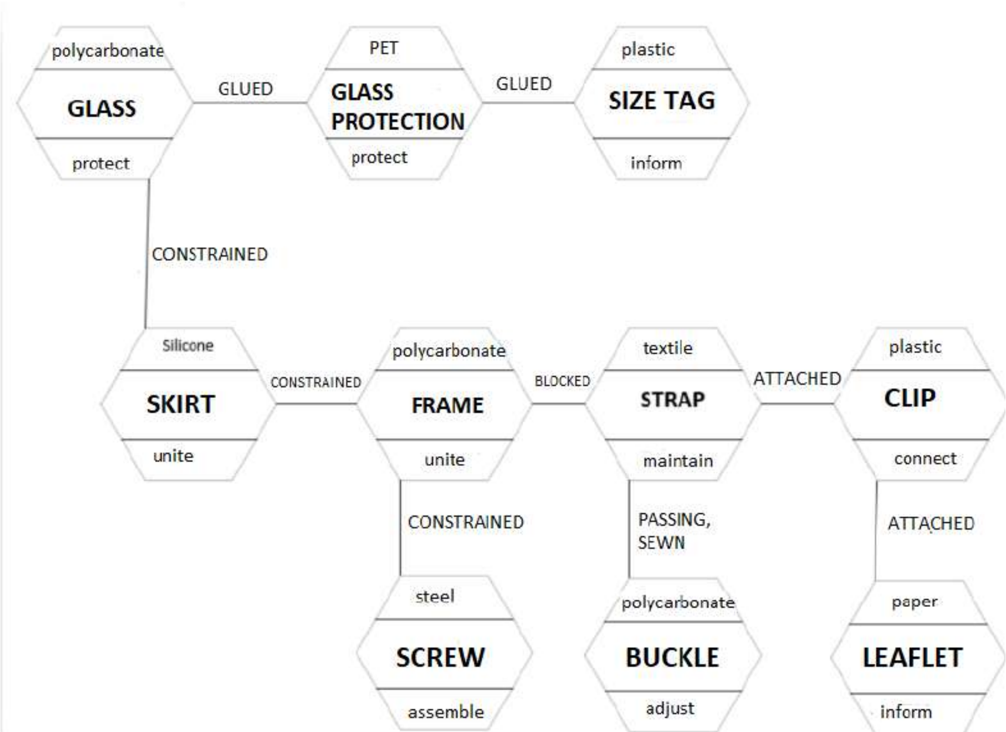

Fig. 6. Unlinear Methodology for a mask (translated)

Figure 7. Example of a translated mindmap Afterwards, they selected one of the items they have mapped. For example, another group decided to focus on manual disassembly. In Table 1 below, they detailed the defined problem to be developed.

What is the issue you are trying to address and why is it important? Who is it a problem for? What social or cultural factors shape this problem? What evidence do you have that this is worth the investment? Can you think of this problem in a different

What is the issue you are trying to address and why is it important?	Who is it a problem for?	What social or cultural factors shape this problem?	What evidence do you have that this is worth the investment?	Can you think of this problem in a different way? Can you reframe it?
The chosen solution is the manual disassembly of the mask, it is important because we need to be able to recover all the components of our mask without damaging them.	We have encountered a problem disassembling the button. It is a problem for all users.	Lack of the necessary equipment for the manual disassembly of this part, moreover the fact of inciting the users to bring back to the store to be able to reuse the reusable parts.	The investment is worth it because millions of these products are sold, allowing us to reuse millions of non-defective parts to limit the ecological impact and at the same time save money.	From a different perspective, we can say that the problem comes from the design of the button that cannot be disassembled without a tool. It forces us to destroy this piece. One solution to this issue would be to redesign the part so that it can be disassembled and reassembled very easily without the help of a specific tool. The solution chosen has been to develop a tool that people can use directly in the shop.

Table 1. Framework for problem definition—mask manual disassembly

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4.1.3 Discover: results

Some groups explored the spare parts flow and interactions from masks' end-of-life to the reuse phase of some spare pieces in repair. They focused on searching the ways to engage clients in this CE business. It is the case of the group that created the scheme from Figure 8 below.
Another group created a design for machinery that could cut the straps automatically, as shown in Figure 9. A third group designed a tool, presented in Figure

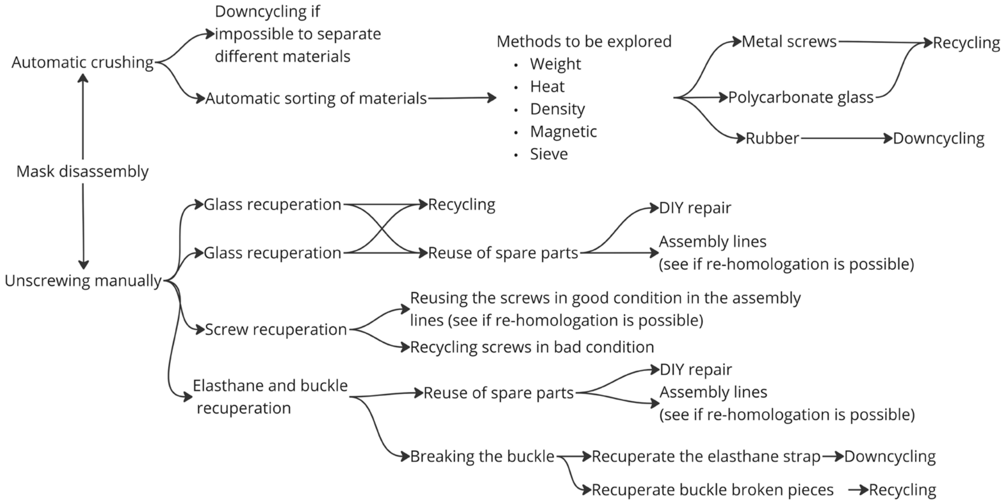

Fig. 7. Example of a translated mindmap

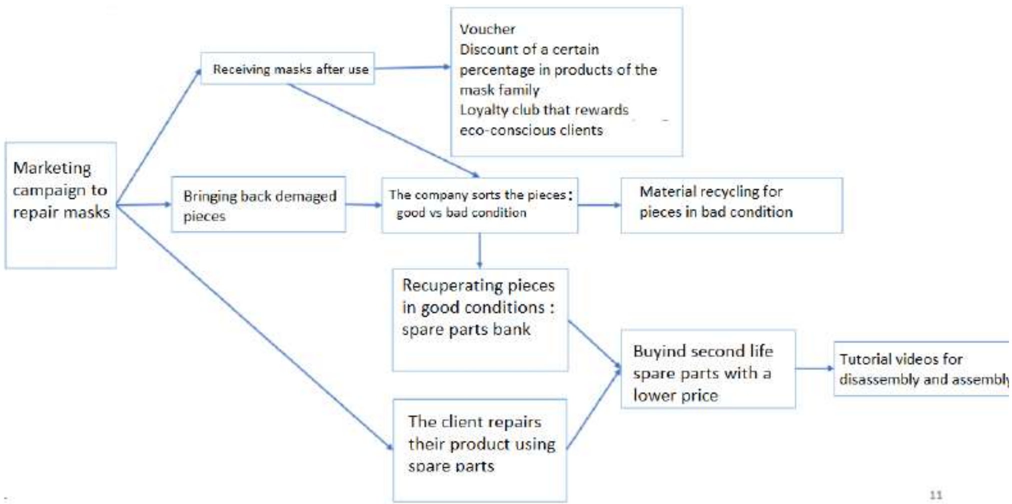

Fig.8. Interactions from the end-of-life to the reuse of spare parts

10, that could help disassemble the mask by triggering a button, which would avoid damaging the product.

4.1.4 Deliver: results

Each group created a BMC that would be adapted to their solution. For example, in Figure 11 below, we present the BMC from the group responsible for the tool above (Figure 10).

4.2. Course evaluation: results

From the fifty-two students, 46.15% responded to the questionnaire. The graphs below present the result of their perception of affirmations about this course. In this context, 1 meant “I do not agree at all” and 4 meant “I agree with it a lot”.

i. The support material was clear, and it helped me to understand the subject (Figure 12).

ii. The activities were interesting to me (Figure 13).

iii. The project helped me to comprehend CE (Figure 14).
iv. The activities had a good duration (Figure 15).

We also received a comment, saying there was not enough time to develop the required activities.

5. Discussion / Conclusion

The students realized that in most of the cases, it was difficult to dismantle the masks and goggles by hand. Sometimes, even with general tools and their engineering background, it was not possible and some pieces had to be broken. The Unlinear Methodology (Demarcq et al., 2022) proved to be useful to analyse the assembly of different components. However, it raised doubts regarding assembly pieces, such as screws: should they be analysed as a component (represented by a hexagon) or a connective (represented by a line)?

When defining the problem, there were two major subjects: automatic disassembly by crushing and then recycling, or manual disassembly to reuse spare parts for repair loops. Regarding the framework for problem definition, most of the students had difficulties when filling in the required cases (Table 1). Instead of choosing one of the mapped elements, the issue they addressed was masks and goggles circularity in general, lacking focus in the problem definition. This could affect the project's evolution, once it causes a more superficial analysis. Yet, one common element was when asked to reframe the issue, most of the groups mentioned the importance of designing for circularity to prevent disassembly difficulties in the end-of-life.

In the explore phases, there was a diverse range of solutions. Some groups developed machinery designs, others tool prototypes, and also service designs. It shows that circularity could be approached from different perspectives, considering products' characteristics, such as price. For example, cheaper products had fewer chances of being repaired, so circular solutions were based on recycling.

Then, in BMC, marketing campaigns were a central point in customer relationships to raise awareness among customers. Also, students explored the role of employees in disassembling, which could increase operations costs. Finally, private clients in a B2C model were the main customer segment, but they also saw an opportunity with companies that worked directly with swimming and diving clubs.We had

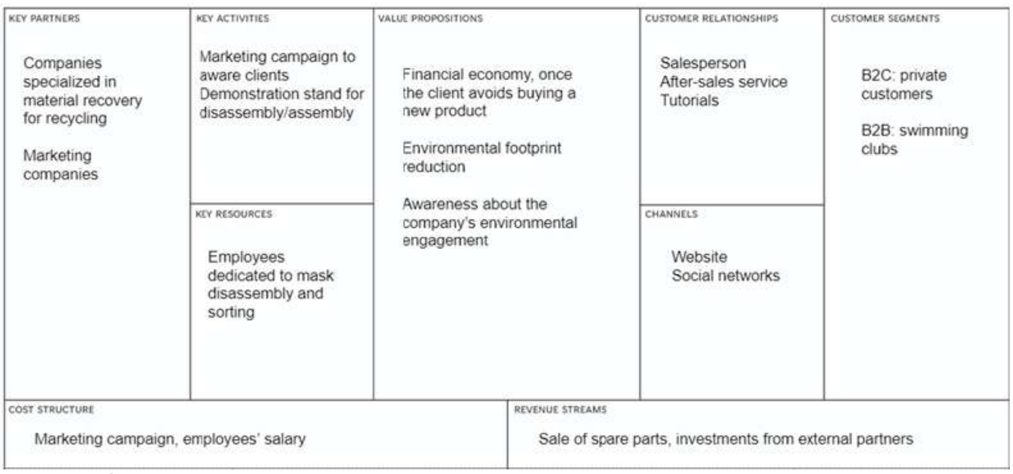

Fig.11. BMC considering on tool-based solution

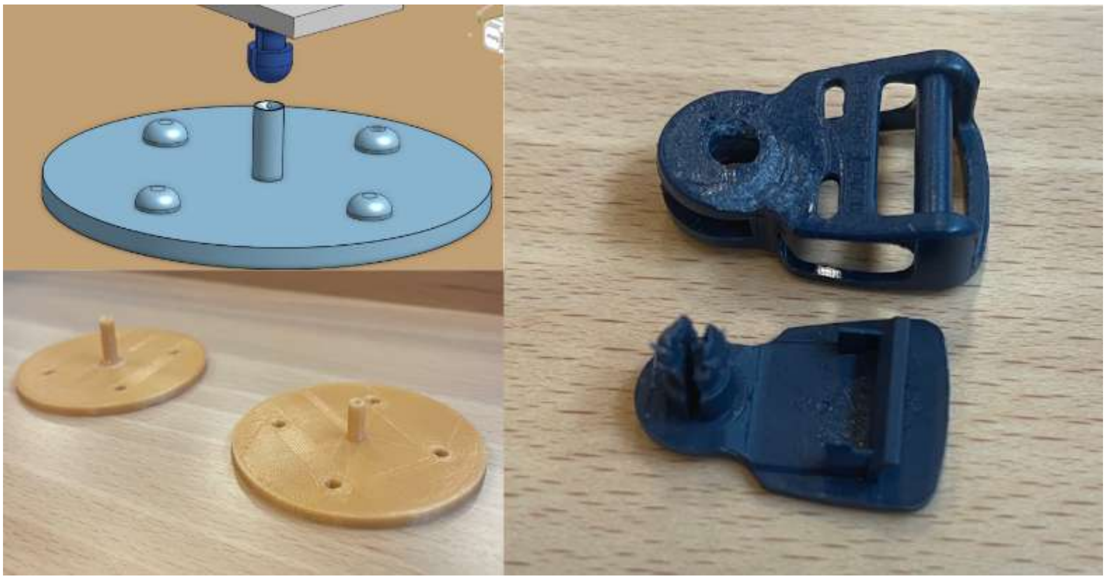

Fig.10. Tool for triggering the mask button

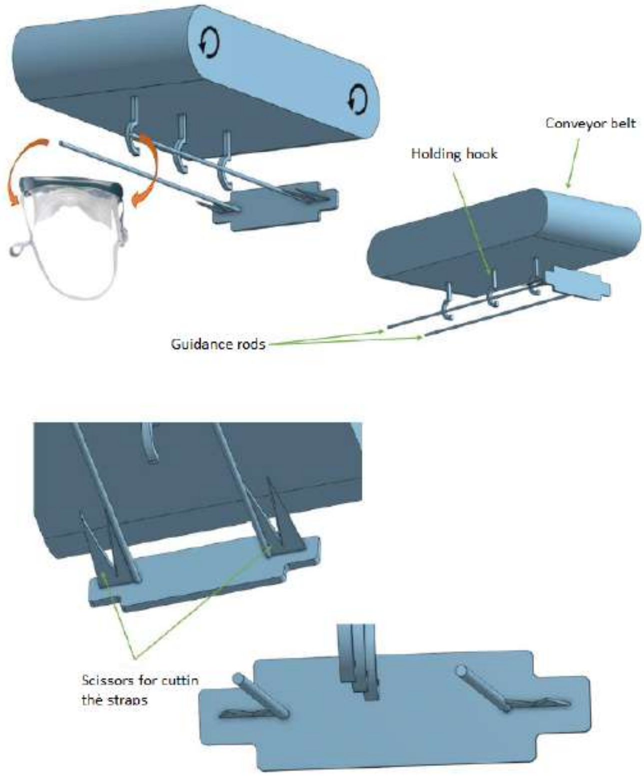

Fig.9. Machinery to automatically cut straps

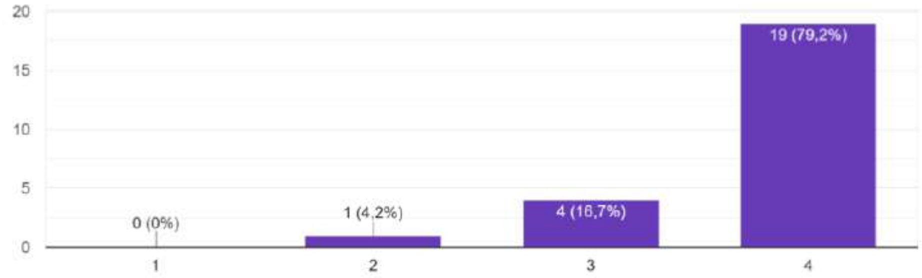

Fig.12.. Evaluation of the class' support material

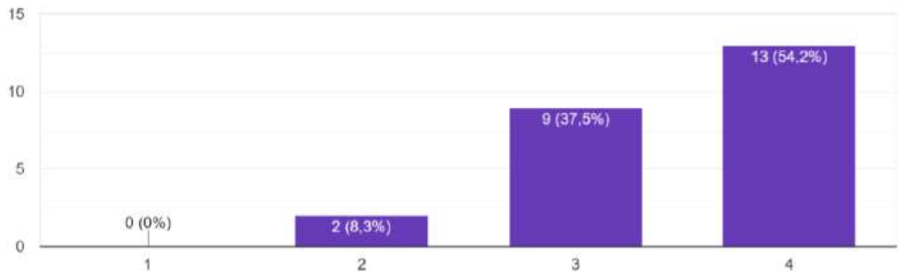

Fig.13. Evaluation of the student's interest regarding the course

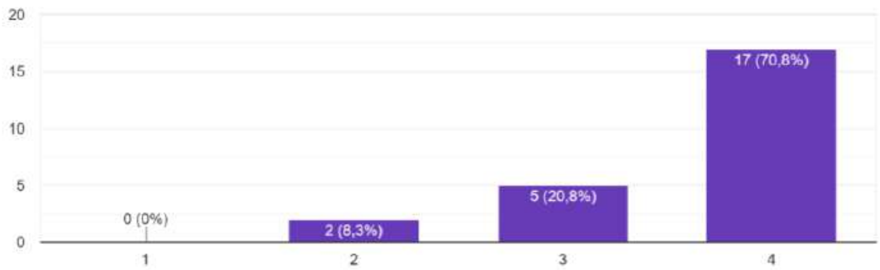

Fig.14.. Evaluation of the student's comprehension regarding CE

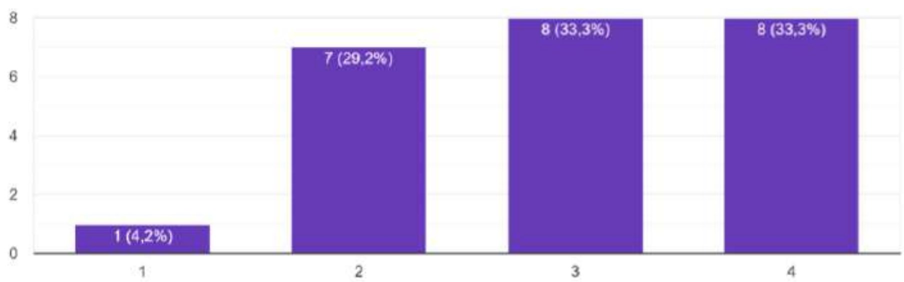

Fig.15. Evaluation of the activities' duration

promising results when analysing the course evaluation. On a scale from 1 to 4, we see that most of the students thought the support materials were clear (3.75 average), that the activities were interesting (3.46 average) and that this course helped them better understand CE (3.63 average). Yet, the activities had a very limited time (2.29 average): only four 2 hours long classes to develop the projects were not enough to deepen the project's solutions. However, this course was a good initiative to educate students of their future role as engineers in the context of CE.

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Assuring a human-centred transition to Industry 4.0 in the textile-clothing sector

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Industry 4.0, Human Factor, Cobot, Textile-clothing Industry

Abstract

In France, the textile-clothing sector is one of the most affected by the relocation phenomenon ongoing since the 1960s and has been greatly impacted by supply disruptions due to the COVID-19 pandemic. This research proposes using 4.0 technologies to promote the relocation of textile production in France while keeping people at the heart of the industry. This paper first explains the "human vs machine" paradox by analyzing previous research on human responsiveness to Industry 4.0 technologies and then presents the study case results with a collaborative robot (cobot) within a clothing workshop. The case study allowed the understanding of human needs in Industry 4.0 and contributed to a successful improvement in productivity. The article concludes by highlighting good practices for human management to have a successful application in 4.0 projects.

1. Introduction

The textile-clothing is one of the oldest industrial activities in the world (Ammar & Roux, 2009) (Messaoudi, 2015). Since the 1960s, French manufacturers have been moving their production tools to developing countries to reduce cost prices. The cost of production in these countries was much lower than in developed ones, this generated a new organizational scheme which follows a central/peripheral logic of maintaining noble value-added activities in France and moving low-value activities abroad (Ammar & Roux, 2009) (Messaoudi, 2015). Owing to the delocalization of manufacturing and textile activities, many companies have disappeared, and many jobs have been lost, whether it be due to the partial relocation of the business or the complete cessation of this activity.

The textile sector has not evolved like other ones in terms of technologies due to the phenomenon of delocalization (Crouzel, 2021). In the textile-clothing industry, mostly manual manufacturing significantly influences the selling price because it requires operators who are technically competent in sewing. The cost of labour was one of the main reasons that led to the delocalization of textile production. This production cost is the challenge that must be met today so that this sector can once again develop locally and offer local production.

To date, the problem of textile relocation in France is primarily linked to the inability of the local textile network to produce larger quantities (Huriez, 2019). According to INSEE data, there is a lack of resources and most industries that have partly maintained a local activity use subcontracting to obtain the finished product.

Faced with constant competitive pressure, manufacturing companies must offer productivity gains by increasing production to meet new demand or reducing direct and/or indirect costs. To do this, manufacturers seek to develop innovative products and services, or new ways of manufacturing them, requiring the teams to evolve their skills (Pellerin & Cahier, 2019). 4.0 technologies come to support manufacturers to improve the efficiency of production and maintenance operations, reduce production costs, improve the quality and customization of products, reduce hardship and Musculoskeletal Disorders (MSDs) in jobs and possibly win the challenge of competitiveness and relocation (Manyika et al., 2017) (Sufian et al., 2021). In this scenario, this paper presents a strategic business case that can be used by manufacturing organizations as a reference frame for a successful transition from traditional manufacturing to Industry 4.0.

2. Literature review

2.1.Industry 4.0 and cobotics

The fourth industrial revolution or Industry 4.0 is believed to offer exciting opportunities to address sustainability concerns in industrial operations (Ghobakhloo et al., 2021). As part of Industry 4.0, smart physical objects, decentralized subsystems, and even human components are seamlessly integrated into an interoperable and decentralized hyperconnected production system capable of adapting in real-time and autonomously to environmental stresses (Butt, 2020). This intense focus on digitization and the implementation of technological advancements affects the structure and performance of work in industries (Müller et al., 2018). According to Xu et al. (2018), one of the main goals of Industry 4.0 is a cooperation between machines and humans. In this context, collaborative robots, which are the origin of the term cobotics, very quickly became a technology of the 4th industrial revolution (Chowdhury et al., 2020).

Cobots enable human-machine interactions in the manufacturing sector (Kadir et al., 2018) (Simonin, 2022). They represent a new generation of industrial robots that do not require a fence or protective enclosure, opening borders and workspace to cohabitation and collaboration with humans (Adriaensen et al. 2022). Equipped with sensors and very responsive to detections of any unexpected force, cobots can stop immediately when they encounter humans or objects.

Even if cobot technologies are often integrated to increase efficiency, competence and competitiveness against competitors, the associated human factor should not be neglected in teaming perspective (Adriaensen et al. 2022). Longo et al. (2017) say that Industry 4.0

is most easily implemented through an incremental evolution process whose main dimensions are automation and intelligence: the product, the machine and the operator are central paradigms. For Longo et al. (2017), as Industry 4.0 takes shape, human operators must perform increasingly complex daily tasks: they must be very flexible and show adaptability in a very dynamic work environment. According to Kadir & Broberg (2020), the reaction of humans to new technologies and mainly the resistance to change are essential factors for the successful implementation of Industry 4.0.

2.1.1 Human Factors and issues related to cobotics

Robots are seen as a solution to workforce challenges in the industrialized world. However, if it is to be used by human actors, it must also be accepted by them. According to Heerink et al. (2009) technology acceptance, user non-adaptability and social influences remain sensitive issues. To measure this acceptance, Heerink et al. (2009) created a questionnaire model that takes into account human feelings when using technologies.

Longo et al. (2017) advise on how to succeed in an Industry 4.0 project with the implementation of project management to secure each stage and control all its dimensions: human, organizational and technical. Longo et al. (2017) also proposed an integrative approach to enable human resources to become the centre of gravity of Industry 4.0. The considerations made by the authors served as an inspiration to create a clean way of integration adapted to the industrial environment and the human resources of the company in this study case. The objective was to support employees by providing the appropriate training on the use of a cobot and information that is not generally available: suggestions on how to increase productivity, the planned maintenance operations, and warnings on the dangers and the risks likely to happen. To do this, a questionnaire inspired by the study of Heerink et al. (2009) was developed. Following the questionnaire, a presentation of the system was made. The methodology used is presented in the next section.

3. Methodology

Since the beginning, the cobot has been brought close to everyone in the sewing workshop. This was intended to encourage operators to adopt the technology without forcing them to change their work habits. The first configurations and settings were carried out by internal staff in full view.

These implementation steps were considered the first qualitative measurement of acceptance inspired by the study by Heerink et al. (2009). The main objective was to create a social presence link when interacting with the system and to verify the interest shown by employees in using the cobot according to their level of interaction with the teams in charge of its implementation.

