PILOTING FASHION-TECH EDUCATIONAL STRATEGIES

PROOF OF CONCEPT FOR INNOVATIVE FASHION-TECH PRODUCTS AND SERVICES

edited by
Daria Casciani, Chiara Colombi

FTalliance

PILOTING FASHION-TECH EDUCATIONAL STRATEGIES
Proof of Concept for Innovative Fashion-Tech products and Services

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

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This publication is the result of a didactic research process involving students, teaching staff and industry experts from across Europe in three (3) learning experiences implemented over a period of almost one year (2021-2022). It aims to identify and describe the major lessons learned from the testing and piloting of three innovative Fashion-Tech learning experiences in order to discuss opportunities for Fashion-Tech (i) Strategic Innovation, (ii) applied Research for the future Education Agenda and (ii) cooperation, networking and partnership opportunities.

The work has been organised and synthesized by Politecnico di Milano as leader of the activities related to designing and piloting Fashion-Tech learning experiences (WP2), and project coordinator of the Fashion-Tech Alliance, a 3-years European academia-industries partnership project aimed to facilitate the exchange, flow of knowledge, and co-creation within the Fashion-Tech sector to boost students' employability and fashion-tech innovation potential. This project specifically involves five renowned Higher Educational Institutions Academic partners (Politecnico di Milano, Dipartimento di Design, ESTIA École Supérieure Des Technologies Industrielles Avancées, Högskolan i Borås, University of the Arts London - London College of Fashion, Technische Universiteit Delft), one Fashion-Tech research Centres (Centexbel) and seven industrial partners (Decathlon International, Pangaia Grado Zero, Pauline van Dongen, Pespow, Stentle / M-Cube Group, We Love You Communication, and PVH Europe). The aim of this project is to provide an evidence-based perspective on the Fashion-Tech education reporting on the relationship between advanced teaching/learning approaches about design, business management, and engineering that can be applied to the future generation of fashion-tech professionals.

This publication consists of five chapters presenting the learning experiences' workflow starting from the research premises, the implementation, and evaluation, followed by a reflection on the results with concluding remarks and future perspectives on Fashion-Tech education. Chapter 1 sets the premises of the Fashion-Tech educational research, meanwhile, the following chapters (2,3,4) present the case studies of the three piloted learning experiences describing the contents, objectives, and outcomes, reporting the methodology and lesson learned in terms of Fashion-Tech emerging topics, and reflections on the phases of the didactic experiences. Each of these chapters is followed by visual charts that present the results showcasing the portfolio of innovative Fashion-Tech concepts of products/services developed during the learning experiences. Finally, chapter 5 sets out the findings and future trajectories for Fashion-Tech education and collaboration. It discusses how the research findings led to setting the premises for prospective scenarios of the Fashion-Tech education, which serve as an invitation to open a collaborative discussion on the future of Fashion-Tech educational models, collaborative engagement between different stakeholders of the sector, and all concerned about the skills of future Fashion-Tech professionals.

This publication contains the deliverable D2.2 Proofs of Concept for innovative FT products/services, in fulfillment of the European Project FTalliance Weaving Universities and Companies to Co-create Fashion-Tech Future Talents (612662-EPP-1-2019-1-IT-EPPKA2-KA - FTall).

2. CASE STUDY FASHION-TECH INTERLINE

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2.1 THE VIRTUAL DIMENSION OF FASHION DESIGN

From the early 21st century, the introduction of digital technologies has ubiquitously changed communication, production and design processes. This kick started the digital culture of fashion companies investing in the virtualization of design phases (ideation, prototyping, testing), production, retailing (communication, distribution, showcase, selling), and consumption toward more innovative (faster, smarter, more efficient) products, processes, services and networks. Their new technological and organisational approaches has allowed new design practices and processes occurring in the cyber-physical space, and also new business models that could drive a real digital transformation in the Fashion 4.0 paradigm *(Bertola & Teunissen, 2018)*. The digital transformation of fashion towards a virtual dimension has been propelled by COVID-19 pandemic with the challenge of enhancing innovation and sustainability in all phases of the fashion supply and value chain *(Brydges, Retamal & Hanlon, 2020)*.

To cope with the disruptive impact of the pandemic, digitalization has invested the fashion sector at different levels such as design processes and products, new production and manufacturing cycles, different marketing, distribution, sales and communication activities *(Kalbaska & Cantoni, 2019)*. In particular, one of the streams of fashion 4.0 technologies has been focusing on 3D modelling and simulation software for fashion products' development, visualization, and marketing *(Sarmakari, 2021)*. During COVID-19 crisis, fashion companies using 3D product design, virtual sampling, and digital material libraries have reacted faster to issues like social distancing, remote teamworking conditions, and time-to-market *(Gonzalo, Harreis, Sanchez Altable & Villepelet, 2020)*. Scholars *(Ronchetti et al., 2020)* evidenced that digital-related skills were highly researched in job posting by European fashion companies during the pandemic period.