3.1. Definition of the priorities and implementation of an automated station

After commissioning the cobot with all the necessary tools, and having studied all its functionalities, we analysed the opportunities for automating the workshop. We first focused on low value-added or repetitive positions that do not require huge expertise. According to Biétry & Creusier (2015), the factors of well-being at work are directly linked to the feeling of personal efficacy, the satisfaction felt about the tasks performed and feelings

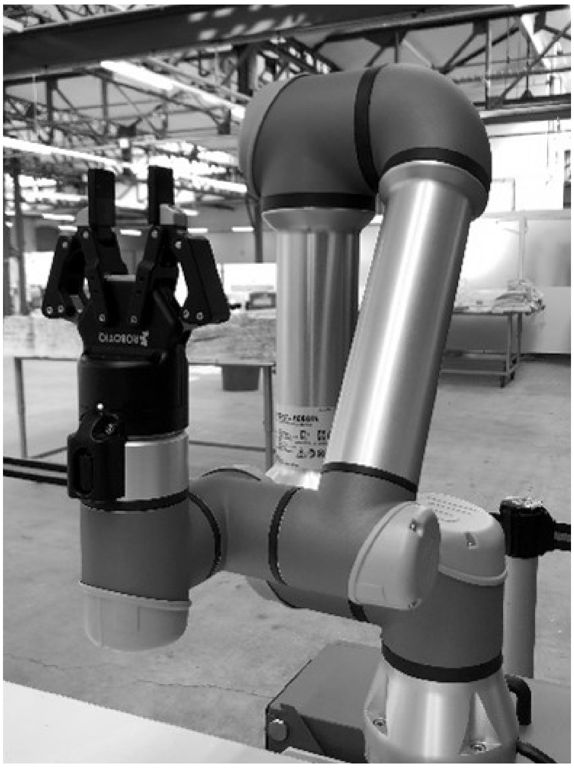

Fig.1. UR5

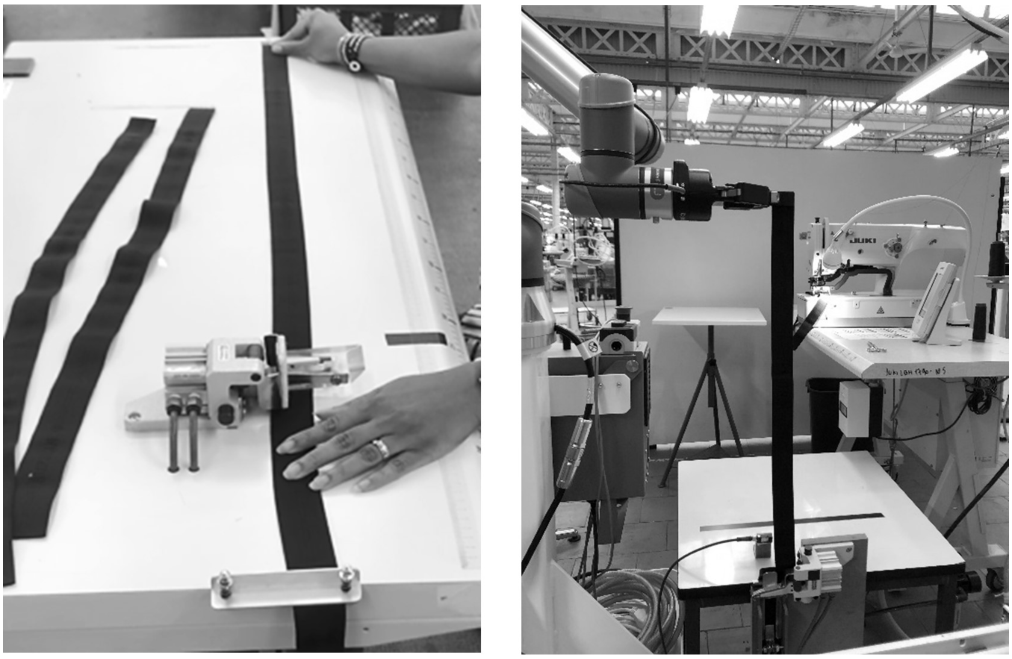

Fig.2. Old cutting station vs automatic cutting station

of commitment. Positions with low added value do not fit into its definitions and have been targeted as factors of ill-being at work. We, therefore, chose the station for cutting the belts of the boxer briefs. This time-consuming and repetitive job was likely to generate longer-term MSDs (Figure 2).

Although the UR5 is a collaborative robot, we decided, as a first step, to automate the cutting operation. The objective was always to test the acceptability of this new technology, to increase user confidence (the belief that the system works by ensuring personal integrity and that it is reliable) and to demonstrate the security of the use of the cobot before proposing human-machine interaction.

3.2. Acceptance questionnaire and protocol used

We were inspired by the work of Heerink et al. (2009) to develop two questionnaires (anonymous) to understand the feelings of staff on the cobot. The questions asked were considered during a brainstorming by a group of 6 people, each linked to a different department of the company to allow the most global vision possible. The desire was not only to assess anxious reactions to the use of the cobot but also to create a link between the sewing operators and the cobot. Given the fact that the French textile industry has very painfully experienced the disappearance of thousands of jobs over the years, a fear on the part of operators for the establishment of automation technologies within the clothing workshop which historically and still today is very manual, was inevitably expected. The questionnaire was therefore developed in a friendly tone, referring to the cobot as a “new colleague” and as a solution to reduce tedious and repetitive work. Precautions have been taken to not present it as a technology that is put in place to reduce jobs, which is not the case, but rather as a concrete desire to make staff aware of the potential for collaboration that could be developed with this type of technology.

The first questionnaire was applied without any prior presentation of the automatic station to know the priorities of the employees and measure their knowledge of cobotics. With these results in hand, we conducted a tailor-made presentation of the automatic station to answer questions, introduce the cobot and its systems and generate the confidence necessary for human-machine interaction in a collaborative station.

This confection workshop is divided into 8 groups, each responsible for assembling a class of products. The first stage of the event was the application of the first questionnaire, and then each group (about 15 people per group) moved to the automatic station to attend the presentation. The demonstration was followed by explanations about the new technology and the difference between cobots and industrial robots, a demonstration of the safety of the cobot in case of an impact with a person or object and a demonstration of the automatic cutting. At the end of the presentation, the second questionnaire was applied.

4. Results

The two questionnaires were offered in paper format to all employees of the department. That day, 87 people were present. The first questionnaire was answered by 100% of the people and the second one (the feedback questionnaire) had a total of 75 answers (86.21%) of which 4 were not considered because they had a lack of precision (in single-answer questions, all alternatives have been marked, for example).

A few identical questions were asked in the first and in the second questionnaire to evaluate changes in perspective and understanding of the subject after the presentation. This is the case for the question “Do you think the cobot could physically hurt you?” which we can see in Figure 3.

Before the presentation, only 39% of people answered that the cobot could not hurt them. After the presentation, the percentage of people who think the cobot cannot physically hurt them increased to 92%, which shows a gain in confidence in the system. Another question that had very satisfying results after the presentation was “Would you be willing to carry out missions where the cobot intervenes to help you?”. We had barely 30% of ‘Yes’ answers in the first questionnaire. After the presentation, we only had two possible answers (yes or no). 76% of the operators answered that they were ready to carry out collaborative missions with this cobot (see Figure 4). This highly positive result was the determining factor for the implementation of the collaborative workstation.

It is also essential to keep in mind that the acceptability of the project by employees must be regularly assessed because it can evolve favourably or negatively. Thinking of this, we asked evaluative Industry 4.0 acceptance questions such as: “Do you think this kind of technology is important in a company like ours?” and “In your opinion, what will be the consequences if Petit Bateau does not adopt these new technologies (cobots)?”, but also, technical questions such as: “What operation do you think this first cobot will be able to perform?” and “Do you have any mission ideas for a second robot or cobot?”. These questions will be re-evaluated continuously throughout the use of the cobot.

According to psychiatrist Serge Tisseron, humans do not evolve as quickly as machines, but if there is a relationship of trust between the machine and the operator, acceptance is more quickly achieved. According to the psychiatrist, the more empathy you create through the robot, the more you feel confident and the more difficult it will be to undo the existing relationship (Tisseron et al., 2015). Intending to create a social link and trust to facilitate the use of the collaborative workstation with an associated feeling of joy or pleasure, we asked the operators to personalize the cobot and choose a first name (male or female) for this “new employee”. Among the various proposals, the most voted first name for the company’s first cobot was Jorge.

4.1. The collaborative workstation and the economic results

After the good results of the questionnaires, we placed a sewing machine next to the cobot and modified its programming to offer the cut elastics directly to the operator. As expected, the collaborative workstation was well accepted by the staff, and it assured the complete production of boxer shorts for a whole confection group. Then, the profitability was calculated.

On the collaborative station, the cut is made at the same time as the sewing and there is no time transfer between the two stations, on the other hand, there is an addition of a few seconds at the start of the cycle so that the robot does its preparatory cycle (it cuts a small piece of the elastic and puts it in the trash to ensure a straight cut in production). The total time of the operation with the collaborative station was 5min20s, which means a saving of 18% of the time compared to a manual station for every 20 belts produced. In terms of monetary profitability, with this reduction

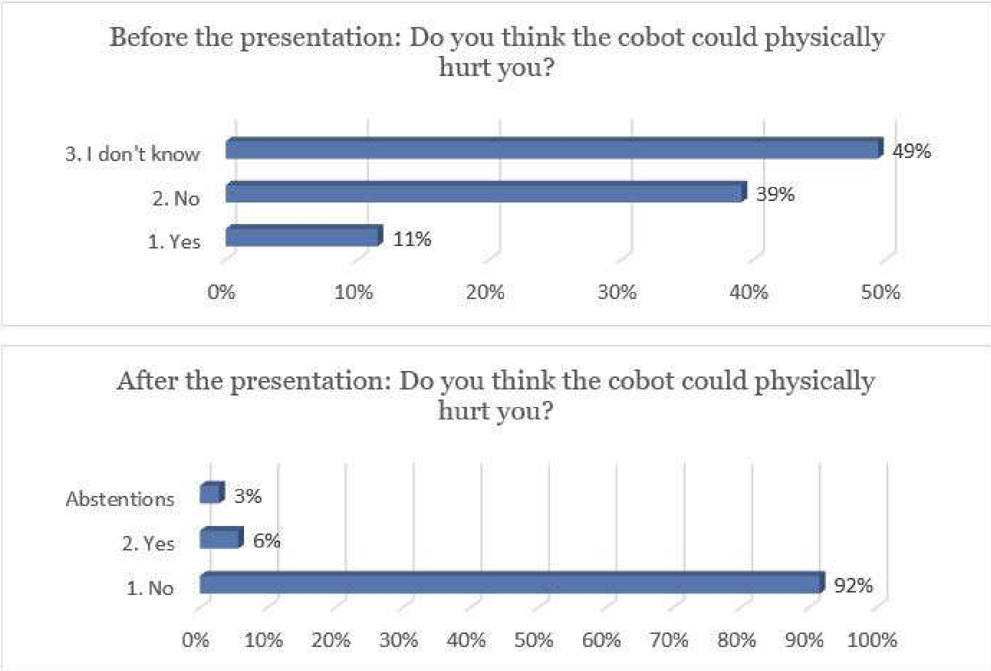

Fig.3. Results Before vs After presentation for the question "Do you think the cobot could hurt you physically?"

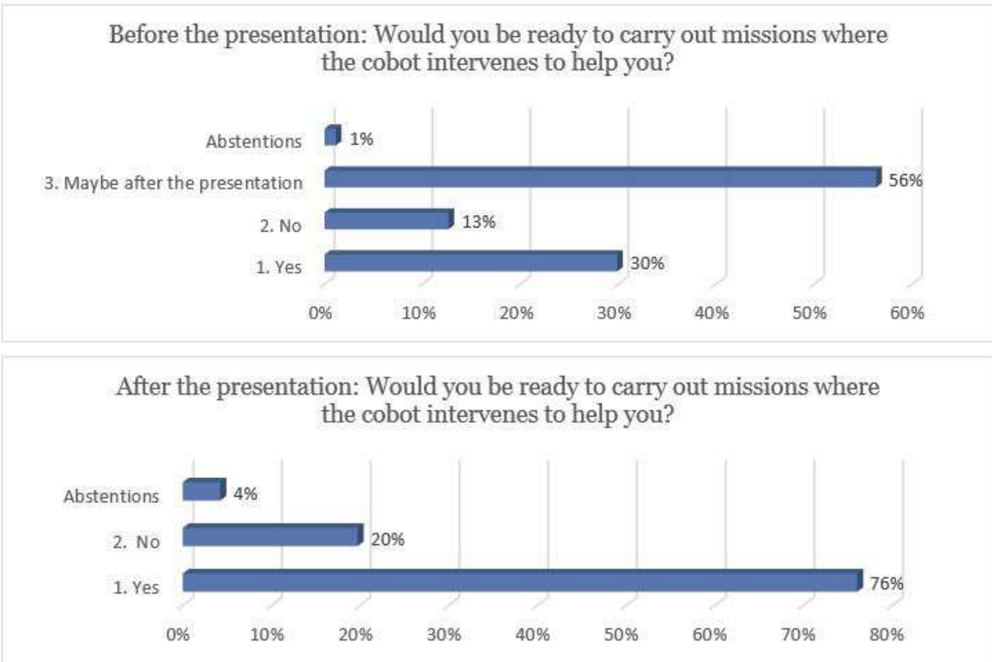

Fig.4. Results Before vs After presentation for the question "Would you be ready to carry out missions where the cobot intervenes to help you?"

in time, we manage to make a saving of 6% per product, which is verified directly in the sales margins. The productivity of this confection group also increased by 13% with the use of the cobot.

5. Discussion / Conclusion

This article presented a practical application of the deployment of a cobot, one of the technologies of Industry 4.0, while keeping humans at the centre of changes in a textile company. The acceptance questionnaire was a determining factor for the start of the collaborative workstation. From these results, we were able to identify the issues and complexities for the people who will work with the new technology daily and this knowledge will allow us to continuously check the well-being of the staff. The good results of the questionnaire allowed us to verify that the way the cobot has been presented since its arrival has influenced the open-mindedness of the employees and contributed to the success of the collaborative workstation.

The results of the collaborative workstation proved that technology acceptance, user adaptability and social influences remain fundamental issues for a successful transition to Industry 4.0. We have reduced the production time and consequently increased the profitability of the products, the efficiency and the productivity of the confection group concerned. The next steps in the deployment of this collaborative workstation are to support the well-being of staff and quantify the workload.

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SECTION 3. FASHION-TECH RESIDENCY DIGEST

Biomimicry Wearable

Smart textile wristband

STUDENT: Cecilia Saffiro
COMPANY: Pauline Van Dongen Studio, The Netherlands
HEI: Politecnico di Milano, Italy

PHYSICAL PROTOTYPE

KEYWORDS
Biophilia Hypothesis, Smart Wearable, Mental Wellbeing, Natural Stimuli Embodiment, Interaction Design

Abstract

Biomimicry Wearable is a set of wearable accessories that aim to make people more aware of the outside world, by encouraging them to detach themselves from their work take a restful break for their mental wellbeing. Based on the biophilia hypothesis, the project focus on the natural stimuli embodiment through sensors and actuators that the user could wear indoors to reconnect with nature. In particular, real-time wind data like speed and direction are captured from a meteorological website to produce both tactile and visual sensory stimuli such as the contact of the air with the skin and the movement of the blown blades of grass. At the start of the residency, a careful analysis of the environment, materials, activities, and previous projects carried out by the studio was undertaken. After this familiarization, concept development was implemented through desk research and learning-by-doing activities. The output is a functioning prototype of a wristband that lets the wearer feel the wind intensity and direction through vibrations, enacted by piezoelectric motors on the skin. A second experimental prototype is a laptop sleeve with a surface resembling wind-blown grass thanks to muscle-like actuators.

1. Introduction

The internship was held for a period of three months from the 28th of March until the first of July at Pauline Van Dongen, a Dutch design studio located in Arnhem specialised in wearable technology. Established in 2010, the studio is continuously involved in a diverse array of projects that span various disciplines, locations and collaborators. This reality is immersed in the dynamic intersection of textile, the body and technology and is dedicated to collaborative projects which enable innovation and experimentation to take the form in a viable product. The BIOMIMICRY WEARABLE project is a smart textile that refers to the macrotrend emerged from the research of biomimicry combined with the desire of the studio to combine the world of fashion with the one of technology, the project wants to give a new perception of this, generally seen as something cold and detached, technology can instead be the key to bring the human body closer to nature. In fact, it has been demonstrated that working indoors in front of a laptop screen disconnects us from the surrounding reality, causing in the long-term increased stress and anxiety in the workplace, while exposure to natural stimuli improves people's moods, reduces stress, enhances stress resilience, and promotes mental and physical health. For this reason, the project wants to make people more aware of the outside world and encourage them to detach from their work to get out and take a break. In particular, the natural element of which we cannot benefit from being inside is that of the wind, this produces several sensorial stimuli including the tactile due to the air contact with the skin.

2. Residence objectives

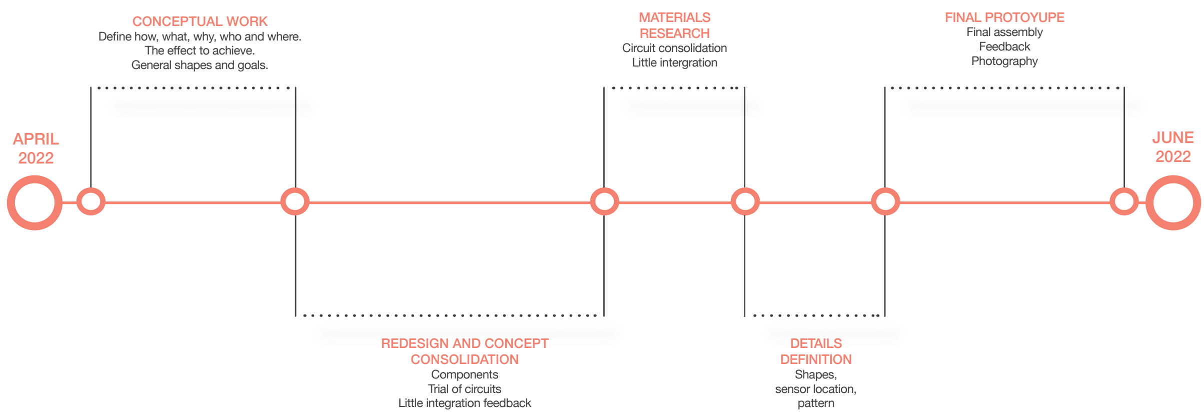
The purpose of the Residency project is to connect young talents who are trained in the field of fashion and new technologies with professionals and companies located in different parts of the world to create new projects that benefit both the intern, the university and the company itself. The main aim of embedding students in Fashion-Tech companies is to make them acquire practical skills through a mentorship scheme. During this experience, they will be able to develop novel Fashion-Tech product/service prototypes, starting from an idea conception until a final object development.

2.1. Pauline Van Dongen

The internship at Pauline Van Dongen studio was proposed by the Politecnico of Milan to their student, the starting point was to analyze the work of the studio and propose concepts of possible projects to be developed within the studio, which usually operates in three main fields: the solar fashion and textiles, the shape shifting materials and the haptic technology.

3. Residency Activities

Initially the understanding of the environment and the activities carried out by the studio required a careful analysis of the garments created by designer Pauline Van Dongen, of the materials, including fabrics, machinery, books, documents and rooms (photo studio and laser cutting)



available, the context rich in stimuli has made it possible to understand what could be achieved through careful research and design. In the first phase the emerging trends, the documents that contained the study's research, several articles and smart wearable case studies were carefully analysed. Then the concept was translated into different interactions between the user and the smart wearable, outlining all the effects that were wanted to get from the product and developing through consistent research several ideas to achieve the desired goals. Starting from the desire to recreate the stimulus of the wind on the skin in an internal environment, it has come through the research phase the need of using piezoelectric motors that could be activated with different frequencies and direction angles depending on the intensity and direction of wind.
Through the programming of an arduino sketch it was possible to recreate with circuits the vibrations of the piezo electric motors connected in real time to the external environment. The analysis of the beaufort scale and wind rose was useful to understand the data related to the intensity and wind direction in order to associate the numbers extrapolated from the meteorological website with different frequencies and times of vibration.

4. Project Description

Through the design of the wristband we started from the analysis of macrotrends to meet the current needs on the market, in particular that of reconnection to nature and attention to the mental well-being of the worker which is becoming increasingly relevant over the years. The innovation of the product is in fact to unite two usually distinct concepts, nature and technology, that instead coexist and dialogue in the BIOMIMICRY WEARABLE. In addition, compared to the countless existing products on the market, the project offers a more emotional connection between the user and the smart wearable, it is no longer just an object to wear that provides us with some information, but an accessory to take care of, that manifests his willingness to connect with the outside world.

5. Residency Results

Through this experience I learned to interface with this new reality of smart wearable design, I acquired a new perspective from the point of view of creating an idea inspired by the working environment in which I was immersed, also i learned a problem solving working methodology starting from an idea and , through research and new possibilities in the field of technology, look for a way to put it into practice by taking inspiration from solutions already existing but related to different fields from fashion. I learned through the assistants' suggestions to use new machines, programs and methodologies in creating a fashion object as well as improving my English proficiency and ability to work in teams. As for the machines I learned in particular the use of laser cutting, how to set the machine and various parameters including speed and intensity of cutting, the use of the welder and the different methodologies to join the various components of a circuit and I improved my ability in the use of the sewing machine, testing new types of seams and methods that I was shown in the studio. Among the programs I learned to use Arduino for the creation of a code, illustrator for the preparation of files to be laser cut and laser work for the input and setting of the laser machine.

Natural dyeing on bio-based material

Zero-waste plants-dyed and biodegradable garments

STUDENT: Meijun Chen
COMPANY: Centexbel, Belgium
HEI: Politecnico di Milano, Italy

PHYSICAL PROTOTYPE

KEYWORDS
Plants Dyeing, Bio-based Materials, Natural Colours, Zero-waste Design, Colour Fasteness, Empirical Test

Abstract

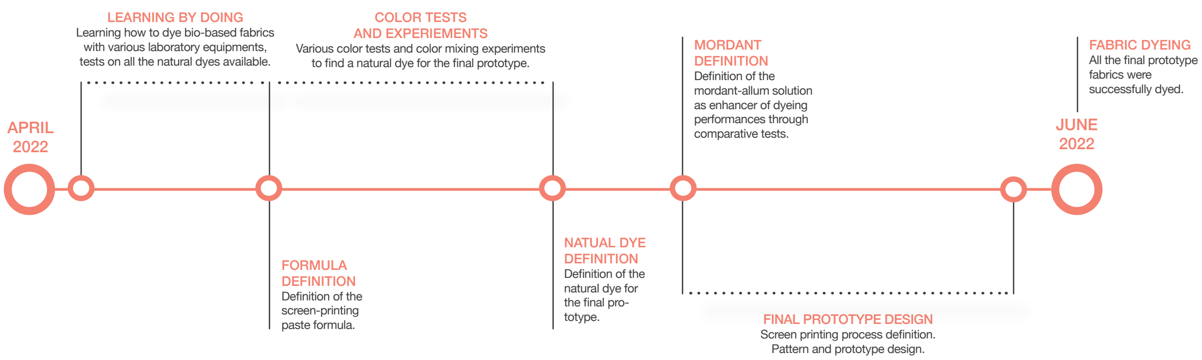
Biomimicry Wearable is a set of wearable accessories that aim to make people more aware of the outside world, by encouraging them to detach themselves from their work take a restful break for their mental wellbeing. Based on the biophilia hypothesis, the project focus on the natural stimuli embodiment through sensors and actuators that the user could wear indoors to reconnect with nature. In particular, real-time wind data like speed and direction are captured from a meteorological website to produce both tactile and visual sensory stimuli such as the contact of the air with the skin and the movement of the blown blades of grass. At the start of the residency, a careful analysis of the environment, materials, activities, and previous projects carried out by the studio was undertaken. After this familiarization, concept development was implemented through desk research and learning-by-doing activities. The output is a functioning prototype of a wristband that lets the wearer feel the wind intensity and direction through vibrations, enacted by piezoelectric motors on the skin. A second experimental prototype is a laptop sleeve with a surface resembling wind-blown grass thanks to muscle-like actuators.

1. Introduction

The goal of this project is to design fully biobased clothing. So I mainly studied how to dye bio-based fabrics with natural dyes through dip dye and screen printing during residency. I chose indigo, comfrey and hematoxylin. During the preliminary experiment, the plant dyes I ordered in China have not been delivered due to force majeure, so I tried many natural dyes from laboratories, which gave me more ideas and choices in dyes and can do more comparative experiments. The problem with plant dyeing is poor colour rendering, low saturation, and poor color fastness, another problem is that most of the plant dyeing is hand dyed, so the quality of dyeing is very random, usually the color of different batches of fabrics will not be uniform, So this is what I need to solve during my experiment.

2. Residency Objectives

In order to solve the problems of natural dyeing, I did different kinds of experiments on fabric pretreatment and fabric color fixation. Before dyeing the fabric, I first tried to pretreat the fabric with a chitosan solution [1,2,4]. After that, the pretreated fabric and the ordinary fabric were dyed together to compare the dyeing conditions of the two, and it was found that the chitosan solution did not significantly help the dyeing rate. Secondly, I tried a rosin powder fixer [3]. However, the material of the fabric treated with the rosin powder fixing agent will be changed, from the previous softness to more rigid, and there is no obvious change in color. At the same time, because the fixing agent needs to be heated during the production process, As a result, the dyed fabric will fade in the fixing agent, so the effect of the rosin powder fixing agent is not ideal. In the process of dyeing comfrey and anthocyanin, I tried to pretreat the fabric with alum [5] and experiment with color fixation. The pretreatment process involves placing the alum in water and heating it to facilitate its dissolution. Soak the fabric to be dyed in alum water for 20 minutes to half an hour. The process of fixing the color is to soak the dyed fabric in the alum solution for 20 minutes. I compared the two and observed that pre-treating the fabric with alum made the fabric easier to color and the color was more vibrant, while making the color firmer in the fixation experiment.
After various experiments and comparisons, it was concluded that for comfrey and anthocyanin dyeing solutions, the use of alum solution to pretreat the fabrics can improve the coloring rate of the fabrics, make the eye color saturation higher and the color fastness better.



3. Residency Activities

I Tried Indigo/curcumin/anthocyanins/ Cochineal/phycocyanins/comfrey/ hematoxylin pastes in total, dyed through dyeing and screen printing.

At the beginning of the internship, I tried different dyeing methods. For example, I first used the Infrared dyeing machine, which uses thermal infrared heating to achieve dyeing. The performance is stable and reliable, energy-saving and environmentally friendly. The machine has a total of 12 testing cups, which can dye 12 different solutions and fabrics each time. I used this machine to perform indigo staining experiments and curcumin staining experiments at different pH values. The second method of dyeing is to use a glass container for dip dye, and then I use a Foulard machine for padding, to make the fabric nip rate the same each time, which is aim to ensure the accuracy of the experimental results and will not be wrung out by hand.. For the first experiment, I tried to pre-treat the fabric with chitosan, then compared the pre-treated fabric with the original fabric, and then performed the turmeric dyeing experiment with the two fabrics. After this I performed experiments with different dyes and different concentrations of the same dye. In order to get more color possibilities, I also conducted mixed dyeing experiments of different colors, and adjusting the dyeing order can also get different experimental results

4. Project Description

After experiments,I started to design final prototype. In the clothing industry, the leftover fabrics in the production process are a serious waste phenomenon. Therefore, I decided to take zero waste as the main design concept and design a garment with the pattern of zero waste pattern [6]. To make this garment sustainable from the dyeing of the fabric to the final recycling. Due to the limitations of the machine in the laboratory, the width of the fabric is limited to less than 50 cm, so I combined the above concepts and constraints to design a bias-cut suspender skirt. The version consists of three squares, each of which is made of Small squares of 45cm are spliced together. So that this skirt does not create any leftovers in the process of cutting the fabric.

5. Residency Results

During the three-month experiment, according to my final prototype design, anthocyanins were found to be superior compared to other dyes, whose best concentration is 2%.

Among different bio-based fabrics, lyocell and silk have the best screen-printing effect, with clearer patterns and stronger detail expression.

In the end, I made a full biobased suspender dress using the results obtained from the experiment, that is, anthocyanin dye solution and its suitable bio-based fabrics, no matter from pattern to accessories and also the sewing thread, which is biobased threads as well.

Garmentity

The process of giving a garment an identity

STUDENT: Laura Chivers
COMPANY: Pangaia Grado Zero, Italy
HEI: University of the Arts London,
London College of Fashion, London, UK

PHYSICAL PROTOTYPE

KEYWORDS
Longevity, Design for disassembly, Biodegradable materials, Zero-waste design

Abstract

Garmentity is a conceptual jacket designed considering "zero waste", size adjustability, and "design for disassembly" as key process drivers. The project takes into account the garment's end-of-life as both a constraint and inspiration for the design process. The jacket is produced using natural, biodegradable materials, and a singular metal zip, all of which can be easily separated and recycled. The garment is made taking advantage of the entire width of the fabric as the basis but using the otherwise unnecessary cut-offs in a functional or decorative way. The residency was developed over four months alternating remote work (project brief definition, preliminary research, and digital prototyping) and n studio activities (pattern-making, material sourcing, physical prototyping, jackets collection finalization). Key learning outcomes include increased awareness of constraints concerning developing a zero-waste pattern (difficulties of varying fabric widths and utilization of all the fabric); increased knowledge around sustainable textiles, natural and biodegradable fabrics, and their features; exploration and development of a system to make a "one size" zero waste pattern adaptable to varying bodies.

1. Introduction

Garmentity is a product in a speculative scenario, utilising an entire piece of material so that the whole fabric is given an identity within a garment. Considering the idea that 'waste is material without identity' (Rau, 2021), and that "15% of fabric is wasted during the cutting process" (Carrico et al., 2022) with meaning that 60 billion square metres, of the estimated 400 billion square metres of textiles produced globally each year, ends up as cutting floor waste" (MIT, 2015). If little to no waste is produced, and all fabric becomes part of the garment's identity, the better for the environment, and all involved in the production process.
This project considers how all the material can be used within a garment, but furthermore, how considering the end of life at the design process can also improve the sustainability of a garment. The jacket produced is designed for disassembly, using natural, biodegradable materials, and a singular metal zip, all of which can be easily separated and recycled.

2. Residency Objectives

My initial objectives for this project changed throughout the duration, due to the number of external factors, such as timing, the requirement to combine the project with another University unit, and limitations in the studio. My original design was going to consider modularity too, but this was not possible with the tools available to me in the PANGAIA studios. Furthermore, I had wanted to explore the use and creation of a digital passport for the garment too, but I could not achieve this in time. Therefore, the final objectives for my residency were as follows: -

2.1. Zero Waste Pattern

The initial idea for this project came from an existing Zero Waste jacket pattern, designed for a previous project, developed to have a better fit and improved appearance, in line with PANGAIA. Through utilising the entirety of a piece of fabric, initial waste at the design stage is significantly reduced, and the entire fabric becomes part of the garment's identity – through features such as the zip pull, back neck hook and decorative details.

2.2 Size Adjustability

The nature of Zero Waste patterns often means the garment is 'one size,' which is problematic and does not allow for varying body types. Therefore, I wanted my jacket design to incorporate adjustable elements that meant the garment could be changed in size and style to suit varying body types. However, due to limitations in the studio, I had to simplify this significantly to being a simple tie system in the hem and cuffs of the jacket. This allows both the fit of the garment to be changed, and the appearance, going from a more oversized, boxy jacket, to something that resembles more of a sporty bomber. It is suggested that transformable garments increase the longevity of a garment, due to the ability to change in appearance and offer more than one 'look.'

2.3 Designed for Disassembly

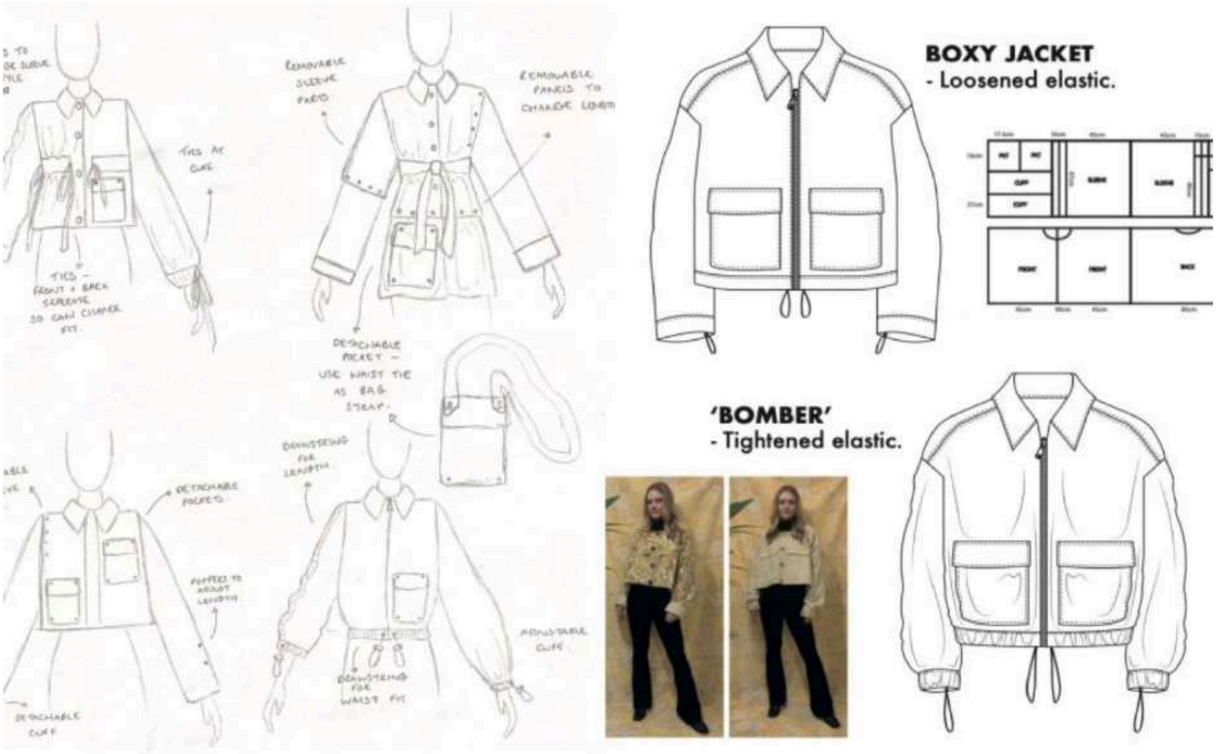
A garment that is designed with the end of life in mind, can be much more considered in terms of ease of recyclability, and overall sustainability. Furthermore, considering the number of varied materials and fibres used within a garment can make the final disassembly much easier. The less fibres used, the simpler the recycling process will be. My jacket is made of 100% natural fabric, a cotton hemp blended twill, like that currently used by PANGAIA. The only accessory used within the design is a singular metal zip, with cotton tape. The other accessories – the ties at the waist and cuff – are made from the same material as the outer jacket. The Zero waste design also means that the panels are quite rectangular and even, meaning that they can easily be taken apart and re-used or are biodegradable.

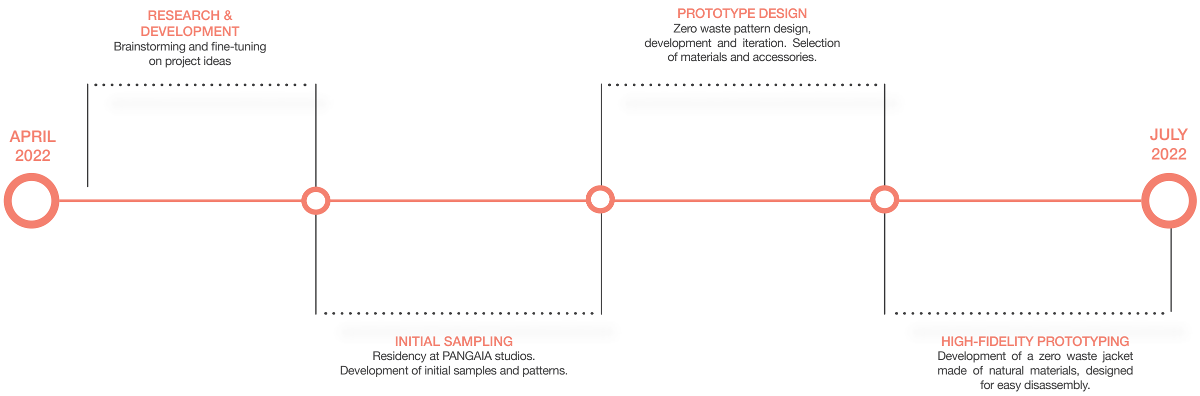
3. Residency Activities

The project was completed over a four-month period, from April to July 2022. This included two visits to the Pangaia studio in Italy, for a total of 5 weeks.

3.1 April – Research & Development

The first month of the project, involved weekly video calls and discussions with Enrico from Pangaia, about the basis of the project, considering some ideas from projects he had already worked on, as well as suitability for the Pangaia brand. It was agreed that my initial Zero Waste jacket design would form the basis of the project, and that I would develop this to consider


BOXY JACKET
- Loosened elastic.
'BOMBER'
- Tightened elastic.



the design, fabrics used and the end of life of the garment. I also explored the ideas of modularity and developing a 'digital product passport.'

3.2 May – First Residency in Italy

I initially went out to the Pangaia studios in Italy for a 3-week period in May. This was where most of the physical design development took place, drafting the pattern for and sampling the initial design, making amendments to the pattern, and then re-toiling the design. We visited a textiles factory and selected the fabrics for the final prototypes, as well as sourcing the trims and accessories for the final prototype too. Due to delays in the delivery of the final fabrics, it was decided I would return to Italy at the beginning of July to oversee the final prototypes being made.

4. Project Description

Garmentity is the process of utilising an entire piece of material so that the whole fabric is given an identity within a garment. In this scenario, the product is a Zero Waste jacket, made from 100% natural materials – a cotton hemp blend, like that used by PANGAIA. By using the entire width of the fabric, and incorporating any extra pieces within the design, no fabric is wasted in the design process. The jacket is also designed with disassembly in mind, using natural fabrics that are biodegradable, so the fibres can be easily recycled and are also biodegradable. Finally, considering that Zero Waste often means a 'One Size' design, the jacket incorporates ties in the cuff and hem to allow for the size and fit to be altered to varying body types.

5. Residency Results

The results of this project were the production of three Zero Waste jackets, all using the same initial pattern, but incorporating the decorative 'waste' elements slightly differently on each one. In order to achieve this, I had to consider and overcome the constraints of developing a

Zero Waste jacket, such as varying fabric widths and utilising all fabric. To do this, I had to increase the seam allowances in some places and develop creative ways of incorporating the waste such as decorative patches.

I have learnt about a variety of sustainable fabrics and the way in which they can be used and recycled, in order to choose the most suitable for my final design. I went with a cotton hemp twill, which has many benefits such as being antimicrobial, incredibly durable and strong, as well as softening with wear.

Although not as advanced as I would've liked, I have considered a way of making a 'one size' zero waste jacket adaptable to varying bodies, through use of ties in the hem and cuffs. This means the jacket can be made to fit different sizes, but also increases the longevity as the style and fit can be changed.

Finally, living and working in Italy boosted my self-confidence and self-belief significantly, as well as learning about PANGAIA as a brand, and some of the ways they implement sustainability.

Hyperfunction

Functional clothing for modern urbanites

STUDENT: Annalise June Kamegawa
COMPANY: Pangaia Grado Zero, Italy
HEI: Politecnico di Milano, Milan, Italy

PHYSICAL PROTOTYPE

KEYWORDS
Techwear, Functionality, Field research, Urban observation, Digital and physical prototyping, Flexibility

Abstract

The project is a waterproof hooded jacket with a nylon lining and a system of multifunctional pockets. The jacket aims to subtly incorporate functionality in an elegant way, moving away from the hyper-militarized language of "techwear", and instead focusing on a uniquely elegant garment in which every feature has sprung from a clearly defined need. Over the course of the residency, observation-based research was conducted on the urban population of Milan. Combined with market and literature-based research, the need for an elegant, yet function-based garment for modern urbanites emerged. Thus, at the Pangaia Grado Zero research and development offices, the jacket was developed using performance textiles, internal and external pocket systems, and a form suited for a body in motion. A combination of digital tools (Clo3D, Adobe Suite) and traditional garment production techniques and machines (pattern drafting, machine sewing) was implemented to execute this piece. The hyperfunction language developed in this project is then expanded, in preliminary explorations, to other garments.

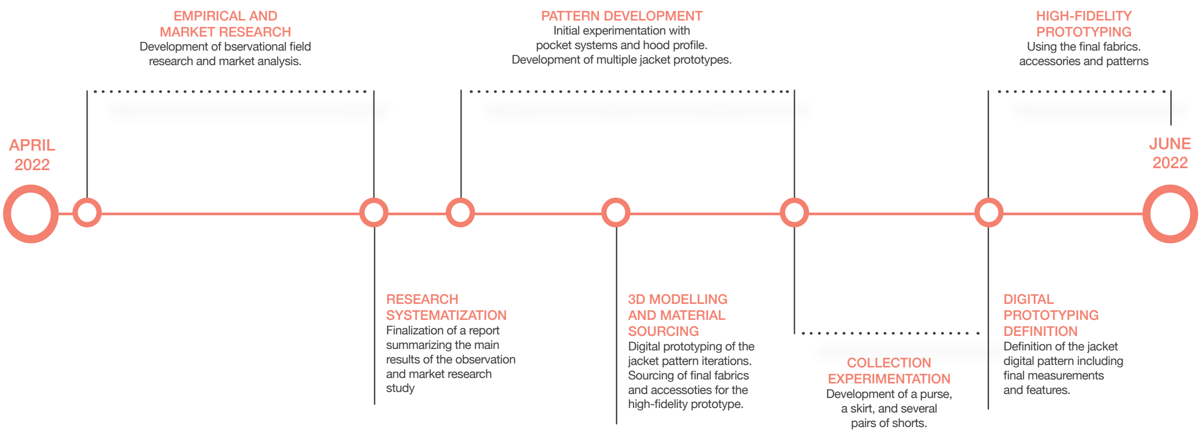
1. Introduction

Much like a climber needs a carabiner to ascend the face of a mountain, the residents of modern urban spaces need tools and garments to effectively traverse the cityscape. This project looks to create a garment that addresses the needs of city-dwellers by centering function in the project's development.

In order to define the problem, I conducted a nine month long observational study of the population of Milan. I captured pictures of how they approached the Milanese quotidien. I then distilled this collection of over 200 pictures into a 50-image annotated record of daily life and the clothing and accessories that accompanied it. The annotations include time, location, and the weather data of the photo. Additionally, they consider the behaviors, relative age, and interactions of the people within the scene. Through this body of research, patterns around the desire for function emerged.

My theoretical basis for this project was also accompanied by market research into clothing and collections that sat at the intersection of high-fashion and functional wear. The groundwork for this kind of exploration has been established by artists and designers practicing in the last few decades. Most modernly, in the commercial space urban-centric, high performance garments have been developed by ACRONYM, Massimo Otsi's Stone Island, and the street wear collections released by The North Face. On social media, artists and content creators have ventured into reimagining the context and form of performance garments. Artist Nicole Mclaughlin (@nicolemclaughlin on Instagram) reconstructs outerwear and nonconventional objects into wearable fashion. Creator Julian Carter (@Juulian.c on Tik Tok) has an account dedicated to tailoring and customizing second hand performance and military gear into streetwear pieces. Based on the research and observations made over the past several months, I've noticed that city dwellers prioritize functionality and comfort in their garments - especially when they have to make so many transitions through the cities they live in. Nevertheless, with their garments, users often have to choose between aesthetic and function. The garments that lie in the middle are adapted or "stylized" to be more aesthetically appealing. The design choices made assume that the function doesn't need to change - for urban people, aesthetics is what makes or breaks the decision to invest in a garment. Where my garment adds value is in its mission to address the needs specifically presented by urbanites. Instead of adapting to the features already present in functional garments, or augmenting a more aesthetic piece with a bag or other modifications, my garment will have features built in to address city uses.

Additionally, there was also a body of research that I referenced that sought to pinpoint how functional garments (military, sport, etc.) constructed certain features around the performance needs and kinesiology of the user. Reports on the evolution of American military garments, the breakdown of biking equipment, and walkthroughs of mountaineering gear have created a library of inspiration for this project.



2. Residency Objectives

One quote from Carlo Rivetti, CEO of Stone Island, beautifully describes the embodied experience this garment is looking to achieve: “My jacket is like my home. So I can face the world knowing the exact geography of my belongings.”
Emotionally, I have created a jacket that reflects the lived experience of moving through life in the urban space. The jacket feels as much a record of life in a modern city as a picture taken of a famous monument, a trinket picked up in the gutter during the rain, or a paper fortune saved from lunch with friends.
Throughout the duration of the residency, I created a concise theoretical basis in which to launch this project. I then created digital and physical models of the garment. Through an iterative process of pattern making and garment construction, I reached a final jacket that can accompany city dwellers through their urban travels.
Through the support of Pangaia Grado Zero (PGZ), I was able to source water proof textiles and accessories to construct the outer body of the garment. After several weeks of designing, I also designed a pocket system around the body of the garment that can assist the wearer in easily accessing the day-to-day products that they carry with them. In addition to this final jacket, I was also able to create some initial, low-fidelity prototypes of garments (a purse, shorts, and a skirt) that also embody the language of city-centric function that I defined in the initial stages of this project.

3. Residency Activities

During the residency, I spent three months at the PGZ offices in Tuscany developing the jacket I’ve submitted for this project. I worked under the supervision of Enrico Cozzoni, the company’s research and development director.
He advised me on what types of textiles would be most appropriate for the specific aims of my project. Additionally he provided us with insights into how the textile sourcing industry operates. The other residents and I were invited to a lecture on sustainability and fashion that Enrico led for buyers and designers in the industry. Also, while at the company, Cozzoni also brought us to a performance textile production facility in Prato. He explained to us the textile and fashion production industries present in the region. PGZ additionally provided the construction & education tools to create the first iterations of my garment at the PGZ offices. Using Clo-3d and traditional tailoring methods, I visualized and prototyped most of the garment on-site. The company also supported me in obtaining the high-quality performance textiles and accessories I needed for my high-fidelity prototype.
The other FT Alliance residents that spent time in the PGZ offices, Shan Lu, Lauren Shivers, and Yiyang Tang, also played as invaluable advisors and collaborators in the project. By sharing the space and this shared experience, we were able to provide enrichment and advice to each other’s work.

4. Project Description

The resultant product is a waterproof hooded jacket with a nylon lining and a system of pockets. These pockets are both internal and external. The jacket looks to subtly incorporate functionality in an elegant way. It moves away from the hyper militarized language of “techwear”, instead focusing on a uniquely elegant garment in which every feature has sprung from a clearly defined need.

This product succeeds in its use of technical fabrics. The textile that makes up the external shell of the jacket is a nylon ripstop with a waterproof membrane. It's rip and erosion resistant, making it suitable for those who carry backpacks and purses through their trips. Additionally, the membrane allows for harsher weather conditions.

The silhouette of the jacket looks to achieve an oversized, yet tailored feel. The wide sleeves with a shallow sleeve cap are made to accommodate thicker underlayers during the colder seasons while not restricting arm movement. Additionally, in warmer months, this same oversized feature allows for airflow within the garment.

There's a large hood on the jacket that serves a couple purposes. On women, it allows them to keep their hair tied or in braids while also having the hood up. It can also accommodate a beanie or a hat underneath it. Moreso, given how much city dwellers need to be in public spaces -transit, cafes, etc. - it allows for a certain sense of privacy and inwardness no matter where they exist.

In terms of features, the jacket has four external pockets. Two traditional, open pockets for keeping low-value things and also to let the hands rest. Behind these pockets are two hidden, zippered pockets that are sewn to the body of the garment that can accomodate small electronics like a smartphone, digital camera, or even a small e-reader. Along the sleeves, there are two channels that contain nylon webbing. When the user needs to take off the jacket, they can use the buckles at the end of the straps to secure the garment around their chest or their waist.

5. Residency Results

Through the course of this residency, PGZ had facilitated in exposing me to the production processes behind creating a collection. The company also advised and educated me on the initial steps to sourcing technical fabrics.

I was immensely supported creatively. Cozzoni had unwavering belief in my vision for this jacket. He facilitated its development and provided feedback that led to the project's growth. Additionally, spending time with my fellow residents at the facility allowed us to connect and share our thoughts and experiences in the design niches we occupied.

Sensorised twin-set for Sportswear

Bio-data monitoring system

STUDENT: Shan Lu
COMPANY: Pangaia Grado Zero, Italy
HEI: Politecnico di Milano, Milan, Italy

PHYSICAL PROTOTYPE

KEYWORDS
Biodata Monitoring System, Comfort, Washability, Sustainable Design, Sportwear

Abstract

The project is a Sensorised Twin-set for Sportswear including a bio-monitoring system for sportswear performances. The purpose of the project was to design a smart wearable sportswear for leisure-time outdoor athletes, such as cycling, long-distance running and other endurance sports and interval training, by monitoring and feeding back information on ECG and EEG during exercise. Collected data could help users to improve their fitness and optimise their sports performance. The project focuses on considering and implementing the needs for comfort, washability and durability of smart wearable sportswear, as well as the usability and stability of a biomonitoring system, and making them easy to disassemble, repair, replace and recycle parts and components with different programmed obsolescence timing, by applying sustainable design principles.

1. Introduction

Wearable technology and smart textiles cover a very wide range of applications. The main problem with smart wearable sportswear currently on the market is the inability to replace integrated sensors and circuitry after the garment has been damaged by washing or use. Also based on the needs for leisure-time outdoor athletes to design a sensorised Twin-set for Sportswear.

2. Residency Objectives

2.1. Sportive Environment of Use

Common outdoor endurance sports include long-distance running, trail running, cycling, hiking, etc. This project focuses on the design of smart wearable sportswear for leisure-time outdoor athletes in the main environmental conditions of these three sports: long-distance running, trail running, and biking. Basically, the main environmental conditions for these three outdoor sports can be divided into wet conditions (including rain, being in water, sweat), windy conditions and cold conditions.

Through the analysis of the sports environment, the most common sports injuries that occur during exercise are temperature loss and accidental injuries caused by energy exhaustion. Therefore, sportswear needs to be windproof and waterproof, and at the same time sweatproof and warm. It also needs to have enough space to provide athletes with the necessary equipment such as energy bars and drinks to prevent them from carrying, so the sportswear should be light enough not to bring extra weight.

2.2. Needs for Biological Data Gathering

The user needs can be divided into two aspects, one is how to protect them from injuries during exercise. The second is how to collect biological data to help them improve their physical performance and optimize sports performance.

2.2.1 ECG monitoring in the sports field

Electrocardiography (ECG) is an electrophysiological monitoring method to record electrical activity related to the cardiac contractions. Electrical activity at the heart level is measured and monitored during the exercise ECG.

HRV can be measured by using ECG. In the meanwhile, HRV measures autonomic nervious system (ANS) activity. This is the balance between the sympathetic (fight & flight) and parasympathetic (rest & digest) nervous systems.

As HRV reflects ANS function and thus stress, it is frequently used in the athletic world to identify periods of optimal training and to monitor recovery status and any potential over-training. Generally, an increase in HRV represents a positive adaptation or better recovery status while a reduction in HRV reflects stress and worse recovery status.

2.2.2. EEG monitoring in the sports field

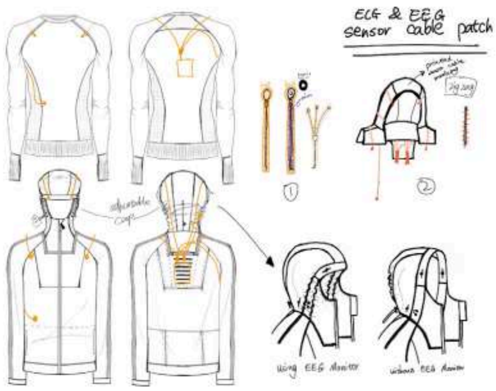
The electroencephalography (EEG) is a continuous recording of waves of various frequencies and amplitudes in the brain. Four dominant frequency ranges are typically observed: alpha (8-13Hz), beta (14-30Hz), delta (1-3 Hz) and theta (4-7Hz) however sport focuses on participants during a waking state so generally only alpha and beta waves are analyzed.