Beside the momentum, digital technologies are seen to have a major impact on the future of the fashion industry, bringing more values and focus on sustainability by intensifying discussions around "materialism, over-consumption and irresponsible business practices" *(Business of Fashion et al. 2020)*. The boundaries and specific features of digital fashion in the use of 3D CAD software are still to be determined since the sector is quickly evolving and expanding *(Noris et al., 2021)*. A definition with specifications about digital fashion delimits and circumscribes the current phenomenon on the use of 2D/3D CAD software and computer technology enabling digitalization of traditional fashion, digital prototyping and sampling, virtualization of fashion imagery, products and spaces *(Wikipedia, 2020)*. Here, CAD (standing for Computer Aided Design) encompasses the use of both hardware and software to create, modify, optimize and analyse a 2D/3D garment to minimize labour, time, cost, raw materials, to optimize efficiency and improve design quality via enhanced communication among the different stakeholders. Integrating techniques of computer science for engineering, technical design and fashion modelling *(Greder, Pei, & Shin, 2020)*, digital fashion focuses on operations of virtual and physical systems of manufacturing resulting in phygital[5] solutions and digital-only fashion. In particular, digital-only fashion exists in non-physical fashion narratives, extending beyond the boundaries of the aesthetics and functionalities of the physical world and could be made of eccentric non-physic-based materials (e.g. liquid silver, steel, water, light). It is independent of body type, size or seasonal production, used to dress all digital identities without the intention of real-life production. In this regard, Slooten defines digital fashion as: "anything that has to do with fashion beyond the physical realm. Fashion you can wear with your digital identity" *(The Fabricant, 2019)* such as avatar (digital body) but also physical bodies using Virtual Reality (VR) and Augmented Reality (AR) technologies. Beside this, digital fashion associates the rise and use of digital technologies and fashion product digitization with the process of datafication by which subjects, objects, and practices are transformed into machine-readable, quantifiable and digital data for the purpose of aggregation and analysis to gain insights about human behaviours and social issues and to convert this information into new forms of value and business.

The shift of fashion toward the digital and virtual dimension is challenging existing ways of conducting fashion business in relation to design practices, product development to test fit, print, placement, materials and chromatic combinations, production cycles by limiting the amount of prototypes for marketing, distribution, sales and communication activities *(Kalbaska & Cantoni, 2019; Nissen & Nerup, 2020)*.

2D and 3D CAD programmes for garment simulation and virtual prototyping through 3D modelling has been investigated since 1980 *(Fontana et al. 2005)* and considered crucial in product development processes that need enhanced communication, simplification of flows among different stakeholders (conceptual and technical designers, patternmakers, marketing people, supplier and manufacturers), cost effectiveness and shorter lead times. Compared to other design sectors such as product and automotive design, the digitization of the design processes in the fashion industry has been slower to be adopted and has

[5]Phygital is the bridge of the physical and the digital using technology with the purpose of providing a unique blended and interactive experience for the user, augmenting digital experiences with human connections or physical enhancements.

long remained in an exploratory stage due to (i) software and hardware technological that only recently has progressed to allow textile draping, stretching and behaving with gravity, (ii) financial constraints, and (iii) fashion resistance to adoption *(Santos et al. 2020; Sassi et al. 2021)*. The aim of this section is to situate the learning experience 'Fashion-Tech Interline' in relation to existing literature on learning and pedagogy about fashion virtual prototyping, along with relevant information regarding digital tools and innovative teaching methodologies. The design and implementation of the learning experience are further described in the following sections, concluding with a discussion of learning experience results from students and educators' perspectives.

Fashion Virtual Prototyping in Education

Research and design on digital 3D-fashion design calls for more empirical case studies *(Arribas & Alfaro, 2018)* to understand the implications on the way fashion designers create with digital tools and also which are the skills necessary for them to tackle digital fashion matters. Teaching digital fashion is important for future generation of professionals and to understand how to ensure European growth toward a better, greener and more resilient future. In fact, the European digital strategy is investing in increasing digital skills for citizens and professionals, introducing digital technologies in learning programmes and experiences *(2030 Digital Compass: the European way for the Digital Decade, 2021).* The implementation of this strategy emphasizes the reach of universal digital skills for students of disciplines with current low integration of digital subjects with computer science and information technology. Upskilling the future design generation in the fashion domain is a must for enhancing basic digital skills and competences such as computing education, ensuring that girls and young women are equally represented in digital studies and careers *(Digital Education Action Plan (2021-2027), 2021).*

Scholars, suggest that digital fashion practices require a balanced mix of 3D targeted technological, technical, digital and fashion skills to tackle virtual garments construction and simulation from concept to production in a virtual environment *(Sarmakari, 2021).* In this hybrid disciplinary field, students' needs to learn how to negotiate among tools and knowledge from different domains. 3D software available for the fashion sector have become more sophisticated in terms of materials' behaviours simulations and realistic rendering. They allow the development of new workflows, fluid communication between pattern making (2D) and garment shaping (3D), the increase of creativity and the reduction of samples, and used materials *(McQuillan, 2020).* Traditionally, fashion designers passed through a creative process based on concept sketching on paper, technical drawing, and material selection for the first physical sample model that is generally realized by the pattern maker: this phase is followed by a conjunct and iterative activity of editing the work toward defects' correction. In 3D digital fashion, all these activities can be developed by the fashion designer in the digital space of the software (2D pattern design, pattern positioning on digital avatars, virtual sewing, drape simulation and design modification in 2D/3D), allowing a faster and simpler communication between designers and pattern makers due to real-time visualizations, thus preventing any misunderstanding during the prototyping phases *(Power, Apeagyei & Jefferson, 2019; McQuillan, 2020).*