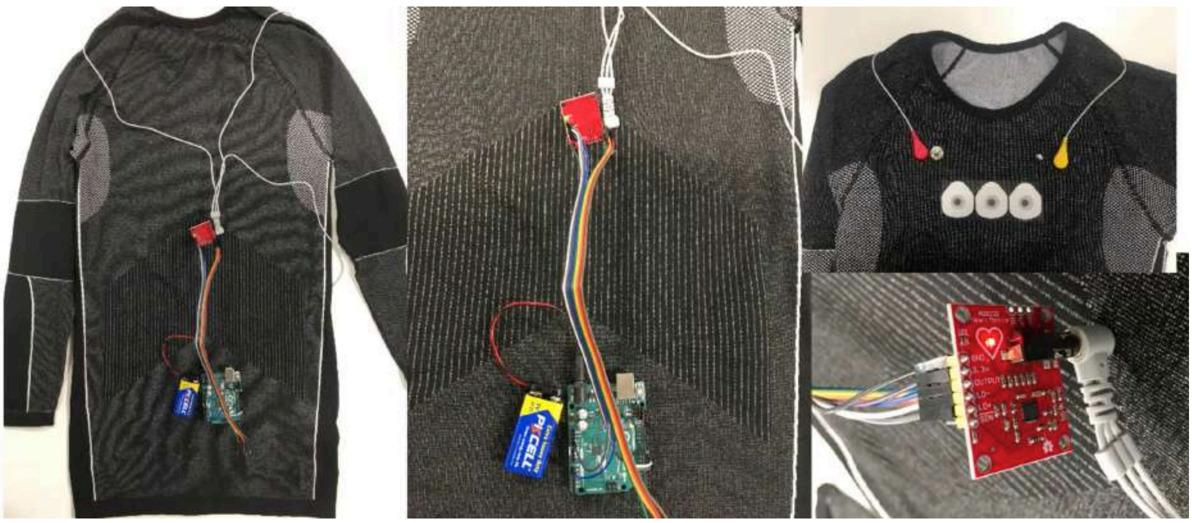
Research shows that when athletes reach fatigue with excessive exercise load, the EEG alpha wave will decrease and theta wave will increase, and the power of delta and theta wave will increase, while the power of alpha wave will decrease, which can help athletes choose the appropriate training load, speed up the athletes' mastery of motor skills and improve the training effect.

In addition, EEG can also determine sports brain injury. Studies have shown that in mild sports brain injury, the EEG waveform will change, with a significant decrease in alpha waves and a significant increase in theta and delta waves, and EEG can be used to detect the recovery of the brain, thus helping athletes to pause or change uncomfortable training patterns.

2.3. Bench Market Research

Market research has shown that most of the heart-rate measuring sportswear on the market use integrated electrodes and removable battery and chip cores. Before wearing them, the wearer must wet the electrodes in order for them to function as detectors. In order to ensure that the electrodes are attached to the wearer's skin, their sizes are designed to be very small and the fabrics used are extremely elastic, but there is still feedback from


ECG & EEG sensor cable patch

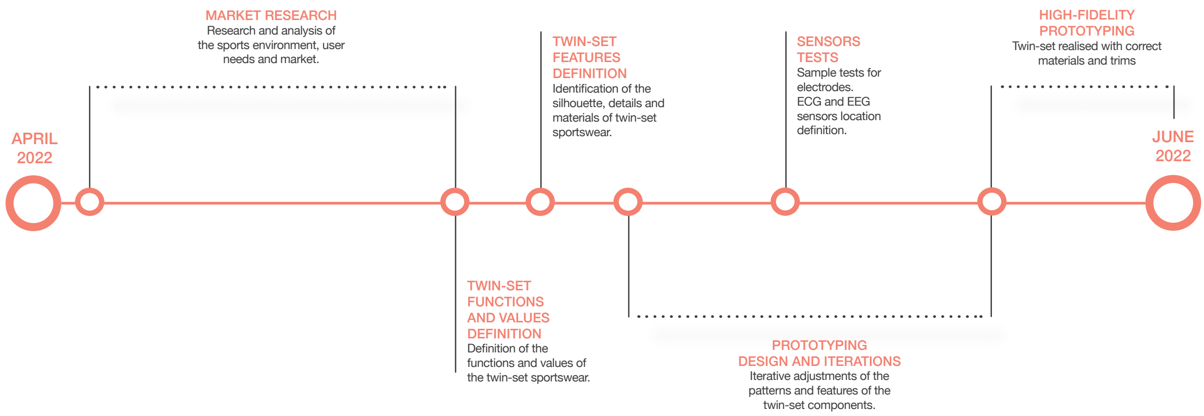


users that they are uncomfortable and inconvenient to wear. With the increase in the number of uses and cleaning, the integrated sensing circuit is easily broken and damaged and cannot be repaired, which makes the user have to throw away the product to buy again, greatly increasing the user's cost of use.

2.4. Functionalities and Add Values

Through research and analysis of the movement environment, user needs and market, the twin-set sportswear needs to cover the following functions and values:

1. Windproof, waterproof and moisture wicking, with warmth and lightness
2. Comfortable to wear, not to obstruct the movement of limbs during exercise
3. Comfortable and reasonable storage space can be placed in some equipment or food needed for sports.
4. User-friendly assembly and disassembly of the biodata gathering and monitoring system, reducing the learning cost of the wearer.
5. Effective biological data gathering.
6. Long service life of garments as well as electronic components or easy to replace with new electronic components.



3. Residency Activities

3.1. Design Process

The design process on the one hand takes into account the washability, user-friendliness, modularity, and durability of the garment. On the other hand, it's important to consider how to optimize the path of the sensor cables, how to make the electrodes tightly attached to the human skin, and how to make these details more aesthetic. The details are designed to ensure the washability and comfort of the garment while solving the problem of smart wearable sportswear currently on the market: integrated sensors and circuitry that cannot be replaced after the garment is damaged by washing or use.

As the sensor is placed on an active, moving person, care must be taken to ensure the sensor always remains in the same location on the body. In addition, the wearable must be designed such that the sensor can capture its data without interference from the wearer's movement or environment.

For the main material of the twin-set sportswear, I chose a ultra-lightweight and durable ripstop fabric laminated with membrane. Waterproof and windproof while still being breathable and water-balanced to keep the wearer warm and dry. The membrane offers breathable, waterproof and windproof properties. It prevents large water droplets from passing through the fabric of garments, keeping wearer warm and dry. Tightly-woven fibers and small pore size restrict airflow through material to provide windproof, protecting wearer from the elements, and I also chose a tightly woven fabric containing reflective fibers while laminated with a waterproof and breathable membrane. It is thick, rigid with a strong sense of surface texture.

3.2. Prototype Phase

First of all, I confirmed the dimensions of the male mannequin with the size 175/92A, and made the 1:5 scale paper pattern for the selected mannequin, and then drew the 1:1 paper pattern after confirming the measurement and drawing the paper pattern. While making the first version of the sample, the 1:5 paper pattern was scanned and converted into an .ai file by Illustrator and imported into CLO3D as digital pattern. After suggesting modifications and considerations to the first prototype, the digital model was modified and adjusted in the CLO3D to simulate the digital effect of the garment on the human body and to improve the details of each part of the garment such as lining, facing and pocket. Then I print the second version of the patterns and make the prototype, and improve the details of the process based on it. At the end, I used the correct fabric to make the sample.

4. Project Description

The main problem with smart wearable sportswear currently on the market is that the integrated sensors and circuitry cannot be replaced after the garment has been damaged by washing or use. Consumers have only the option to repurchase the garment after the integrated sensors and circuits are damaged, which invariably results in waste. Therefore, this project focuses on the implementation of removable pre-assembled battery and chip core, sensor cable patch make the sportswear easy to wash and will not cause damage to the smart system components and replaceable sensor cable patch with clearly marked guide users to connect the corresponding electrodes, which reduces user learning costs. At the same time, it is convenient to replace and renew the sensor cable when it is damaged, and also convenient to recycle the electronic components.

5. Residency Results

In the meantime, the data collection of ECG and EEG bio-monitoring systems can better protect athletes from injuries during sports, and also help them improve physical performance and optimize sports performance. With the following technology enhancement of this bio-monitoring system, it provides more possibilities for the development of subsequent smart bio-monitoring garments.

Eirène

Omnichannel Customer Journey for Mass Market brands targeting Gen-Z users

STUDENT: Chiara Ancesci
COMPANY: Stentle (M-Cube Digital), Italy
HEI: Politecnico di Milano, Milan, Italy

UX AND UI PROTOTYPE

KEYWORDS
GenZ, Body Dysmorphia, Mental Wellbeing
Omnichannel Retailing, Data Ethics, Experience Design

Abstract

Eirene is an omnichannel Customer Journey designed for GenZ targets diagnosed with depression and/or anxiety and/or body dysmorphia aimed at guaranteeing a safe and respectful in-Store experience. The aim of the project is to maximize the comfort of the customers while increasing the conversion rate and the total sales of the store. The Empirical Research was firstly aimed at observing Stentle/M-Cube activities and interactions with clients, diving into the contemporary panorama of the phygital offers on the market. In the meantime, a theoretical research was carried out on psychiatry studies regarding correlations between visual imagery and mental Illnesses, or associations between images posted on social medias and users' diagnoses. Once research foundations were built, a survey was formulated and delivered to 30 users. To communicate the project idea, a video regarding omnichannel experiences was designed and realised for Stentle - M-Cube sales department. The residency results in the prototyping of the Eiréne experience, tested live by 20 test users in M-Cube Demo Area.

1. Introduction

When innovative, Omnichannel Customer Experiences are to be designed, a main driving factor is the target group that may be addresses by the strategy. In this case, the chosen target group had characteristics that became central and preponderant in shaping the whole project.
Generation Z, in fact, makes up to 32% of the global population, and it is predicted that it will have a major impact on the future global market. The so called "Zoomers", however, present a whole different approach to reality than their precedent generations.
On the one hand these tech-natives are ever-surrounded and used to limitless information on the tip of their fingers, moreover, their constant filter-less sharing on platforms such as TikTok has led to a generalized boundaries-breaking regarding delicate matters such as gender, sexuality, spirituality and mental health. On the other hand, in fact, studies prior to Covid-19 have shown a higher disposition toward disorders such as Depression (58% of GenZ

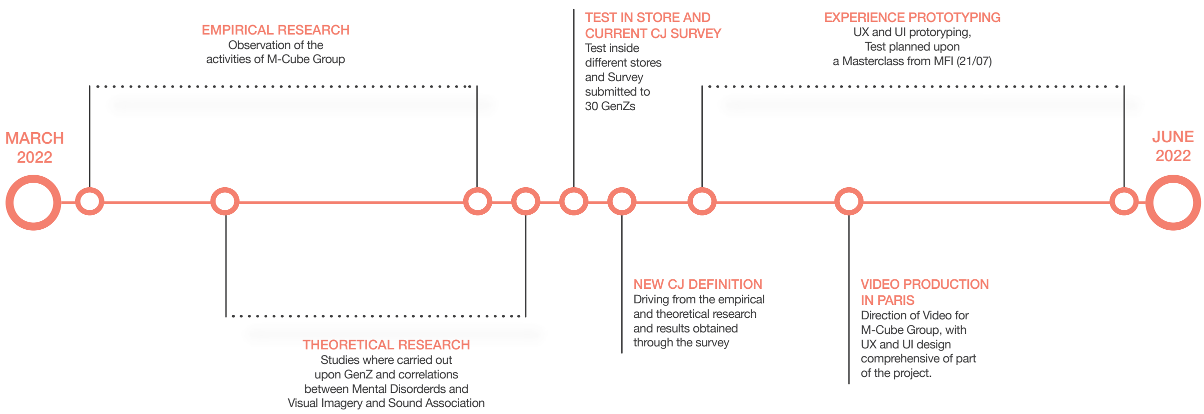
globally) , Anxiety (91% of GenZ globally) and others. After the Pandermic, the data only got even more disturbing, with around a 30% rase of cases on Depression and Anxiety between Zoomers .
Being Retail a Space of interaction built around the consumer, these issues must be taken into consideration, exploiting the plethora of possibilities offered by the Omnichannel knowledge of the customer to create a safe environment.

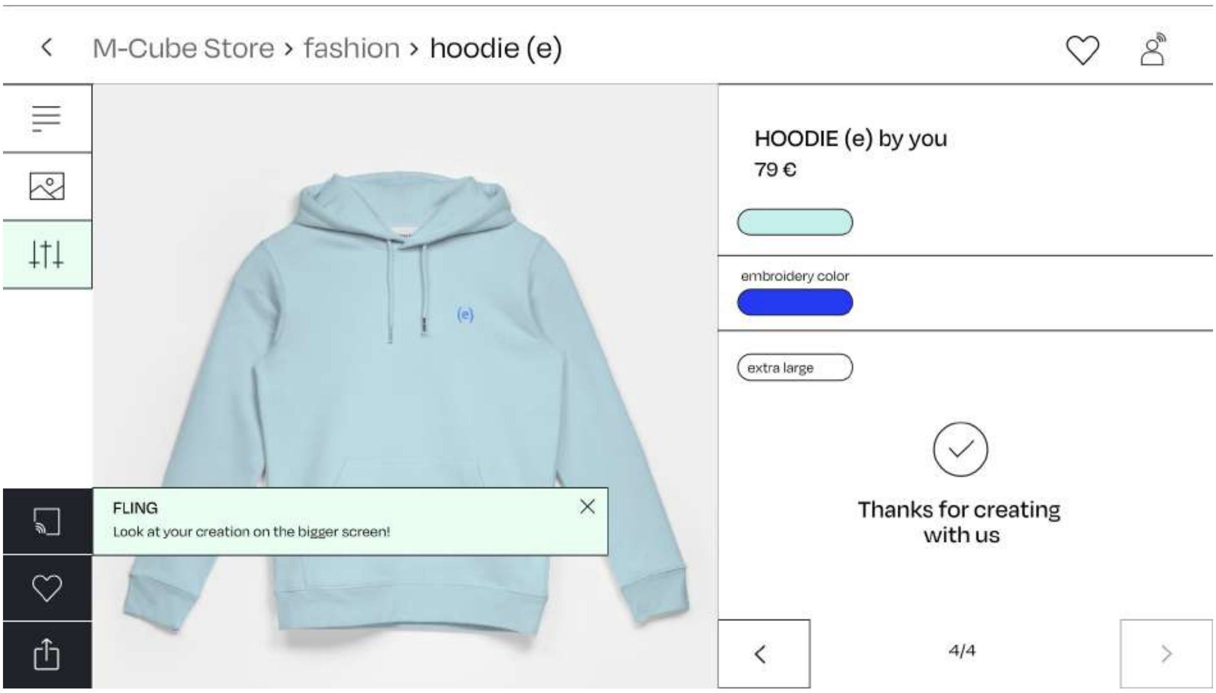
2. Residency Objectives

The Objective of the Residency Project was to design an Omnichannel Customer Journey for Gen Z targets affected by Depression, Anxiety or Body Dysmorphia. To achieve this, the starting point was the research, which was carried on both on an Empirical level and on a Theoretical one.
Once built a founding base with the research, a survey was carried, while a Video for M-Cube Sales Department regarding Omnichannel Experiences was designed. The end result was the prototyping of the Eiréne Experience, tested live by about 20 test users in M-Cube Demo Area.

2.1. Empirical Research

The Empirical Research was firstly aimed at observing M-Cube Activities and interactions with clients, diving into the contemporary panorama of the Phygital Offers on the Market. A thorough analysis of Competitors and their innovations resulted in being fundamental for re-shaping the initial concept of Eiréne in a realistic, feasibile yet innovative framework. Moreover, the participation to the creation of four Videos for the Sales Department of M-Cube regarding new Omnichannel Innovations, was key to gain a crystal overview of the possibilities of the group, not to mention learning to map and shape customer journeys in every detail, from the general view to the details of the UX and UI prototypes.
Finally, the interaction between the different departments present in M-Cube, especially the Sound Design one, allowed to complete the sensorial experience to be designed.

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Look at your creation on the bigger screen!
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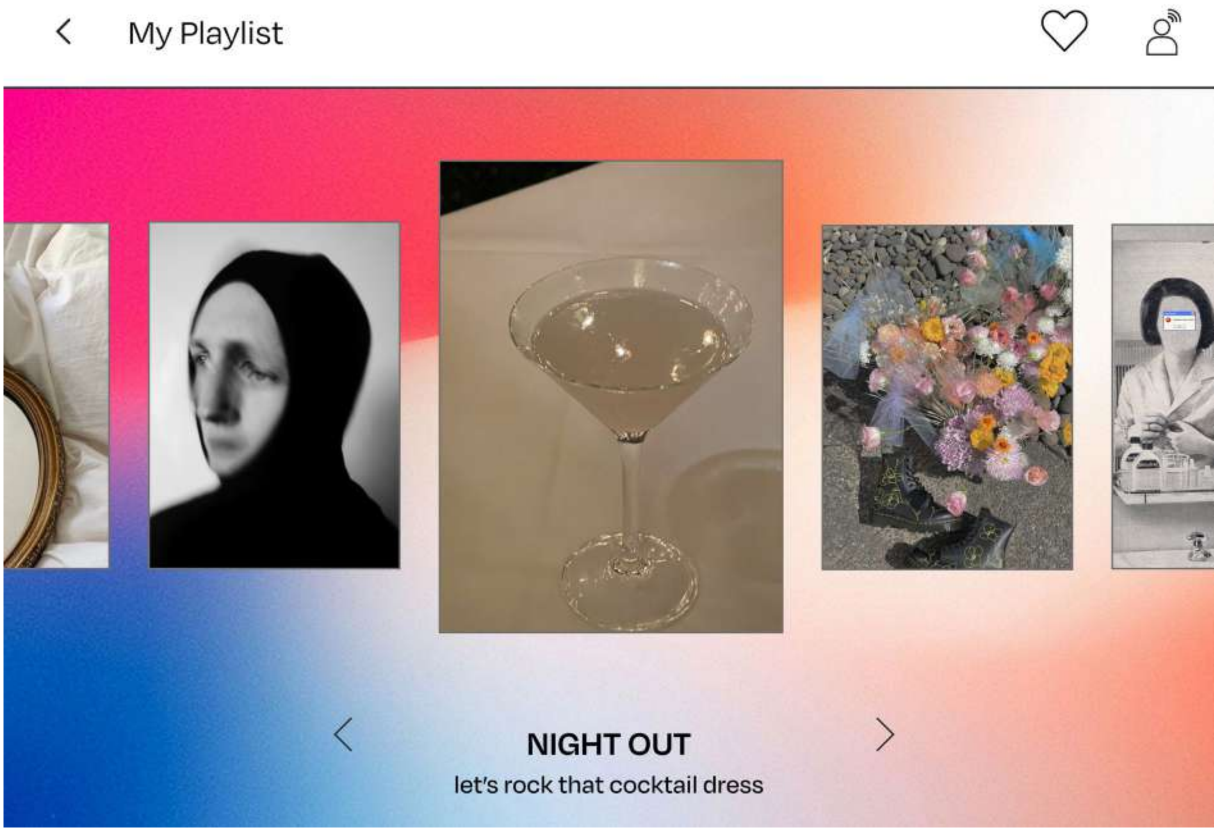
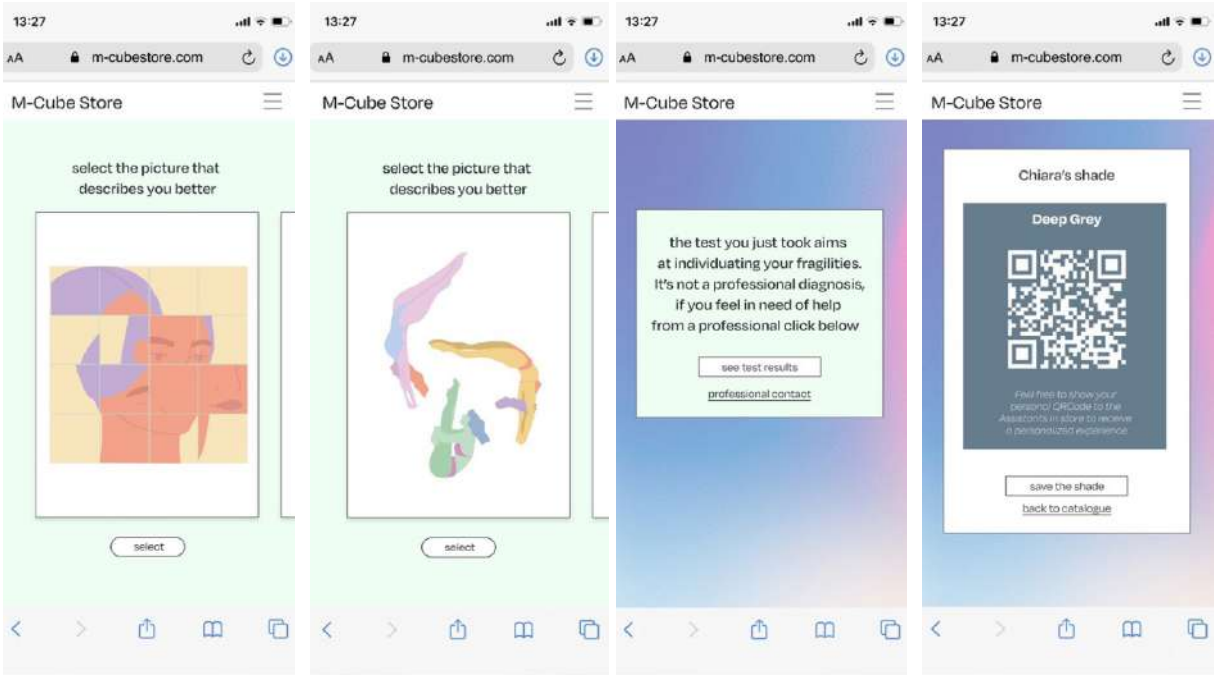

My Playlist
NIGHT OUT
let's rock that cocktail dress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2.2. Theoretical Research

In the meantime a Theoretical Research was carried out upon Psychiatry studies regarding correlations between Visual Imagery and Mental Illnesses Diagnosis, or associations between images posted on Social Medias and Diagnosis of the User. Also other studies regarding Sound Therapy experimentation were analyzed.
Moreover, a survey was carried in a pool of 30 users in the Z age range, to help shape the perceptions of the current Customer Journey inside Mass Market Stores.

2.3. Prototyping and Testing

Taking into consideration all the above, Eirène was designed, prototyped and tested by about 20 Gen Z Test Users.

3. Project Description

Eiréne is an Omnichannel Customer Journey for Mass Market brands targeting Generation Z users affected by Depression, Anxiety and Body dysmorphia, ensuring that all the phases of the experience are customized around the needs of the customer. The first touchpoint will be the Website/App of the brand, where the user will be asked by a pop-up whether he'd like to take a personality test to personalize his experience. One entered the test he will be faced with seven levels, each comprehensive of three illustrations to choose between based on resonance with oneself. The result will be a shade of RGB colour, calculated translating the obtained percentages respectively of Anxiety in R, Depression in G and Body Dysmorphia in B level. Upon the personal colour shade, there will be a QR code, with the possibility to save the result and show it later to the Sales Assistant once in the shop. All the real percentages obtained by the test, in fact, will not be displayed to the user, since it would risking a triggering effect.
Only if he will be willing to display his QR code to the Assistant, the ladder will eventually have the possibility to access to the percentages obtained by the user. These results are not to be taken as a definitive diagnosis, but rather as a guideline on how to approach the customer. The Sales, inside the Clienteling App, will in fact be disposed not only with these percentages, but also with products that were related by the brand to categories determined by rough percentages, that might appeal to the customer. Moreover, the Clienteling App already disposes a set of information about the
customer, such as recently liked products, saved carts, wishlists, past orders and reservations.
Inside the Store the user will have the chance to save products on his Fitting Room List through to the Digital Extender, which is part of the M-Cube offer, by scanning the QR codes of the products.
Once chosen all the desired products he will be able to book a Fitting Room directly from the Website/App. A Sales assistant, after receiving the Fitting Room Booking request on the Clienteling App, will prepare the room with the required items and notify the customer when ready.
Inside the Fitting Room the user will find a tablet, where he will find a set of playlists selected for him based on his percentages, apart from being able to request different sizes and variants of the products directly from the changing room.
The journey ends with one of the various Smart Payment options available in the M-Cube plan, comprehensive of Smart Pos, Pay by Link and Payment through QR Code.

4.Residency Results

The Residency was fundamental steep the Eirène project into the truth of the Omnichannel Retail landscape. Diving into the expertise of M-Cube, spanning from Digital Signage to Sound Design, to Omnichannel Customer Journey Design, helped me gaining a realistic vision regarding the feasibilities and requirements of the market. At the same time, it widened the horizons allowing a comprehensive approach through the use of Sound and Visual Design.

The end result was a valid Customer Journey for Mass Market Brands, carried out with solid research both on a theoretical level and on an empirical one, ensuring a professional output comprehensive of the trending needs of a Generation that already has, and will have even more in the future, a great influence on the market.

Optimising Impacts

BYBORRE's online platform CreateTM

STUDENT: Eva Feld
COMPANY: Byborre, The Netherlands
HEI: University of the Arts London, London College of Fashion, London, UK

UX AND UI PROTOTYPE

KEYWORDS
Service Design, Ecological Footprint, Grounded Theory, Action Research, Material Sustainability

Abstract

Create TM, from the textile manufacturer BYBORRE, is a textile design platform aimed to educate the user in an engaging, informative, and playful way to encourage better, less impactful choices. The research purpose was to investigate how and where impact data results could be implemented on CreateTM platform in a thought-provoking, motivating, and informative way, leading to users conscious decision-making. Impact data encompasses the data related to the company's ecological footprint. A systemic design framework was used for data collection and analysis for this cross-sectional grounded theory and action research. During the residency, the student developed a body of research compiling resources and tools to visually communicate complex impact data in a tangible form and acquired a new skill-set concerning the creation of interactive prototypes and presentations. The quality of the research was assessed against process, invention, extensibility, and relevance. The result of this research is relevant for every stakeholder involved in the textile industry thinking of ways to implement impact data in supply chain processes and it should be understood to drive change towards an educated use of materials in every industry that uses textile.

1. Introduction

Driven by the question of how to make impact data more tangible, BYBORRE, an innovative textile manufacturer with ambitions to reduce their global impact, asked for research support addressing this aspect to improve their newly launched textile design platform CreateTM (https://byborre.com/). The purpose being to educate the user in an engaging, informative, and playful way to encourage better, less impactful choices.

I joined the sustainability department, called the Impact Team, to help accelerate BYORRE's actions towards enhancing their positive impact, aiming to educate a new generation of creatives and to 'lead the responsibility movement' (BYBORRE, 2022).

The Residency project was undertaken as a hybrid-model over four weeks of which two weeks took place in person at the company's headquarters in Amsterdam, the Netherlands, followed by two weeks remote collaboration with online meetings twice a week.

2. Residency Objectives

2.1. Aim

The research purpose was to investigate how and where impact data results could be implemented on the CreateTM platform in a thought-provoking, motivating, and informative way, leading to conscious decision-making. Three subordinate objectives were defined to address the different aspects and the complexity of the research question.

2.2. Objectives

In the first instance the study compiles suggestions for the impact data to be communicated to educate the user of CreateTM.Secondly, it investigates ways to engage the user during the selection of the textile and tests the application's feasibility in the company context through creating a prototype. Finally, the study collects, assesses, and analyses the data and the feedback received.

2.3. Methods

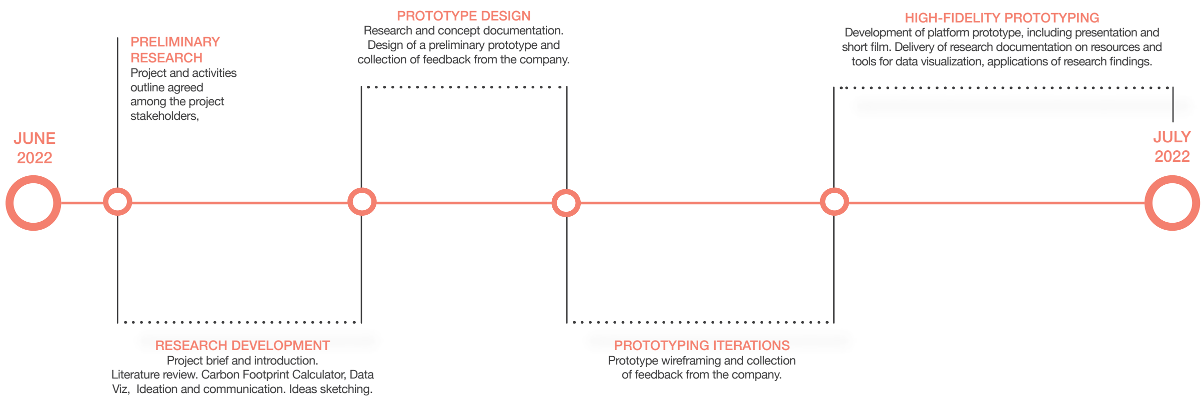
The research design chosen is a cross-sectional grounded theory and action research utilising a positivist, deductive and mixed methods approach.

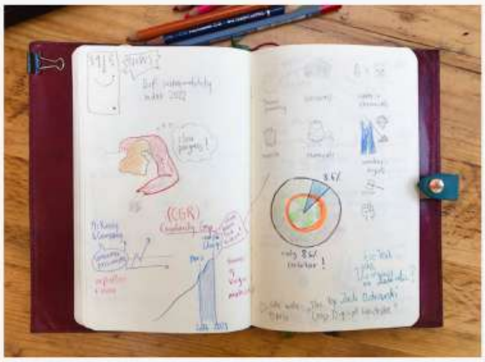
To meet the objectives within the context of a progressive, sustainable, and responsible business environment, and taking my role as a researcher and designer into account, a systemic design framework - Beyond Net Zero: A Systemic Design Approach (Design Council, 2021) was used as a tool for data collection and analysis.

Moreover, for research quality assessment, Zimmerman's (et al, 2007) quality assessment method was adopted utilising the pillars of process, invention, relevance, and extensibility.

Secondary research comprised carbon footprint services, data visualisation, data equivalences, prototyping interactivity, and simple animation.

Overlapping and interdependent with the secondary research phase, primary research included wireframing, sketching, testing ideas through conversation and presentation, visiting BYBORRE's Window of Textile OpportunitiesTM, their textile showroom (WoToTM) and exploring the software CreateTM. Brief informal and communal coffee breaks, proactive visits to other teams, introducing myself and my task and opening conversations, played an important role for obtaining a broader understanding of the context of





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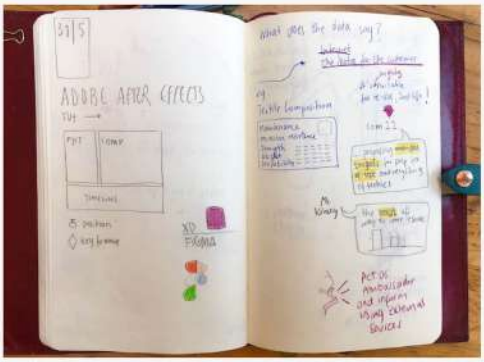

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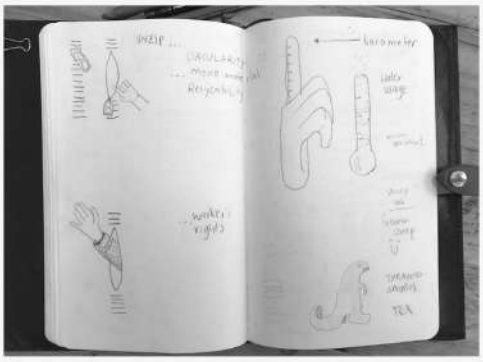

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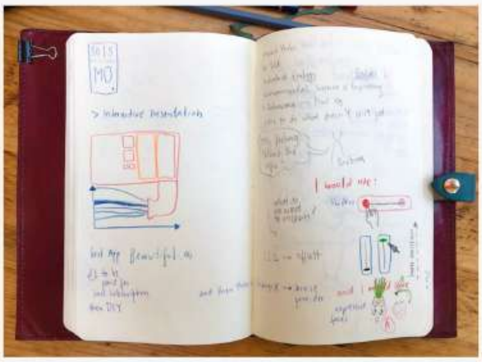

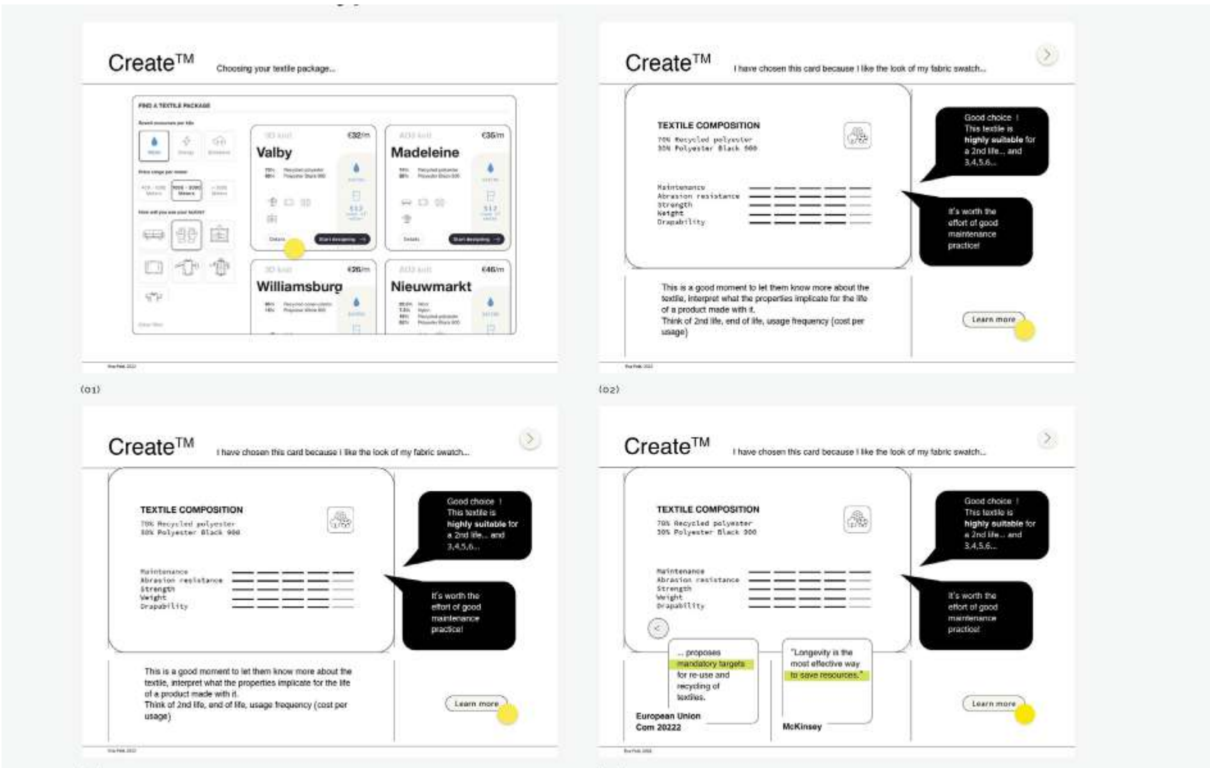

CreateTM
Choosing your textile package...
Valby
Madeleine
Williamsburg
Nieuwmarkt
(01)
CreateTM
I have chosen this card because I like the look of my fabric swatch...
TEXTILE COMPOSITION
Good choice ! This textile is highly suitable for a 2nd life... and 3,4,5,6...
It's worth the effort of good maintenance practice!
This is a good moment to let them know more about the textile, interpret what the properties implicate for the life of a product made with it. Think of 2nd life, end of life, usage frequency (cost per usage)
Learn more
(02)
CreateTM
I have chosen this card because I like the look of my fabric swatch...
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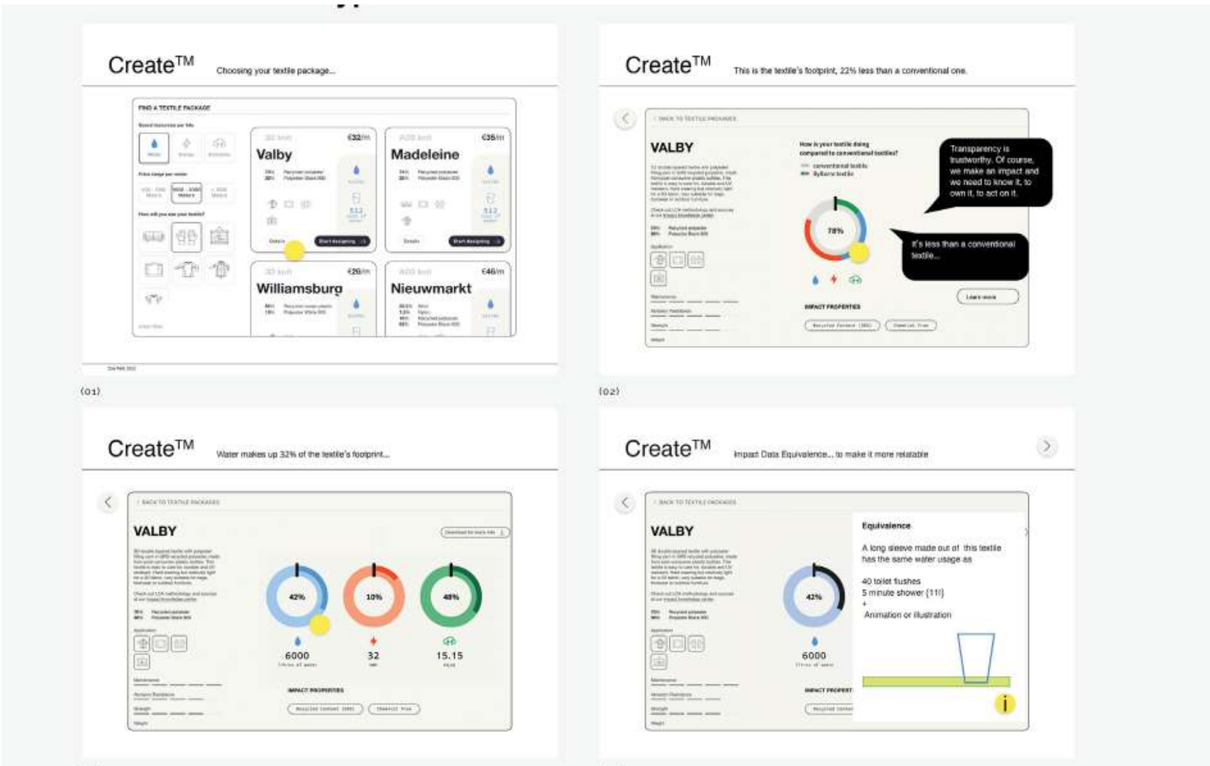
I have chosen this card because I like the look of my fabric swatch...
TEXTILE COMPOSITION
Good choice ! This textile is highly suitable for a 2nd life... and 3,4,5,6...
It's worth the effort of good maintenance practice!
... proposes mandatory targets for re-use and recycling of textiles.
European Union Com 20222
"Longevity is the most effective way to save resources."
McKinsey
Learn more



CreateTM
Choosing your textile package...
Valby
Madeleine
Williamsburg
Nieuwmarkt
(01)
CreateTM
This is the textile's footprint, 22% less than a conventional one.
VALBY
Transparency is trustworthy. Of course, we make an impact and we need to know it, to own it, to act on it.
It's less than a conventional textile...
78%
Learn more
(02)
CreateTM
Water makes up 32% of the textile's footprint...
VALBY
42%
10%
48%
6000
32
15.15
CreateTM
Impact Data Equivalence... to make it more relatable
VALBY
Equivalence
A long sleeve made out of this textile has the same water usage as
40 toilet flushes
5 minute shower [11]
Animation or Illustration
42%
6000

the task and in establishing connections and relationships. For instance, by visiting the knit lab, BYBORRE's on-site textile sampling facility, I gained a more profound understanding of what was simulated in CreateTM. The timeline of the project was planned using the online collaborative whiteboard platform Miro, the process was recorded using a shared Google Docs document and personal notes, nascent ideas, experimentations, and feedback were recorded in a sketchbook individually. After an initial introductory tour of the company, gateways were arranged twice a week for the impact team to check in with one another on progress, thoughts and to collect feedback.

3. Residency Activities

3.1. Resources and Facilities

I had access to a dynamic showroom space called the Window of Textile Opportunities and to BYBORRE's Knit Lab Atelier with a range of circular knitting machines and an extensive yarn library. The yarns on their cones, ready to be changed evoke a vibrant atmosphere. BYBORRE's textiles are known for their 3-dimensional optic and versatility. Understanding how the software CreateTM relates to the textile production was vital for being able to consider the wider context to make informed suggestions of how and where to implement impact data best. Using a sketchbook for ideation, communication and note taking in meetings was useful to allow spontaneity, flexibility and expressing the connectivity of thoughts. During phases of individual, independent work, it was the primary tool used to capture the essence of research findings and planning the prototype.

3.2. Conclusions

Proposing to integrate an interpretation of the impact data, not only meets objective one, to educate the user of CreateTM, but underpins BYBORRE's role within the industry context as a driving force in their stated mission of "educating a whole new generation of designers". Serving the second objective to test an increase of engagement, using the created prototype, the study established that introducing coloured visuals, interactivity and animations resulted in positive feedback of stakeholders in the company.

Thirdly, drawing on evaluating the outcome and stepping back to see how the task sits in the wider picture of ways to use and communicate the impact data, this research can be utilised as a piece of learning in the impact team's continuing task.

Further, perceiving this work as a foundation stone, more iterations can be designed to fulfil the purposes of educating, enabling, and playing on CreateTM as well as in internal and external communication. (WoToTM, the website, social media).

4. Project Description

4.1. Reflections on Originality, Innovation and Relevance

Implementing impact data information and education in a creation software is unprecedented to my knowledge and secures BYBORRE's claim to be an innovative force in fashion to drive positive change and presents a welcomed original challenge.

The objectives are largely achieved, within the project's timeframe and limitations. I identified propositions for each defined objective, such as providing interpretations for educating the user and visualisations to engage them. To consolidate conducting research into a broad range of topics within the timeframe, I concentrated on resources that are informative, fun, and visually attractive meeting BYBORRE's aesthetics. However, due to the limited availability of time, I have not been able to explore the implications of my suggestions in sufficient detail to gain deeper insights. Furthermore, I could not find data equivalences that are fun, memorable and, moreover, relatable. I encountered difficulties in creating custom animations for BYBORRE and to find accurate, representative ones in Lottie's resource library (Lottie.com, used as Adobe XD plugin) turned out to be disproportionately time consuming. In addition, I was hoping to find a simple way, an app or software, that could interactively visualise interconnected data, but I failed in finding one. Yet, I found several commercial service providers who deliver on this demand.

4.2. Limitations

Scope: The small sample size of the feedback collected, and the time spent on each inquiry affected the depth of the outcome and proof of validity.

4.3. Evaluation

For me, an outstanding, unexpected, and innovative aspect is that BYBORRE considers how and where they can communicate the actual impact of the textile created, manufactured, and sold. It was neither part of the task, nor a defined objective, but it surfaced whilst working on it. Potentially, this aspect empowers the user to act upon the footprint they create. In conclusion, assessing the quality of the research against relevance, process, invention, and extensibility, as explored above, it resulted in a comprehensible foundation with the potential to set change in motion. This work should be understood "as an element among different activities (from design to policy to culture change) pushing towards a more regenerative future." (Design Council, 2021).

5. Residency Results

Resulting from this residency is a body of research compiling resources and tools to visually communicate complex impact data in a tangible form, their analysis, further reflection, and feedback. The outcome is captured in an interactive presentation, testing the proposed improvements to CreateTM: Prototype (adobe.com)
The research delivers a fresh perspective on the role that BYBORRE plays within the industry context as a committed ambassador to promote more conscious and sustainable choices and generates ideas of approaches that can be taken to support this path. Another learning experience I took away from the residency is the acquisition of a new skillset: creating interactive prototypes and presentations using Adobe XD. I took the initiative and made the decision that I could communicate and test the propositions best based on an interactive prototype. At first, I was unsure if the hours I dedicated to the autodidactic learning would pay off and were justified in relation to the project scope. Drawing on my knowledge of similar Adobe software such as Illustrator and InDesign, I advanced quicker than estimated, which raised my confidence of having made the right choice. The feedback I was given after my concluding presentation at the end of the residency affirmed the efficacy of the medium I chose, and my efforts were well received and appreciated.

A multipurpose Parka

Modular design and system for disassembly

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COMPANY: Pangaia Grado Zero, Italy
HEI: University of the Arts London, London College of Fashion, London, UK

VIRTUAL PROTOTYPE

KEYWORDS
Modular Design, Circular Economy, Desgin for Disassembly, Digital Garment Prototyping, Multi-purpose

Abstract

This project investigates the innovative application of a modular design approach to the multi-purpose jacket parka, exploring how easy disassembly and design recyclability can be achieved while ensuring the performance of the garment, thus responding to the challenges of developing a circular economy in the fashion industry. Two methods of observation and analysis were used to examine the structural characteristics of the commercially available multi-purpose parka, followed by field observations to document the environment in which the product is used and the lifestyles of the target users. Three main design methods were used: modular design, design for disassembly, and digital garment prototyping. The results of this research could help guiding designers to think of innovative ways to recycle garments and offer potential buy-back solutions from the consumer's perspective.

1. Introduction

The topic of sustainability has gained widespread attention as environmental problems caused by industrial production and energy use have become more prominent. Recycling is a global issue in the manufacturing industry that deserves long-term attention but has not yet been addressed (Rosen & Kishawy, 2012). To translate the promise of a circular economy into action, McDonough and Braungart (2002) propose the principle of disassembly design, which helps to easily deconstruct products at the end of their life cycle in order to recycle components and materials. Changing the way materials are joined and the way they are layered makes them usable, reversible and robust. Current corporate expectations for recyclability in design are mainly achieved by maximizing the use of a single material or increasing the recyclable content of materials while minimizing the use of auxiliary materials and fasteners (Interreg, N. & Fibersort, 2018), and designers need to consider incorporating sustainability at an early stage of product design, integrating sustainability with design and manufacturing (Rosen & Kishawy, 2012).

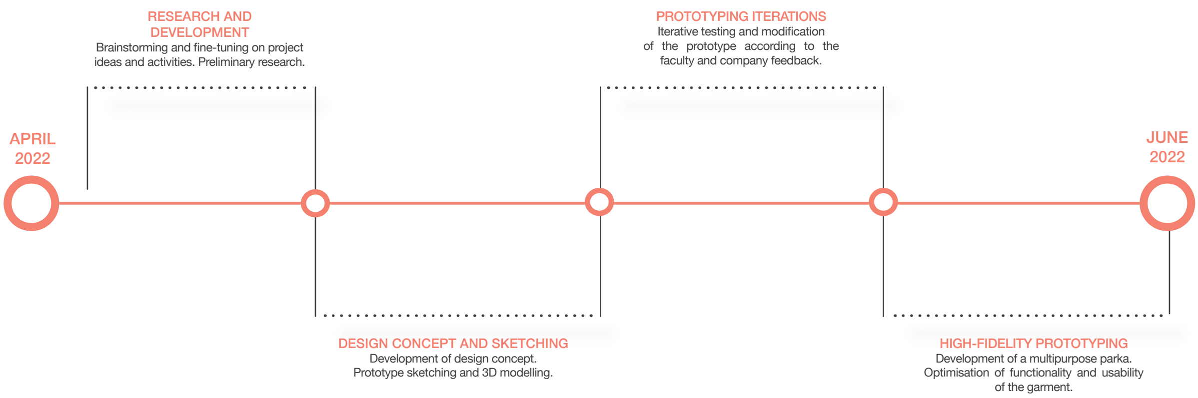
Barriers such as the complexity of the disassembly process and the lack of innovative recycling technologies currently faced by the fashion industry (Riemens, et al., 2021) hinder the sustainable development of the circular economy. In the case of functional clothing, for example, the complexity of the garment structure makes disassembly more difficult. Firstly, functional garments produced by traditional processes are difficult to disassemble due to issues such as material diversity and cross-contamination (Jin Gam et al., 2011). Although the use of a mono-material can solve some of the problems posed by blended materials (Jin Gam et al., 2011), the scope of application of a mono-material is limited. The properties of a single fibre often don't meet the needs of a multipurpose garment, so the use of blended fabrics in the production of this type of garment is inevitable (Forst, 2019).
Based on an analysis of current sustainability trends and the current state of the fashion industry, as well as the urgent need to develop a circular economy, the industry is prompted to seek faster and smarter ways of innovative disassembly. Current digitally enhanced technologies in the fashion industry create opportunities for innovative textile recycling systems (Sandvik & Stubbs, 2019), such as 3D printing and on-demand and real-time production technologies (Moorhouse & Moorhouse, 2017); secondly, product design should incorporate embedded design and the use of smart materials to enable active dismantling (Jovane et al., 1993). Linking disassembly design through digital platforms is expected to have a significant impact on consumers and supply chains (Schwab, 2017).

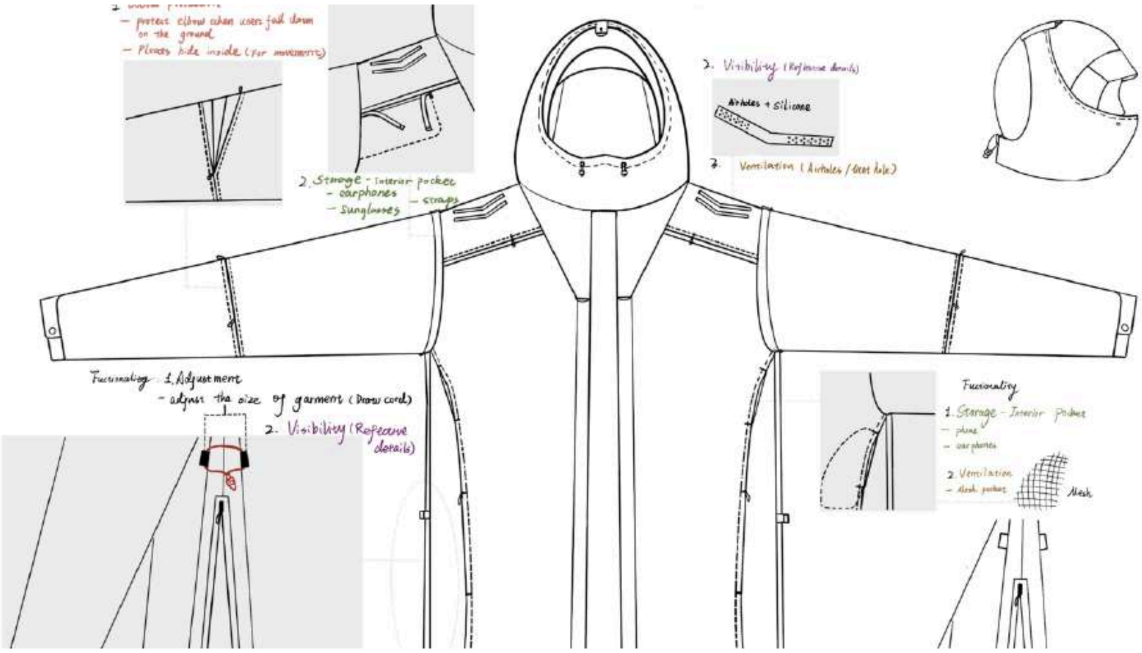
2. Residency Objectives

The researcher engaged in the residency activities for four weeks and focused on the following: conceptual design of modular functional garments and accessories, sketching, digital modelingas well as experimentation and evaluation.

2.1. A purely digital prototype

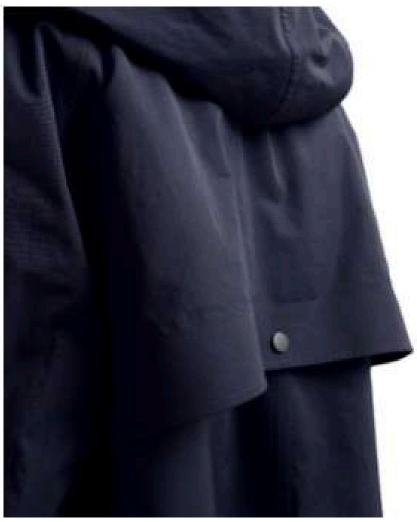
The silhouette and structure of the digital garment prototype need to clearly demonstrate the functional details.




- protect elbow when users fall down on the ground
- Pleats hide inside (for movements)
2. Storage - Interior pocket
- earphones
- sunglasses
- straps
2. Visibility (Reflective details)
Airholes + silicone
3. Ventilation (Airholes / heat hole)
Functionality 1. Adjustment
- adjust the size of garment (Draw cord)
2. Visibility (Reflective details)
Functionality
1. Storage - Interior pocket
- phone
- earphones
2. Ventilation
- Mesh pocket
Mesh







2.1.1. Conceptual design of modular functional garments and accessories

The design concept focuses on multi-purpose, redesign, usability, modularity, easily disassembling.

2.1.2. Sketch and digital modeling creation

The design of garment components and the matching of hardware needs to reflect the design concept of modularity and simplified disassembly.

2.1.3. Test and evaluation

The researcher conducted experiments in tailoring, simple paper pattern making and the functional feasibility of accessories to confirm the details of the product.

3. Residency Activities

The researcher used the learning resources provided by Pangaia Grado Zero: equipment and raw materials for garment production, computers equipped with relevant virtual garment production software, and Adobe and other commonly used office and design software. Due to the late start of the internship, the researcher had to familiarise herself with the product concept and rethink its design in a short period of time. The Pangaia Grado Zero supervisor had a lot of experience in functional and practical research on clothing and ergonomics. During the residency, he advised the researcher on brand research, functional design of garments and guided the development of the researcher's design concept, helping the researcher to adapt to the conditions of the residency as quickly as possible. The researcher also received valuable advice and feedback from the supervisor from the HEI and research funding support from the HEI during the residency.

4. Project Description

This project developed a design concept combining modular design and easy disassembly, based on the Parka model, a celebratory product jacket for Pangaia's iconic model 'Absolute Frontiers' (Fig.26). Putting the focus on usability in urban environments and commuters' lifestyles, the garment design was considered from a multi-purpose perspective. The Parka was set up to be used in three environments - rain, shine, and windy days - and two use scenarios - cycling and walking - respectively. Versatility and modularity are the highlights of the garment, with the Parka featuring Ventilation (thermal management, Visibility (reflective details), Storage, Movement, Adjustment, Anti-slip and more. For example, most commuters usually carry a backpack or handbag, which tends to move backwards and forwards due to the inertia created by human movement (walking or running). The researcher designed a structure in the jacket to prevent the shoulder straps of the backpack from sliding.

4.1. Research methods

The research methods used in this project were Field observationand Market Observation. Firstly, the researcher considers urban commuters as design objects and users and through field observations investigate their daily needs. There were three main aims:

- To record the behavior of users (commuters)
- To record the location/time/season/ commuters belongings.
- To observe what they usually wear

Secondly, the researcher analyzed the market for functional outdoor clothing and its features through online research, as well as studying the fabrics and Parka structures often used to make the jackets. The emphasis was placed on the usability of the garments in the chosen environment (rain, sun, wind) and the corresponding conditions of use (cycling and walking). The following objects have been selected for analysis: Multi-functional parka, Raincoat, Urban jacket for cycling, and Everyday-wear jacket.

4.2. Design Methodology

The modular system of the Parka is characterized by the ability to disassemble and reassemble components. The garment consists of five main modules: hood, sleeves, middle replacement component, side replacement component and vest. Each module can be interchanged for other styles and colors. The researcher has taken into account the compatibility of materials, the way the components are connected and the structure of the components in the design process. In this project, the customer will have ownership of the Parka. They can take it apart and exchange the components to create a new look. Each modular piece can be exchanged for another modular piece the following season, becoming a buy-back offer where the detachable vestcan be used as part of the Parka or assembled into a daily-use bag. For consumers, consumer products with ease of use and low cost of ownership are more likely to engage consumers in circular design, functionality and unique products that evoke consumer interest (Gomes, 2022). The study attempts to explore the simplification of the external construction lines and maintaining the garment's functionality: the Parka has a streamlined shape and offers excellent visual comfort. The researchers have translated the external pockets of the Pangaia garment model from into the internal structure of the garment. This approach simplifies the external structure of the garment while increasing the usefulness of the pockets: in addition to their regular storage function, they also have a thermal management function. All hardware for the entire garment (zipper, cord & cord end, stopper, button, eyelet) is made using thermal welding materials through 3D printing technology and some of the hardware, such as the zip and eyelet, can be printed directly onto the fabric. At the end of their life cycle, the hardware can be melted down and remolded into 3D filaments.

5. Residency Results

The residency result is a purely digital prototype that combines fashion and technology showing in detail the functions and usage scenarios of each design, as well as how the modularity works on the garment. The researcher learned ways to optimize the functionality and usability of the garments from the exchange of knowledge with the company, as well as revisiting and improving the design details of functional garments, exploring the construction and connection of the type of garments, and attempting to provide innovative solutions and production possibilities for the development of circular fashion.

Digitally Empowered Fashion design

Modular design and system for disassembly

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HEI: Politecnico di Milano, Milan, Italy

VIRTUAL PROTOTYPE

KEYWORDS
Digital Fashion, Clod3d, Gargment Digital Prototyping, Hyper-realistic Simulation, 3d Modelling

Abstract

In this project, digital technology has been tested to digital prototype and simulate outerwear with a hyper-realistic scope not only in terms of style but also in relation to the physical properties of clothing fabrics such as folding and draping, chromatic and tactile properties rendered through visual images. During the residency, the process of pattern simplification for software compatibility, tridimensional modeling of garments and accessories, virtualization of materials, and properties definition on the digital software has been tested on many outerwear examples using CLO3D software. A refined process for fashion designers empowered by digital technologies has been implemented. The result of this research is relevant for fashion practitioners who want to achieve the best results by using digital technologies to prototype and simulate garments in a hyper-realistic way exploiting both time and processing resources of the hardware.

1. Introduction

During my three-month internship at Pespow, I mainly explored the possibilities of the application of digital technology in fashion design, especially sample making. During my internship, I made dozens of digital garments based on the upcoming clothes of WoolRich brand, trying to restore the style, fabric texture, accessories details of these clothes as much as possible. From the first garment to the last, I constantly push the boundaries of digital technology.

2. Residency Objectives

Create realistic digital clothing copies based on unreleased clothing from some brands.

1. Clothing digitization (restore the silhouette of the real clothing as much as possible.
2. Fabric digitization (restore as much as possible the physical properties of fabrics such as color, folds, drape and weight
3. Accessories digital (detail accessories)
4. Render

3. Residency Activities

During the internship, my main job was to use a computer to digitally model clothing in Clo3D, and use a scanner with PhotoShop to digitize fabrics, At the beginning I was not proficient in using it, and the effect of the digital clothing made was not very ideal:

1. Because the garment half piece is too complicated, a piece of clothing is often composed of hundreds of pieces, which puts too much pressure on the computer, making the entire modeling process too laggy, and the software often crashes.
2. The digitization of the fabric is not ideal, for example, the fabric looks a little distorted on the computer due to the wrong settings of the fabric's physical parameters, normal map, and reflection parameters.

However, with the accumulation of experience and three Clo3D classroom teaching organized by Pespow, the above problems have been solved to a certain extent.

4. Project Description

During the whole internship, I probably completed the production of more than ten pieces of digital clothing. This includes making 3D models of these clothes, digitizing the fabrics they use, and digitizing the accessories they use (such as buttons, zippers, etc.). 3D rendering of these garments was carried out, and a series of pictures and short videos were finally produced.

Unfortunately, due to copyright issues, these results cannot be displayed here. So at the end of the internship I made a costume for display under license from Pespow.The making of this costume includes almost all the technical points that I have used before,

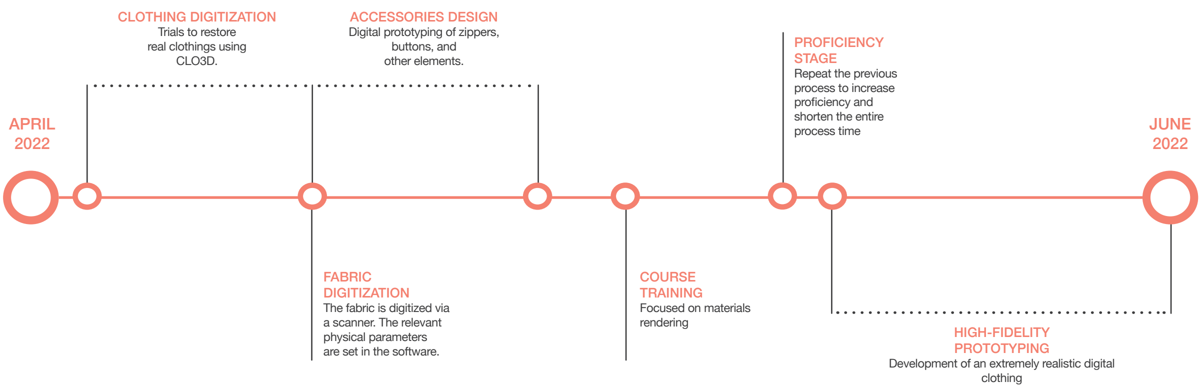
1, optimize the layout file, delete unnecessary layout, make the whole file smaller and smoother.

2, Production of digital fabrics, including the production of normal maps, displacement maps, reflection maps, and physical parameter settings.

3, Customization of accessories, such as sunken LOGO effect on buttons.

5. Residency Results

Through this internship experience, I have gained relevant knowledge of Clo3D and a deeper understanding of the production of



digital fashion. In general I have been able to make digital fashion fast and well.
Here are some of my experiences:
I learned that in some cases digital fashion can simplify the parts of the real fashion and make the whole file more lightweight without compromising the overall effect, rather than replicating the real fashion 1:1.
The biggest influence on digital fabrics is the normal map and displacement map, you can use these two layers to achieve basically all the effects you want. In addition, the transparency map can be used to make mesh fabrics, and the reflection map can make the fabric achieve the effect of local reflection.In the final rendering in Clo3D, it is best to have no more than 4 light settings. The ambient light that comes with Clo3D itself is already a very rich light source.
In the final render, you can use the Color tool in Clo3D to render multiple color combinations of clothing at once. Instead of having to set it every time. So it is best to “dilute” the original color of the fabric and then set a new color in the “Color” tool.
In order to achieve a more realistic effect, we can adjust the “rendering thickness” of different whole patterns to achieve effects such as “the back piece presses the front piece”, these small details can make the digital clothing look more realistic.

Bridiging Infrastructural Holes

Traceability for circularity in textiles

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HEI: Swedish School of Textile, Högskolan i Borås, Sweden

MODEL/FRAMEWORK

KEYWORDS
Textile Recycling Industry, Traceability, Value Chain Transparency, Supply Chain Map Circularity

Abstract

The purpose of this study is to investigate on how fashion brands can improve their existing state of traceability that can enhance the sorting and recycling of textiles. Existing traceability can be improved by focusing on ensuring a transparent value chain, sharing recycling-related information between the actors, and mapping the supply chain. During the residency, a small sample size of stakeholders was involved in the research. This study advances our understanding of how transparent information sharing and traceability and transparency can support opportunities for textile recycling industry. It also suggests that sorting and recycling operations can be enhanced with an improved traceability system implemented by fashion brands.

1. Introduction

The global second-hand textile and clothing sector was valued at around USD 33 billion in 2020 (THREDUP 2020). In comparison, the worldwide textile recycling business was only valued at USD 5 billion in 2020 (Imarc 2020). To be a part of the answer to this challenge, textile and apparel recycling must have a coherent understanding of its operations (collection, sorting, textile-to-textile recycling) and recycling technology. Indeed, this goes beyond the requirement for technological advancements in the recycling process itself; new technologies and accompanying infrastructure must be further developed. To generate a recovery stream of recovered textiles across the value chain, a system change is required (Mathews 2015; Roos et al. 2019; Sandvik and Stubbs 2019; Weetman 2017).

2. 1. Residency Objectives

Large-scale textile recycling facilities require consistent feedstock material to be viable, which is currently hampered by a lack of traceability, insufficient or absent fiber labeling legislation, and mixed materials (many fabrics and yarns are blends of natural and synthetic fibers, with the latter being blends of different polymers) (Roos et

al. 2019). Textile recycling will thus stay at its current low levels unless steps are done to guarantee recyclers have confidence in the source, composition, and chemical content of their feedstock (Notten 2020). Therefore, answering the following research question, this study will investigate the requirement of traceability for textile recycling and way of improvement for fashion brands in this regard.
RQ. How can fashion brands improve their existing state of traceability for sorting and recycling of textiles?

3. Residency Activities

The seminars/meetings conducted on ongoing FTAlliance residency project was insightful and informative which helped me to fast-forward with my work. More importantly, the different aspects/views on the selected topic surely broaden my knowledge and scope to work. Recommendations regarding the area I should focus to have an interview had an greater impact as well.

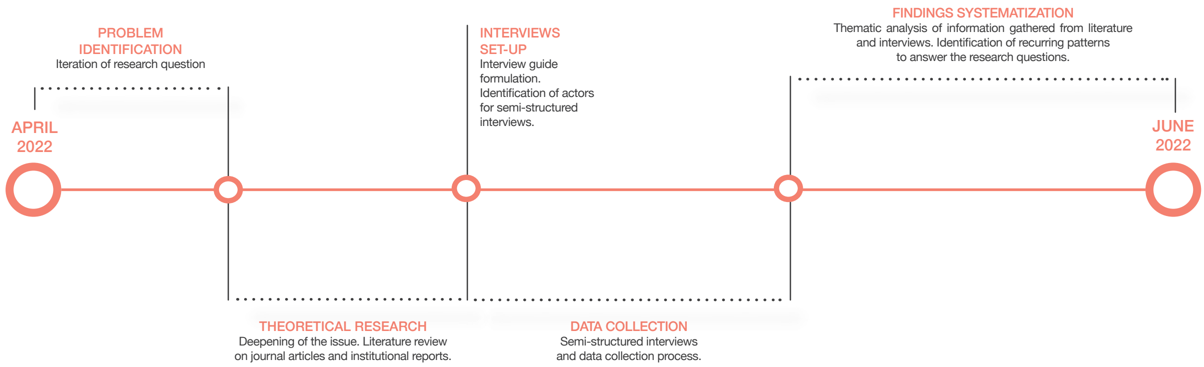
4. Project Description

The research method applied for this study is explained in Figure 1. As there is little known about how the fashion industry can improve their product's traceability for circularity, this study employed a qualitative exploratory research design.
The information was gathered from a variety of sources, including primary and secondary sources. The method used to collect primary data was semi-structured interviews. The secondary information was obtained not only through literature review, but also through a review of institutional reports, and examining reports of similar scope. The sampling technique was purposive sampling, as it was chosen to represent the network's core actors to provide a comprehensive assessment of infrastructural needs and factors.

5. Residency Results

5.1. Need to share recycling related information

Interviewee I01 (recycler) mentioned about material composition, origin, and washing history is important when it comes to the requirement for the textile sorter. Whereas, for the recycler, material composition is the most important to know, at the same time, I01 emphasized more the process on



which the material has passed throughout its life cycle. However, the priorities of information required for the sorting and recycling operations have been shown in appendix 2. According to I01:

[…] fiber composition is the primary requirement for the recycler, after that, we look for the process information like dyeing and printing process, whether it contains any additives or whether it went through a special finish or not. (I01)

Moreover, the requirement of QR code or RFID also varies according to the type of sorting according to I01. Garments having tags, QR code or RFID goes through an information-based manual sorting process, which is mostly considered to make an accurate judgment for remake/ reuse. This type of sorter is the distributor for the second-hand market as well. (I01)

Based on having information tags or not, incoming materials are separated, according to Englund et al. (2018). Eliminating the manual sorting step is difficult as it is effective for sorting out incoming goods that are spotted, torn, or unsuited for direct reuse (Englund et al. 2018). According to I01, the sorting industry is not fully automized, so still there is a need of having manual information-based sorting (I01). Based on having fiber content information tags, goods are further sorted on material sorting stage, therefore, accurate and fastest sorting happens on Tag-based automated sorting stage. Rest of the goods, having no tag goes through NIR- based automated sorting process. For recycling industry, as of commercial perspective, automated sorting in a bulk is mostly required (I01).

5.2. Need to create transparency in the value chain

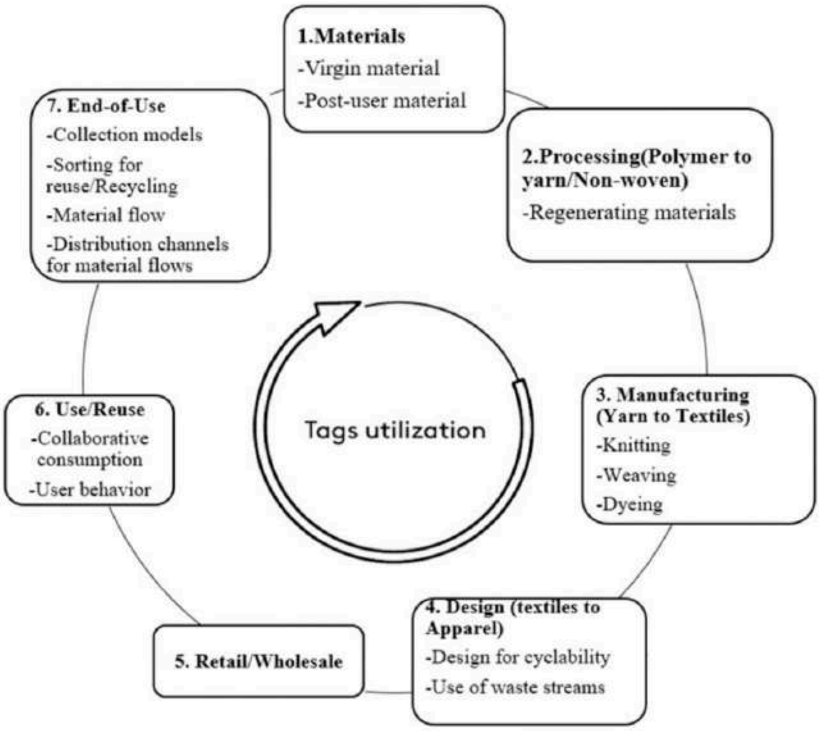
Both interviewees agree that there is a lack of transparency regarding information between the stakeholders. I01 addressed fashion brands, apparel manufacturers and some waste traders are the main actors in the recycling industry, and they should play a vital role to ensure transparent information flow throughout the chain. Whereas I02 is quite unsure what kind of information recyclers are looking for and emphasized the need for information flow to answer their customer's questions. From the recycler (I01) perspective:

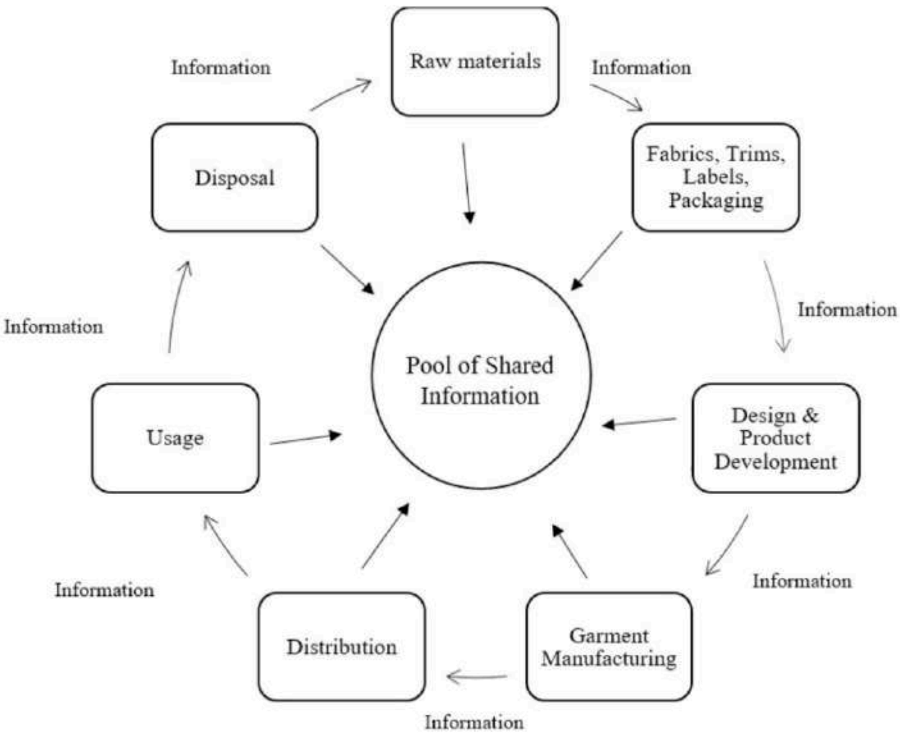
[…] actually, information should come from the fashion brands initially, from the ground level, they are the main actors, if they ensure the transparent information flow from the designing stage to the end of the use of the garments, then it would help for the other stakeholders. (I01).

However, there is a consensus on the need for transparent information flow between their partners and stakeholders. As we can see, there is a transition from pre-consumer to post-consumer waste, and that comes from a variety of producers and sources passed through a variety of processes, transparency becomes more difficult in regard of that (I01).

5.3. Need supply-chain mapping

When the next questions arise regarding the importance of knowing the origin of the material, fashion brands agreed on the need of improve on their supply chain mapping to enhance traceability and transparency. Transparency in the source of recycled fibers is required, in part, due to the perception that traces of hazardous, persistent chemicals in textile and non-textile waste will find their way into new garments and textile products (Watson et al. 2017). Supply chain transparency is also required so that brands can be confident that the recycled-content yarns and fabrics they are purchasing contain the claimed recycled content (Watson et al. 2017). The


1.Materials
-Virgin material
-Post-user material
2.Processing(Polymer to yarn/Non-woven)
-Regenerating materials
3. Manufacturing (Yarn to Textiles)
-Knitting
-Weaving
-Dyeing
4. Design (textiles to Apparel)
-Design for cyclability
-Use of waste streams
5. Retail/Wholesale
6. Use/Reuse
-Collaborative consumption
-User behavior
7. End-of-Use
-Collection models
-Sorting for reuse/Recycling
-Material flow
-Distribution channels for material flows
Tags utilization


Raw materials
Fabrics, Trims, Labels, Packaging
Design & Product Development
Garment Manufacturing
Distribution
Usage
Disposal
Pool of Shared Information
Information
Information
Information
Information
Information
Information
Information

same goes for the suppliers as they require assurances about the waste they are purchasing (I01). Moreover, I02 mentioned some barriers regarding mapping their Tier 3 or Tier 4 suppliers mentioning:

[…] mapping Tier 1 and Tier 2 suppliers require fewer resources than mapping further upstream, such as Tiers 3 and 4 suppliers. Additionally, some of the Tier 2 or Tier 3 suppliers are large players, so they are difficult to map. (I02)

5.4.Need for requirements of tags with information and with specific properties:

For tracing the material unique identifier tag such as RFIDs, QR codes or barcodes are generally used. While overcoming the omnichannel retailing challenges, can reduce the risks in the supply chain by identifying the upstream source and downstream recipients in real-time Agrawal et al. (2018). Englund et al. (2018) demonstrated within Mistra Future Fashion how tags can be used within the lifecycle of the product. According to the author, when a garment is discarded by its owner, it should be considered first for reuse and then for other end-of-life options. If the product is reused, the tag can be updated with information about how it was used, and if it is recycled, the material information loaded on the tag during manufacturing can now be used for fast automated sorting. Furthermore, practical data for collection management, such as the weight and type of garments in a batch, can be added to facilitate logistics.Though RFID and QR code has a significant role on sharing data between all the actors, there are major downsides as well from I01 perspective.

Though some brands are having garments with RFID and QR code, the presence of them in the sorting stage is limited. Then the question arises, are the consumers are willing to be tracked with those tags? Moreover, there is a question regarding its durability through-out its life cycle. Can they withstand with multiple washes, can they withstand with temperature? Then it will be a burden for the sorters, I think. (I01)

Considering the new developing technologies or adapting existing ones, regardless of type, it is important to consider specifications or factors that the tags should meet (Englund et al. 2018). Those requirements such as, contents: producer, material (s), production date, model, size, color, individual ID, washing instructions, able to withstand at extreme temperature and washing, inexpensive, easy to apply and so on- also showed up in the conversation with I01 as well.

However, it is obvious that, while the tagging system will be introduced in the system, information-based sorters need to wait for period of time until significant amounts of tagged clothing begin to appear in the collection bins and sorting lines (Englund et al. 2018).

Above all, it is clear that the industry is not well-connected. Circularity holes are created by a lack of knowledge about the areas of activity and capabilities of the industry's players, a lack of collaboration, an insufficient exchange of information, and a lack of value creation in the industry. To accomplish this, all actors must share a common understanding of the industry's requirements in general and of its individual actors in particular. In conclusion, this study demonstrates that a significant improvement in infrastructure is required, along with that, they should have the willingness to change and should have the responsibility for recycling-relevant practices.

Collaborative Fashion Consumption

Business Model analysis of clothing rental digital platforms

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MODEL/FRAMEWORK

KEYWORDS
Clothing Rental, Digitalization, Collaborative Business Model, Digital Platforms

Abstract

The study analyzes the value perspective of clothing rental business models and the influence of digital platforms and technology on clothing rental to gain a deeper understanding of the rental business in the fashion industry. A higher number of studies focused more on consumers' perspectives in clothing rental business, while the business perspective of clothing rental gained minor focus. This creates a research gap in academia, understanding rental business models which function differently according to the companies. Therefore, qualitative research was conducted based on the case studies of five clothing rental companies. The study results showed the key components of clothing rental business models in value creation, value proposition, value delivery, value capture, and value communication, and the influence of digital platforms and technology in rental business that has the potential to grow.

1. Introduction

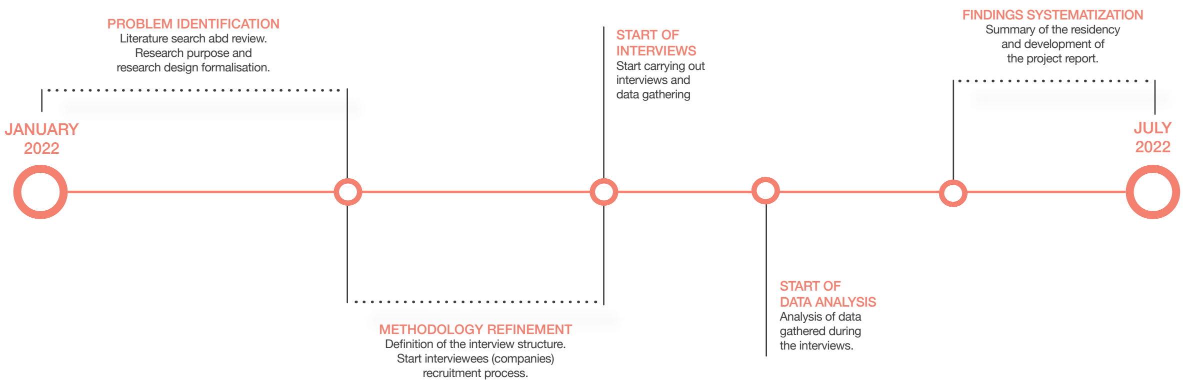
The fast-growing fashion industry has been producing cheaper clothing in high volumes that lead consumers to over-consume beyond their needs. This overconsumption and the throwaway culture contribute to resource scarcity, pollution, and increased textile waste. Hence, minimizing new purchases and promoting product reuse can be seen as feasible options to avoid wasting resources and generating waste. Renting; the Collaborative consumption (CC) method recently gained popularity in the fashion industry which focuses on lengthening the product lifespan and reducing generating waste before the product becomes unusable. The clothing rental initiatives build on digital platforms to offer consumers clothing items for a certain period, facilitating a massive group of consumers to access a vast range of clothing collections anytime. Since renting has multiple engagement times between the business and consumers for a certain period rather than one-time buying, digital platforms play a significant role in the clothing renting process.

2. Residency Objectives

There is a limited understanding of clothing renting business models and the role played by digital platforms and digital technology in clothing renting. A higher number of studies focused more on consumers' perspective in the clothing rental business, while the business perspective of clothing rental gained minor focus. This creates a research gap in academia, understanding rental business models which function differently according to the companies. Hence, this study aims to analyze clothing rental business models from a value perspective and the influence of digital platforms and technology on clothing rental to gain a deeper understanding of the rental business in fashion industry.

3. Project Description

An inductive research approach was adopted in this study to fulfill the residency objective by collecting empirical data. A qualitative research design with an exploratory approach was used to conduct a comprehensive analysis of clothing rental operations from a business perspective since limited research on the business perspective of collaborative consumption currently exists in the fashion context. Multiple case study research design is adopted to collect data from executives working in rental companies functions in digital platforms or physical stores, which supports comparing and illuminating different aspects of the research problem and receiving more reliable results that support generalizing the research findings. Primary data were collected from 5 semi-structured, in-depth interviews with managerial-level representatives from 5 clothing rental companies. The 360-degree business model framework is used as the foundation framework for the interviews to identify and analyze the business models concerning value creation, value proposition, value delivery, value capture, and value communication. For analysis, the codes were based on each subcomponent of the 360-degree model framework and later categorized and contrasted with structuring the data interpretation.
The finding of the study contributes to knowledge in academia and the fashion industry on the business perspective of collaborative fashion consumption and clothing rental by analyzing the business models of five clothing rental companies and the influence of digital platforms and



technology on clothing rental. Moreover, the study provides preliminary findings that support continuing deeper understanding in a specific context and cross-cultural studies since the studied sample included companies from four different countries.

4, Residency Results

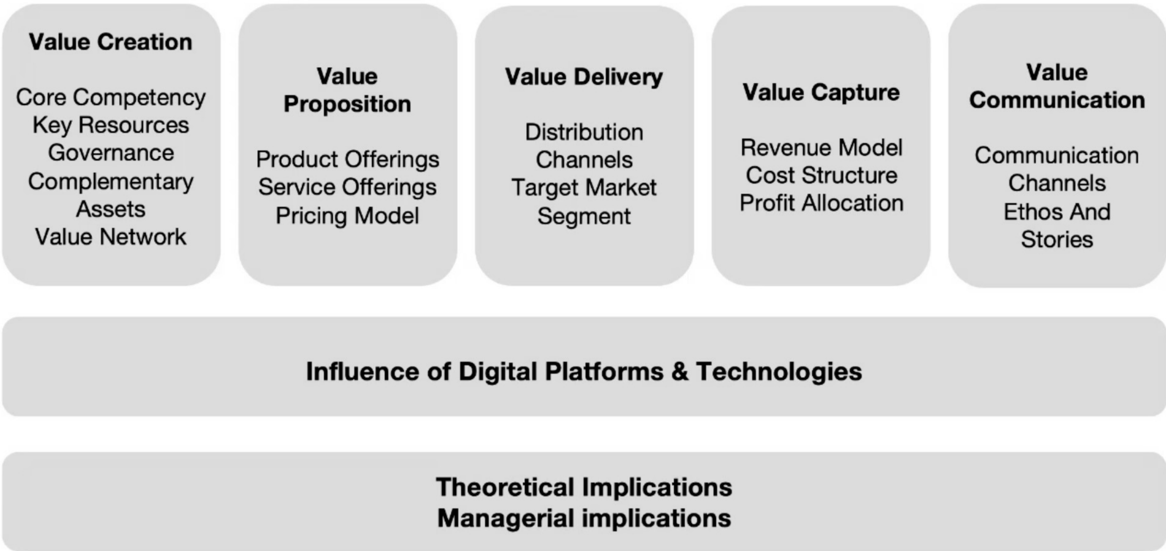
All the studied rental platforms have emerged in recent years, more or less integrated with digital technology that shows quite similar concepts at first glance. Almost all the companies offer one or more monthly subscriptions that give access to various clothing items in the wardrobes, while one company is deviating from the general subscription model by offering functional wear for a short period. However, analyzing these six models using the 360° Framework (Rayna and Striukova 2016) reveals numerous and critical differences in rental business models. The results are discussed briefly here under each 360° Business model framework component; Value creation, Value proposition, Value capture, Value delivery, and Value communication.

4.1. Value Creation

In creating value within clothing rental companies, most companies provide one or more monthly subscriptions that give access to up to 1 to 5 pieces out of the wardrobe, depending on the subscription plan. Also, companies offer a festive seasonal subscription and occasional wear subscriptions apart from regular subscriptions. In general, the companies provide a greater variety of styles in a wide range of sizes and personal styling assistance as the core competencies. Considering the key resources, a sufficient clothing collection is a main financial resource for companies. Warehouse spaces, office spaces, laundry, drying spaces, related equipment, physical contact points, delivery, and IT infrastructure are the physical key resources that are common. Procurement planning, merchandising, logistics, marketing, sales, IT, and software are the most common human key resources, while brand and customer databases are the intellectual key resources for companies. In governing, investing in an appropriate team that thrives towards success as one team, implementing necessary workshops and activities make the team managers and employees motivated and knowledgeable, and maintaining good relationships within the company and with external parties can be seen as essential activities in governance. Supporting the successful commercialization of the business, marketing, sales, and distribution channels and delivery, laundry, and repair services with no additional charges, after-sales support, trial facility, customer base and relationship, good reputation, Connections with external parties, google tools for administrative work can be seen complementary assets. The common suppliers are well-known brands, sustainable brands, homegrown designers, second-hand stores, and charity organizations. Members of the clothing community, Individual customers, are also involved in supplying. Moreover, partners in delivery and laundry services, storage, and other spaces are common members of the value network.

Value proposition

In offering the created value to the customers, companies generally position themselves with the freedom to play with different styles, have fun clothing experiences and break the conventional Consumption routine. Womenswear, including everyday clothing, occasional



wear, and accessories from high street brands and some high-end brands, is the prominent product offering. At the same time, laundry, repair, and two-way delivery with no additional charge can be seen as the prominent service offerings by clothing rental companies. Considering the pricing model, companies offer consistent fixed pricing for the customers through subscription plans based on the total cost of a product or service.

4.2. Value delivery

Women aged 25 to 60 years, ranging from 18 to 70, are the most prominent customer segment. In addition, the target market segment consists of green-minded people who value sustainable consumption, Creative people who prefer to have fun clothing experiences, and value seekers who see the economic advantage of accessing a wide wardrobe at affordable expense. In delivering value to the customers, E-commerce platforms that are integrated into the company website, brand Apps, and physical contact points are the main distribution channels.

4.3. Value Capture

The direct revenue comes from the subscription fees. Also, late return fees and selling the backdated styles generate limited revenue. Considering the cost structure, building digital platform architecture, maintaining warehouse space, and purchasing products are the highest capital-intensive investments. In addition, laundry and drying, delivery services, and other operational expenses (digital platform and software maintenance, office and physical contact points and other rents, staff salaries, marketing, advertising, and other consultancies) also have a high cost. Moreover, the clothes that have never been rented and have too many in one size and style also have responsibility for the cost.

4.4. Value Communication

Company websites, social media (Facebook and Instagram), and physical contact points are the most prominent communication channels. Moreover, Customer services, newsletter emails, google ads, and partnering services are involved in communication. The general communicating stories are based on the fun clothing experiences, a wide range of clothing collections, economic advantages of renting, and Creating awareness of renting concept.

Influence of digital platforms and technologies on clothing rental business.

The findings showed that digital platforms and technologies are essential in efficiently managing the clothing rental business models. The digital platforms and the technology facilitate customer convenience in product browsing, creating orders in the online rental stores, and making payments while facilitating companies to efficiently manage operational tasks such as maintaining customer profiles, inventory handling, planning, and purchasing new styles for the collection, 2-way delivering products, tracking until the cleaned product comes to the inventory again. Moreover, digital platforms and technology support creating a core network and strong interaction among all the members in the value network where everyone can access the necessary information. Furthermore, digital platforms and technology enable strong interaction with the customers and maintain good customer relationships through keeping customers up to date, providing necessary assistance, and collecting customer feedback. Also, the customer feedbacks and data analytics of products and consumer information are used in planning future collections to fit customer expectations and tradeoff products from brands. Also, digital platforms and technology play a significant role in communicating, extending the market reach, and attracting more customers. The ability to reach the mass market without limiting it to a local area can be seen as the advantage of digital platforms. However, building digital platform architecture and maintenance is the highest capital-intensive, where companies need high financial strength to implement digital platforms.

Discussion topics on Fashion Rental

An application of Topic Modelling with LDA and Sentiment Analysis with data from Twitter

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MODEL/FRAMEWORK

KEYWORDS
Social Network Platform, Fashion Rental, Text Mining, Data and Semantic Analysis

Abstract

The purpose of this study is to investigate the opinions and discussions related to fashion rental using social media platforms such as Twitter. By applying a primary data analysis and a topic modelling approach with a following semantic analysis, the research showed differences to the current understanding of opinions and motivations of consumers towards fashion rental. Whereas in literature, sustainability is mentioned as a main argument by consumers, this research showed that features such as the availability, price point and service, and subscription options are the main drivers to engage in fashion rental.

1. Introduction

The fashion industry is criticised for the ever-increasing pace of trends, the overconsumption of clothing and a growing pile of textile waste. Besides the effort the industry makes to reduce the environmental impact by using less impactful materials and processes in production, a study discovered that a significant share of carbon footprint originates from the usage and post-usage phase (Iran & Schrader 2017). However, alternative consumption models like renting promise to cope these challenges, by increasing the utilisation of apparel and reducing the risk of over-production and -consumption. Thus, fashion companies and brands are increasingly getting in touch with this model and start to identify decisive advantages. Whereas several studies analysed the motivations and concerns of consumers towards rental in interviews and surveys (Mukendi & Henninger 2020; Yuan & Shen 2019; Armstrong at al. 2015), no study investigated the opinions and discussions spread on social media platforms. Thus, this study is utilising data from Twitter and applying a topic modelling approach followed by a sentiment analysis.

2. Residency Objectives

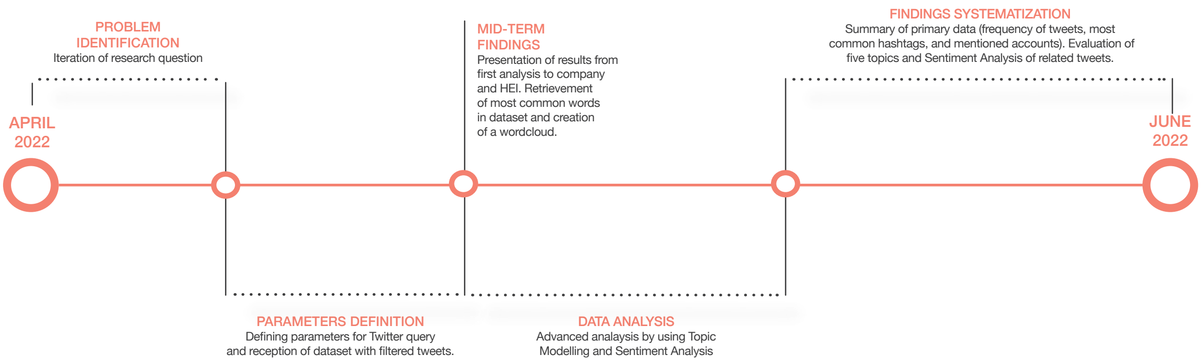
By using the Twitter developer platform, a dataset containing more than 70k relevant tweets relating to fashion rental could be gathered. The objective in analysing this dataset, is to examine the discussions and further understand the opinions and topics of consumers, when tweeting in context of fashion rental. By analysing the primary data, the research revealed the frequency of tweets, most common hashtags, and most mentioned accounts in the dataset. With a topic modelling approach, the study assessed five predominant discussion topics in the dataset. A following sentiment analysis gives insights on the general sentiment of the examined topics.
The findings of this study result in a different perspective of consumer behaviour and opinion about renting fashion and therefore is questioning some of the current literature.

3. Residency Activities

The exchange process has been very active during the residency project. We have conducted several meetings and a workshop in which our intermediate- and final results have been discussed and developed further. Very valuable was the feedback we received during the research project by the company, which helped to find a scope relevant to the industry.

4. Project Description

As illustrated at the beginning, renting fashion items is a more sustainable alternative to our current fast fashion mass consumption model, which promises to increase the usability of clothes and therefore reduces the impact per use and the constant need for newly produced clothing. Thus, the industry is very interested in alternatives such as the renting of clothes, which could result in new business opportunities. Whereas scholars already examined the opinions and motivations of consumers and barriers of implementing fashion rental, the discussions spread on social media about renting fashion haven't been analysed. Therefore, this study solely observes the content spread about renting of fashion on social media. While text mining approaches have been utilised in different contexts, the application of this technique on tweets shared on Twitter with



the objective of understanding more about fashion rental, is novel. Additionally, the high influence of social media platforms in the life of younger generations strengthens the approach and relevance of the results of this study.

5. Residency Results

The residency project allowed to acquire the use of a variety of different techniques and tools for the work with large datasets. Since the project is based on the analysis of data, the handling, managing and analysis of such has been acquired. In support with the HEI, the necessary programming skills and analysis tools have been learned and applied.

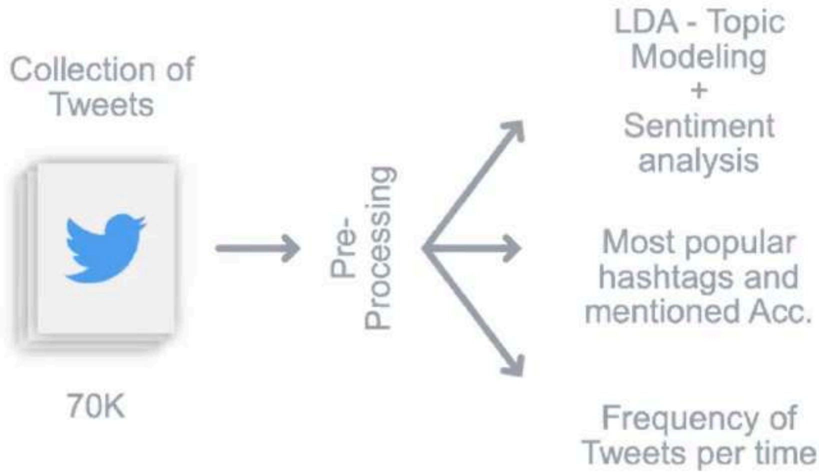
Presenting some of the results from the research, figure 1 shows the total frequency of tweets per month, from the dataset. Additionally, is the total number of tweets complemented by an orange and blue graph, representing tweets filtered for business and sustainability terms. These more specific tweets have much less traffic and therefore are less relevant to the Twitter user.

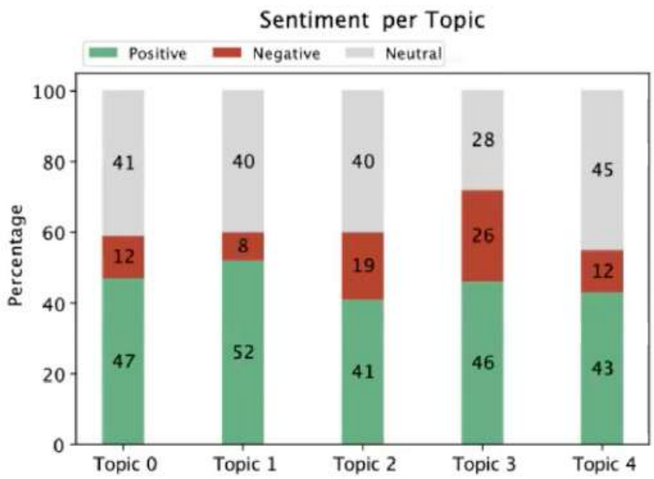
The conducted topic modelling approach with a Latent Dirichlet Allocation model (LDA) (Blei et al. 2003), resulted in a list of five topics with ten respective words, sorted by coherence value (Table 1). Predominant through different topics were words like wedding, prom, and event, relating to occasions. However, in Topic 0 these terms are connected to financial terms like money, cost and pay, whereas in Topic 1 business model terms like service and subscription, were dominant. The Topic 2 has a focus on industrial terms like start-up, industry, platform, brand, and market. Which have been used together with the word's luxury, future and sustainable. Topic 3 relating to e-commerce and logistics with use of the words online, order and delivery, but also mentioning pant, snow, and jacket as products, which are likely to be rented. Whereas Topic 4 do not show immediate coherence among the words to the research subject.

The sentiment analysis (Fig. 2) shows the distribution of positive, negative, and neutral assigned tweets, which remains mainly consistent. Positive tweets form in 4 out of 5 topics the majority, ranging between 41% and 52%, neutral tweets ranging between 28% and 45% and negative tweets always make the minority, by ranging from 8% to 26% share of total tweets per topic. Worth mentioning is Topic 1 with the highest share of positive tweets and lowest in negative tweets and Topic 3 with the highest share of negative tweets with more than 26%.

Summarising the results and putting them into context. The predominate discussed topics clearly show that consumers are more interested into the features of renting itself, like accessibility, the price point, and service and subscription options, than into sustainability. Even though, the users like to use sustainable terms in their hashtags, it is very little discussed. This leads to the assumption that sustainability is not a main driver for consumers to engage in fashion rental.

However, for a better understanding the dataset requires more and deeper research, to understand even more coherences. An analysis of the bi- and trigrams and thus understanding more of the relationship between words, would complement this study and the research in the field.


Collection of Tweets
70K
Pre-Processing
LDA - Topic Modeling + Sentiment analysis
Most popular hashtags and mentioned Acc.
Frequency of Tweets per time


Sentiment per Topic
Positive
Negative
Neutral
Percentage
0
20
40
60
80
100
Topic 0
Topic 1
Topic 2
Topic 3
Topic 4
47
12
41
52
8
40
41
19
40
46
26
28
43
12
45

Developing KPI Framework for Children Fashion Management

A study on circularity initiatives of fashion brands in connection with EU taxonomy

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MODEL/FRAMEWORK

KEYWORDS
Circular Economy, EU Taxonomy, KPI Framework, Circular Business Models

Abstract

Due to the linear consumption models and increasingly higher demand for fashion products, textile waste has become a crucial issue nowadays. The industry stakeholders, academia, and policymakers are seeing the Circular Economy as a solution and the fashion brands are also going in that direction to achieve a sustained competitive advantage. At this stage, challenges exist to guide the circular initiatives of the industry in the right direction with proper definition, measurement and monitoring. The purpose of this study is to develop the KPI framework for the brands that helps them to align their organizational goals with thre European Taxonomy while adapting to CBMs (Circular Business Models) to face the sustainability challenges in the industry.

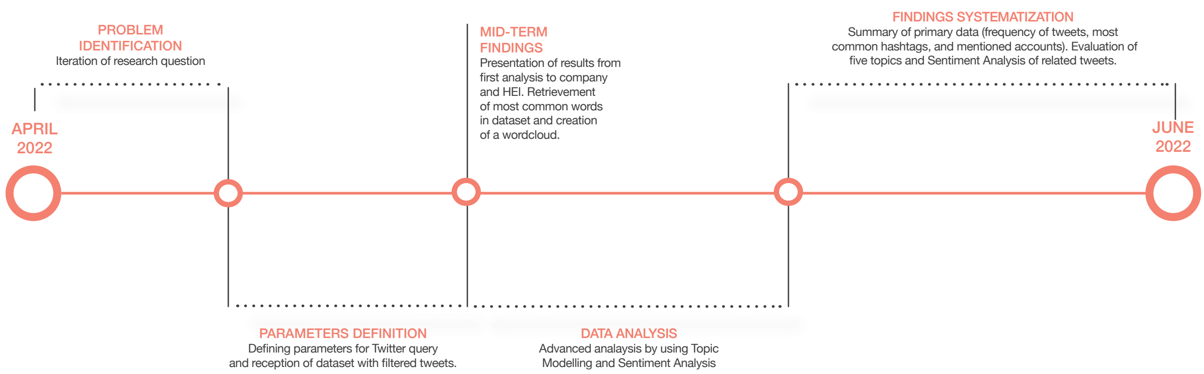
1. Introduction

Fashion and textile have been labelled as intensely overconsumed industries. Unlike the earlier centuries' ample resources and minimal demand, 21st century is having an immense demand, tremendously increased consumption and resultantly, a high volume of textile wastes. There is no alternative left for this enormous textile and fashion industry but to transform into a more responsible in its value chain to minimize the environmental and social impact and leave the resources for future generations through a sustainable business strategy.
Realizing this fact, the fashion and textile industry has started acting responsibly and trying to make their business models sustainable. From the traditional take-make-dispose model, textile and fashion brands are driving themselves towards Sustainable Supply Chain Management

(SSCM) by adapting circularity into their business model organizational, institutional and customer drivers. Multidimensional circularity activities starting from a circular design, responsible raw material selection till the enhanced product stewardship are being added to their regular business operation along with a highly developed concept of not harmfully impacting the environment and society instead, initiatives with an aim to contribute to the betterment of the world are being carried out by this industry stakeholders.
Circular Economy (CE) is one of the popular and effective concepts that the industry has well-accepted to achieve its goal over the past few decades. To ensure the proper governance and regulation of this vast and impactful supply chain, European Commission (EC) has distinguished textile as a priority product category within the circular economy. For regulating the circular activities around this sector, the EU has adopted an operation scheme called Circular Economy Action Plan (hereafter CEAP). There are several initiatives and regulatory frameworks under the European Green Deal like Emission Trading System, Energy Taxation Directives, EU Forest Strategy and so on. But the recent framework that came into force is EU Taxonomy for sustainable activities. This is expected to prevent greenwashing and direct the investment towards sustainable business initiatives.
Although extensive research has been carried out on EU regulations on circularity initiatives, the latest powerful legislative tool EU Taxonomy which will govern the financial investment flow to the sustainable actions does not speak much about the textile and fashion industry yet. Therefore, the lack of guidelines is hindering the proper categorization and recognition of their circularity initiatives. Although CE is a highly attended topic in academia, no study was found which represents the KPIs with which the fashion brands can steer and monitor their circularity initiatives in accordance with the updated EU taxonomy as of writing this report.

2. Residency Objectives

Arguably some part of the Circular Business Model (CBM) has less transferability which make the transition of the companies to the CBM complicated (Lewandowski, 2016). While making the transitioning plan, proper insights into CE help a lot. The high amount of diversified definition often makes it ambiguous since different notion focuses



only on a specific area very narrowly such as recycling whereas in the definition waste hierarchy is a critically important part of the conceptualization which was missing for quite a long time (Kirchherr et al., 2017; Hofstetter et al., 2021). These misconceptions could lead the fashion brands to an unclear realm which will be a hindrance to practising circular activities. KPIs can contribute to validating the alignment of the adapted concepts with the organizational goals. What is very interesting to see within the transformation is the brand's innovativeness to keep the revenue stream unharmed. To maintain this, brands often have to compromise with the pace since there is no specified and pre-defined detailed plan that a KPI can help with.

KPI is considered to be one of the strongest and oldest operations management tools to navigate the workgroup in a specific destined direction. A substantial transformation in the business model like the transformation from usual to CBM needs a very extensive and multidimensional set of KPIs to manage it productively and profitably. Even though there are ample existing metrics available to quantify the sustainable actions, yet, organizations need KPIs to understand how the teams are performing according to the adapted metric systems. Metrics are often mixed with the KPI, nonetheless, both have two distinct functionalities to take the organization in the desired direction (Bielski, 2007). In the case of CBM of textile and fashion brands, KPI is rarely developed to guide their circularity initiatives.

In reference to KPI, benchmarking is a significant fact. An important question is, how brands will realize that their KPIs are aligned with the demand of the current world? In that context, EU Taxonomy is the latest prime framework that can help the companies to verify whether their circularity practices are up to the mark or they need to improve. Though EU Taxonomy is the unequivocal central point of the EU Green Deal which will regulate a majority of the sustainable actions, it does not explicitly talk about circularity only. In this scenario, CEAP would be a very strong merging tool to complete the circuit. Besides EU taxonomy could be a possible help with above mentioned financial constrain that the organizations face facilitating the CBM. Therefore, the objective of this study is to develop the KPI framework for the brands that helps them to align their organizational goals with EU Taxonomy while adapting CBM. With the help of FTAlliance residency program, this research had a strong platform and was able to connect with a policy expert of EU Taxonomy to bring out the authentic outcome from this study which will be a remarkable impact on the circular economy study.

3. Project Description

This study has developed a KPI framework for the brands that helps them to align their organizational goals with EU Taxonomy while adapting CBM to face the sustainability challenges in the industry. The scope of this study covers a wider spectrum of areas, in accordance with the six types of CBMs described by Lüdeke-Freund et al. (2019)

3.1 Methodology

The qualitative study follows an exploratory approach with an abductive reasoning strategy to fulfil the research purpose. Primary data include semi-structured interviews, which are complemented by secondary data documents, and both were analysed qualitatively via thematic analysis.

4.Residency Results

4.1 Finding the KPI areas

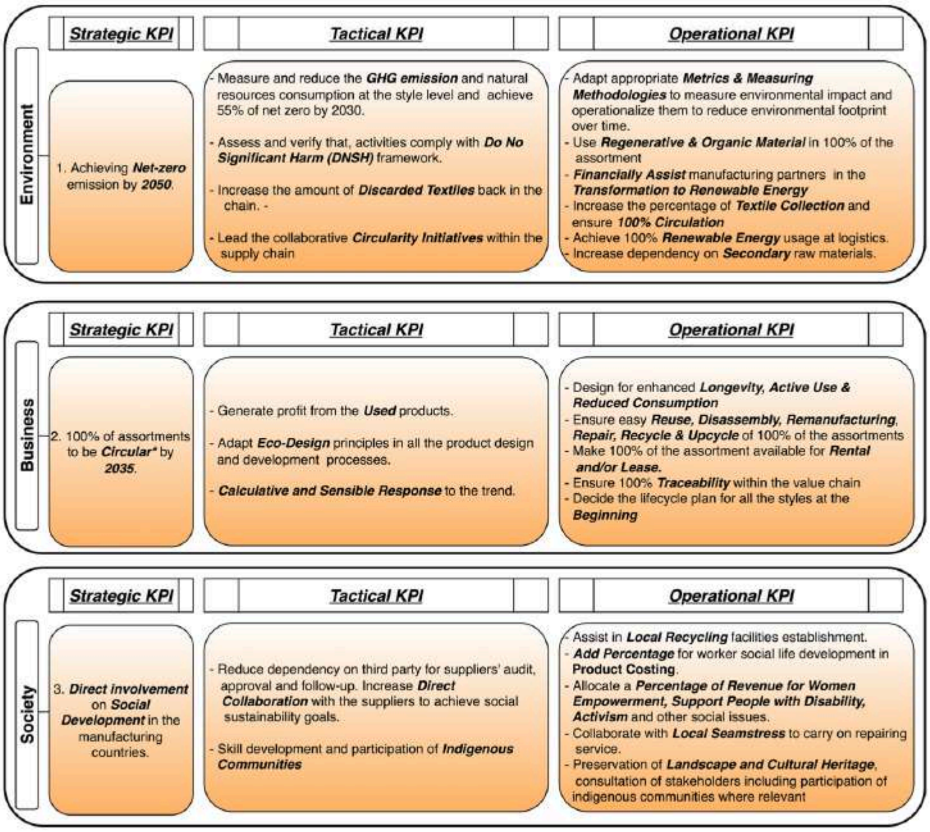
To gather and analyze the empirical data to answer the research questions, this framework has been developed. The heart of this framework is the EU Taxonomy with the KPI areas from the operational scopes of CEAP. The framework connects circular activities with the objectives of EU Taxonomy and thus helps the company to develop their circular activity KPIs accordingly. These circular activities are derived from CEAP and modified for the fashion and textile industry activities in accordance with the scope of the study. The framework follows the common steps of a textile value chain - design and development, sourcing and logistics, planning and production process and marketing and customer communication. It is also extended to product stewardship and enhanced responsibilities and addresses some actions that are related to overall business strategy. These value chain segments are discussed as "framework criteria" followed by 25 areas that KPIs will be discussed. Almost every department of a fashion brand takes part in these actions and thus this framework can successfully engage managers and executives from all the departments in the formation and action on the circularity KPIs. Besides, this framework also focuses on the multitier supply chain activities of the brand and specialises in knowledge-gathering, development and sharing among its stakeholders.

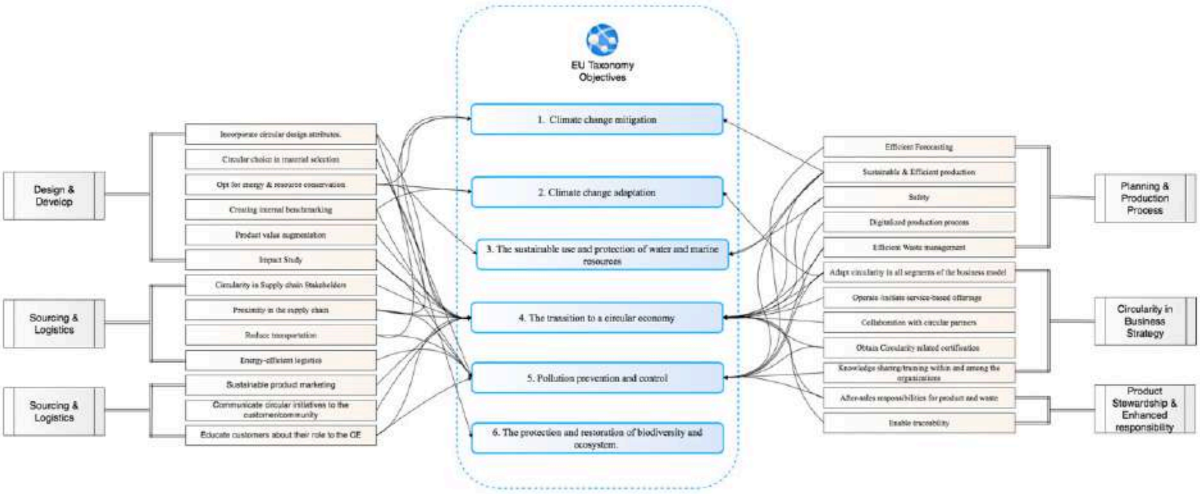
The KPI areas are further expanded into a total of 86 action roots that would have a direct connection with the KPIs. These KPI areas and their sub-areas relate to the EU Taxonomy objectives shown in Figure 3. It is found that, out of 25 KPI areas, 23 of them have a connection with objective 4 and if we go to the root level of KPI subareas, around 80 per cent of them are related to objective 4. This reinforces that, objective 4 covers a broader area of the sustainable and circular fashion industry.

4.2 KPI Framework for the Fashion Companies

The study result indicates that there is a lack of set processes or frameworks therefore, the brands are going for a mix of different methods and often adapt their methods which arguably has a gap with different legislative frameworks like EU Taxonomy and CEAP have been used for this study. Additionally, the disconnection between the actors is one of the reasons for the industry's slower transition to the CE. This study also finds its alignment with the lack of scalability of CBM that one of the responsible factors for slower transition to CE as well (Hultberg & Pal, 2021). In contrast to these challenges, this study suggests a framework that will help the fashion brands to have a well-defined set of KPIs to benchmark, supervise, tweak, problem analysis and solution findings during their quest toward achieving the CE. The final framework is constructed based on three main pillars viz. environmental, business and society as illustrated.

helps companies to set their focus on distinct paths. This framework supports the SMART (Specific, Measurable, Attainable, Relevant, and Time-bound) characteristics which means, the organization can set their KPIs using this framework which will be following the SMART style of KPIs. Strategic KPIs are the ultimate objective of the circularity KPIs of the company that they can present as a broader picture. Usually, these KPIs are very broad to represent the company's wider goal or achievement. To define and guide the trajectory towards this


Strategic KPI
Tactical KPI
Operational KPI
Environment
1. Achieving Net-zero emission by 2050.
- Measure and reduce the GHG emission and natural resources consumption at the style level and achieve 55% of net zero by 2030.
- Assess and verify that, activities comply with Do No Significant Harm (DNSH) framework.
- Increase the amount of Discarded Textiles back in the chain. -
- Lead the collaborative Circularity Initiatives within the supply chain
- Adapt appropriate Metrics & Measuring Methodologies to measure environmental impact and operationalize them to reduce environmental footprint over time.
- Use Regenerative & Organic Material in 100% of the assortment
- Financially Assist manufacturing partners in the Transformation to Renewable Energy
- Increase the percentage of Textile Collection and ensure 100% Circulation
- Achieve 100% Renewable Energy usage at logistics.
- Increase dependency on Secondary raw materials.
Strategic KPI
Tactical KPI
Operational KPI
Business
2. 100% of assortments to be Circular* by 2035.
- Generate profit from the Used products.
- Adapt Eco-Design principles in all the product design and development processes.
- Calculative and Sensible Response to the trend.
- Design for enhanced Longevity, Active Use & Reduced Consumption
- Ensure easy Reuse, Disassembly, Remanufacturing, Repair, Recycle & Upcycle of 100% of the assortments
- Make 100% of the assortment available for Rental and/or Lease.
- Ensure 100% Traceability within the value chain
- Decide the lifecycle plan for all the styles at the Beginning
Strategic KPI
Tactical KPI
Operational KPI
Society
3. Direct involvement on Social Development in the manufacturing countries.
- Reduce dependency on third party for suppliers' audit, approval and follow-up. Increase Direct Collaboration with the suppliers to achieve social sustainability goals.
- Skill development and participation of Indigenous Communities
- Assist in Local Recycling facilities establishment.
- Add Percentage for worker social life development in Product Costing.
- Allocate a Percentage of Revenue for Women Empowerment, Support People with Disability, Activism and other social issues.
- Collaborate with Local Seamstress to carry on repairing service.
- Preservation of Landscape and Cultural Heritage, consultation of stakeholders including participation of indigenous communities where relevant


EU Taxonomy Objectives
1. Climate change mitigation
2. Climate change adaptation
3. The sustainable use and protection of water and marine resources
4. The transition to a circular economy
5. Pollution prevention and control
6. The protection and restoration of biodiversity and ecosystem
Design & Develop
Incorporate circular design attributes.
Circular choice in material selection
Opt for energy & resource conservation
Creating internal benchmarking
Product value augmentation
Impact Study
Sourcing & Logistics
Circularity in Supply chain Stakeholders
Proximity in the supply chain
Reduce transportation
Energy-efficient logistics
Sourcing & Logistics
Sustainable product marketing
Communicate circular initiatives to the customer/community
Educate customers about their role to the CE
Efficient Forecasting
Sustainable & Efficient production
Safety
Digitalized production process
Efficient Waste management
Planning & Production Process
Adapt circularity in all segments of the business model
Collaboration with circular partners
Obtain Circularity related certification
Knowledge sharing/training within and among the organizations
Circularity in Business Strategy
After-sales responsibilities for product and waste
Enable traceability
Product Stewardship & Enhanced responsibility

strategic KPI as well as integrate circularity within the business model, several tactical KPIs are needed. Often, they complement the strategic one as well. That strengthens the interconnectivity between the stages. And finally, the KPIs that will be maintained during the operationalization of different concepts depending on the strategy and tactics of the company to achieve their circularity and sustainability pledge, are placed as the operational KPIs. Compared to the other two stages, these KPIs are narrower but depending on the company's goal, they can further break it down into different sub- KPIs.

SECTION 4. FASHION-TECH COMPANY TESTIMONIALS

Reshoes: the new innovative French sole recycling programme

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AFFILIATION: CETIA, Bidart, France

KEYWORDS
Recycling
Footwear
Innovation
Automatisation

Why to recycle shoes?

Nowadays, the vast majority of shoes, around 224 million pairs each year, are shredded due to the lack of state-of-the-art technology to extract the soles from the upper, and end-of-life shoes do not benefit from dedicated recycling channels that can handle a volume commensurate with the market. Recycling end-of-life or unsold textile and footwear items is an carried out manually and is a very costly activity. It does not allow the textile and footwear recycling sector to develop on an industrial scale. Most of the products, which are not reinjected into the second-hand market, are eventually exported.
In this framework, CETIA is the first innovation platform dedicated to the automated sorting and dismantling of end-of-life or unsold textile and footwear items.
Thanks to automation, robotics and artificial intelligence, CETIA builds efficient systems to make recycling operations competitive. We support marketers, collectors and recyclers in the design and deployment of innovative solutions to bring their textile and leather recovery projects to life.

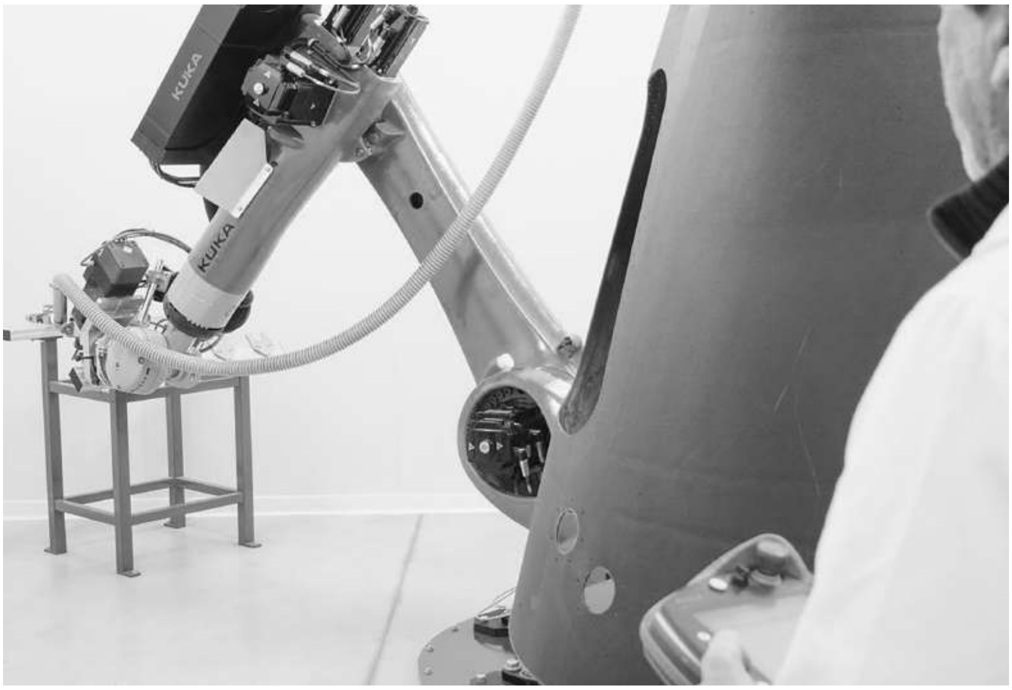
How can new technologies help recycling on an industrial scale?

The following services can help companies accelerate recycling of footwear and other textile items:

- Identification of products through artificial intelligence, traceability and digital passporting, to direct them to the right dismantling process;

- automated sorting to automatically orientate the deposits by composition and colour;
- material and colour characterisation to classify deposits;
- automated dismantling to separate the different components;
- preparation of new resources according to the needs and criteria of the recycling actors in the textile sector.

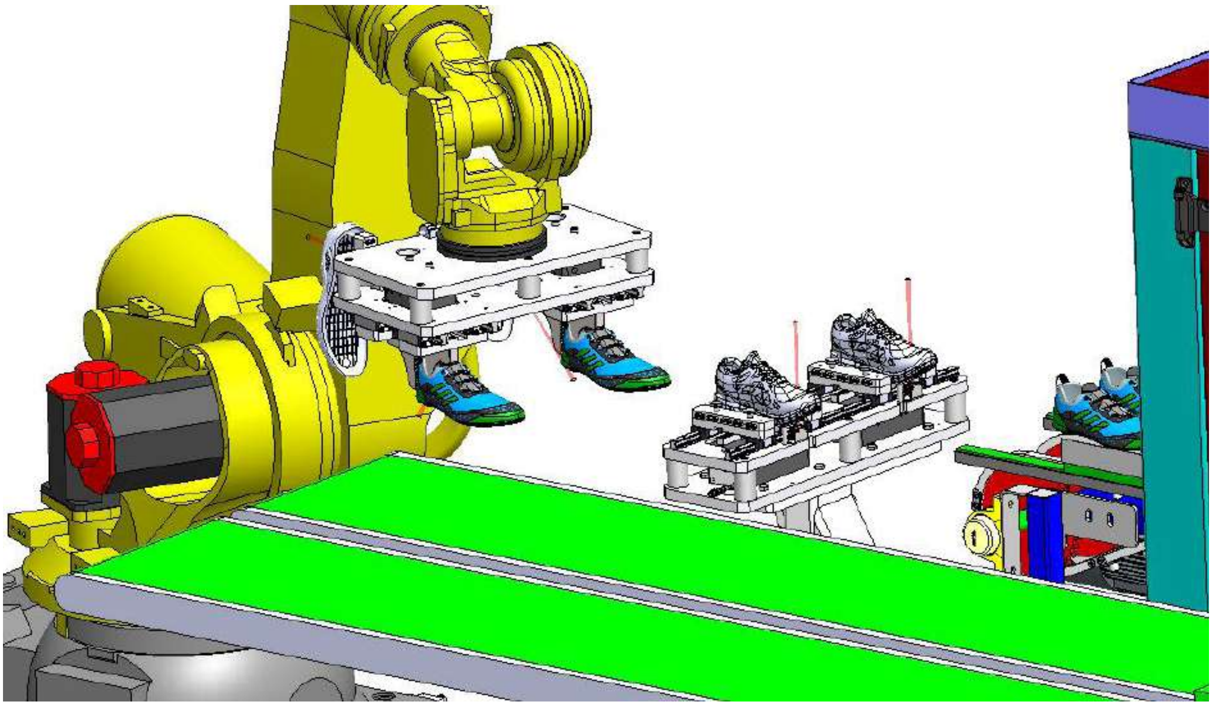
The aim is to enable recycling and encourage the production of textiles incorporating recycled materials in a closed loop, which would reduce the carbon footprint of a textile product by 30%.



Reshoes and the recyclability of soles

Reshoes is an innovation programme on recyclability of soles. It is a good example of how new technologies can accelerate the set up of industrialised recycling process within textile industry.
This innovation programme is leaded by CETIA in collaboration with industrial partners (Zalando, Decathlon, Eram Group, Revalorem) and the public sector (Nouvelle Aquitaine region).
The aim is to combine several technologies to create an automated process that will allow the detection of materials, the removal of soles and their sorting in order to recycle the materials.
In March, a 100% automated line will be installed in Hendaye (France), in a dedicated space of 1,200 square metres, which will be able to process a thousand shoes a day, whether they are luxury, city or sports shoes and whether they are glued, stitched or injected soles.

The recycling process will reduce the environmental impact of textile industry but also could help reducing the cost of production. In this way, rising raw material prices make the potential for recycling certain materials at the end of a product's life even greater. As a concrete example, at a time when oil-based raw materials are skyrocketing in price, the recycling of polymers from shoe soles is a great opportunity for decarbonisation and price stability.
Reshoes should enable the sector to move forward rapidly in order to create the conditions for the industrial deployment of genuine product sorting and material recycling in the footwear industry.



Ecollant: the first women's tights recycled from used tights

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AFFILIATION: COO Ecollant

KEYWORDS
Recycling
Footwear
Innovation
Automatisation

The (urgent) need of recycling tights

Ecollant is a textile innovation start-up with strong environmental values allowing our recycling processes to be in a circular loop.
The tights produced today are very beautiful, comfortable and designed to make women elegant. Nevertheless, 130 million pairs are sold each year in France, but 104 million pairs are thrown away in the bin, in the middle of our household waste.
In short, we are talking about more than 7,000 tons of pairs of tights thrown away each year on our territory, which have no recycling process because it is impossible to mechanically recycle tights. This is how Ecollant was born in September 2019, a start-up created by fashion, tights and textile specialists who wanted to change the way we design and produce by recycling tights. Écollant was created with the aim of challenging an ancestral know-how in France: the design and manufacture of French textiles by bringing, through science, new techniques that are environmentally friendly.
The yarns used in tights are made of two materials: 85% nylon and 15% elastane, depending on the brand and the origin of production.
The yarn is called "guipé", which means that the nylon is wrapped around the elastane, giving an elastic and comfortable yarn that allows the tights to adapt to women's morphology.
However, mechanical recycling remains impossible to recycle this nylon.
We have therefore devised more complex green recycling routes, which are currently being studied and tested.

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To implement this research, we have focused on nylon, a polymer more specifically named polyamide 6.6 (PA6.6), which is composed of strong bonds.

What are the progress made by now?

Today, our R&D is underway to achieve green recycling routes, where each stage of production will then be studied by specialists to measure and then limit our environmental impacts as much as possible and finally offer the first tights recycled from damaged tights.

In this way, we participate in a more sustainable production by limiting the transport of our materials and products, adding a positive social impact on our regions by promoting French know-how.
Ecollant has launched a research programme for the technological aspect and, at the same time, is starting to organise the collection of the raw material.
While waiting for the arrival of our recycled tights made from used tights, we are intensively training to learn how to design and product sustainable and comfortable recycled textiles in France with our industrial partners.
In this way, we produce 2 collections per year for our customers. These ranges are designed in France and made from recycled plastic bottles. More specifically, we have launched a range of 10,000 swimming costumes in polyester from recycled PET bottles in 2021, for a French brand that has ordered twice as many for the 2022 season. This success has prompted Ecollant to launch its own brand next year, starting with a collection of socks 100% recycled and French: the name is “Révélation”.

Our next step

- collect more tights
- validation of our industrial scales
- deployment of patents
- industrial development
- New R&D path

Research Funding and Acknowledgements

We are financed in large part by the Bourgogne-Franche Comté region, the ADEME and BPIfrance.
We have been lucky enough to receive an honorary title from the French Recovery Plan thanks to the calls for projects we have won in this direction, in favor of the ecological transition. In addition, we have received the Deep Tech label for our research to illustrate, in particular, the innovative nature of our research work.
This funding will help us to accelerate the R&D deployment as well as the validation of pre-industrial and industrial processes.
A great thanks to all our sponsors!

We would like to take this opportunity to thank all the BPIfrance “coq vert” community as well as the alumni of clean tech open France. We are proud of being part of it.

EcoCycle: moving towards a circular economy

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AFFILIATION: Product Director for Apparel and Footwear segment

KEYWORDS
Recycling
Footwear
Innovation
Automatisation

What is EcoCycle

The textile industry consumes about 100 million tonnes of new fibres each year and approximately 90% of textiles fibres at the end of life go straight into a waste stream – either incineration or land fill. Recycling has not scaled up in the fashion industry, primarily because most garments have various components made from a mixture of different materials and composites. The dismantling process is manual, labour intensive and costly, yet at the end of life many of the various fibres are reusable. Approximately 25% of clothing is never even worn, with newly bought items being put into wardrobes and forgotten, until they are eventually discarded into a waste stream without ever being used.

Following centuries of designing and manufacturing threads to hold garments together, Coats has revolutionised an element of its core product offering with the development of EcoCycle. The new thread retains its durability during the life of the garment but when washed in an industrial machine at 95 degrees Celsius, seams sewn with EcoCycle dissolve. This enables the garment to be easily and quickly disassembled by simply pulling it apart so the non-textile and textile components can be sorted for recycling.

Ecocycle is a groundbreaking water dissolvable concept that overcomes the challenges associated with garment recycling at the end of a lifecycle. It helps facilitate the easy and low-cost separation of non-textile and textile components. It is all part of Coats journey towards a circular world.


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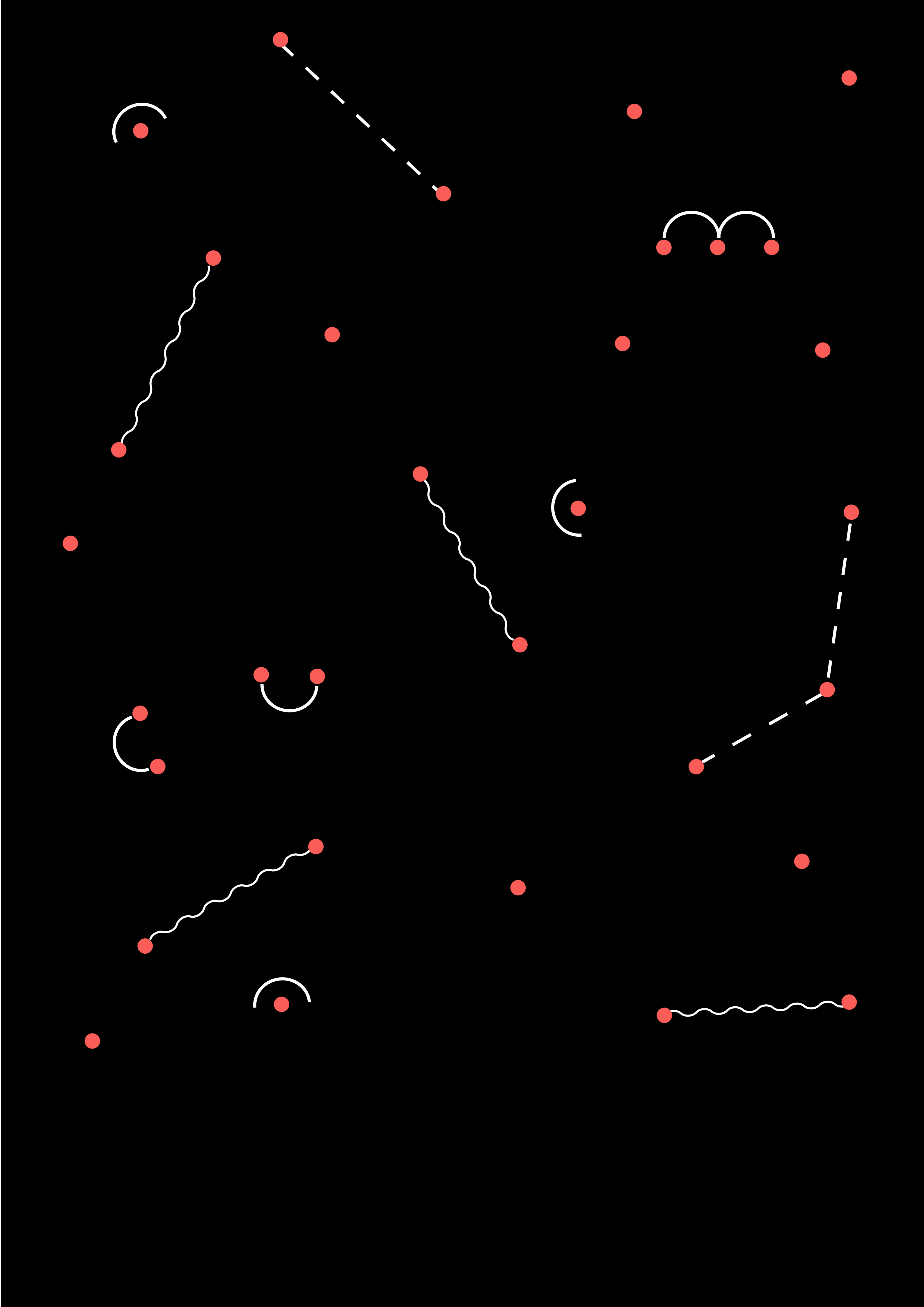

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