Nonetheless digital designers need to have a previous knowledge about the physical properties of materials and 2D pattern making to be proficient in using the digital tools. In addition to this, digital software is recognized to improve students' skills in pattern making *(Hwang & Hahn, 2017; Nissen & Nerup, 2020).* It is also suggested that digital tools should be used in addition to traditional fashion education and analogue tools *(McQuillan, 2020).* The virtual and traditional/manual dimension of fashion are continuously related and coexistent, also by constantly updating the fashion design practices *(Crewe, 2017).* Digital fashion integrates technology with traditional garment design processes toward sustainability, allowing to visualize the overall look of the design, diminishing the sampling quantities to perfect the garment, thus reducing the material wastage *(Lee, 2014).* Teaching fashion design on a 3D virtual model enables students to focus more on garment building, construction techniques and development problems in fitting and in sewing steps planning *(Luo & Yuen, 2020).* It allows the complete and details visualization of garments that students rarely achieve with hands-drawings, thus facilitating creative processes and the dialogue with teammates and teaching staff (*Santos et al. 2020).* Virtual prototyping determines faster, simpler and more experimental design processes because the software allows to visualize a model very close to the final product where the technical components are facilitated by the software *(Santos et al. 2020).* Education of fashion students on 2D pattern making and 3D garment modelling should be based on different software packages, resources and instruments to improve "flexibility" and "adaptability" skills *(Hwang & Hahn, 2017).*

Finally, other scholars argue that 3D fashion design techniques will improve the experience of online fashion design educational programmes, providing more feasible and efficient learning experiences compared to traditional hands-on programmes such as garment construction courses (draping, sewing, knitting etc.) *(Gu & Liu, 2019).*

In addition to these subject-specific aspects, digital fashion designers

require horizontal soft-skills that are related to advanced organization, management and communication due to the multidisciplinary teamwork and global collaboration that this kind of work demands. Compared to traditional fashion designers, the importance of knowing how to work in teamwork and being empathic to other experts worldwide is crucial for digital fashion activities and project *(Sarmakari, 2021)*. Open-source fashion and shared resources between different digital communities of fashion designers is also a new interesting aspect of digital fashion because it offers students extra educational resources freely available on-line that allow a self-paced and personalised instructional: students can deepen certain arguments that are more connected to their specific interests, thus increasing their personal tastes and individual capacities *(Sarkamari & Vanska, 2020).*

On the other side, digital education is also based on a high capacity of computation of hardware and high-priced software licensing, along with the necessity of internet connection to browse and use the shared online services that complement the teaching of digital 3D fashion *(Sarkamari, 2021)*. If embarking in this new digital literacy in fashion education is fitting the required digital transformation of European education, it is also true that it requires new hardware (high-quality computers), new expertise of educators and teaching staff, *(Sarmakari, 2021)* and students' familiarization with 3D software requiring more instructional interactions to understand interfaces and digital sewing activities that may differ from the ones happening in reality *(Hwang & Hahn, 2017).* Even if the literature review shows an increasing interest in digital fashion, research studies on teaching experiences remain scant of deep analysis of (i) students' familiarization with digital fashion design learning processes and tools, (ii) trends and drivers of innovation of digital/virtual fashion solutions, and (iii) sustainability impacts of digital/virtual fashion solutions. In this chapter, we would like to present 'Fashion-Tech Interline' *(2021)* as a collaborative, interdisciplinary and international learning experience about digital/virtual fashion, attempting to address the identified gaps in current digital fashion education and pedagogy research posed by on-line and interdisciplinary teamwork. The learning experience will be used as a case study to discuss results in relation to emerging thematic issues for future research opportunities, and also reflecting on tools and methodologies for future Fashion-Tech didactic experiences.

2.2 FOCUSING ON THE LEARNING EXPERIENCE

Learning Experience contents description

Fashion-Tech Interline has been organised as a learning experience focused on exploring and getting students familiar with the opportunities of digitalization of fashion and the virtual dimension of fashion design, considering the impact of both digital[6] and virtual[7] fashion design on the whole fashion system including design, prototyping, production, selling, distribution and consumption processes. The aim was to understand the impact of digital technologies in the fashion sector, focusing on how digitalization could transform the entire supply and value chain of fashion industries to allow the mapping of new practices and products/systems/processes and market approaches emerging across the design, manufacturing and retailing phases.

The learning experience has been delivered completely in a digital and remote modality and has been divided in two parts: a preliminary theoretical part assigned in an asynchronous way (DISCOVER) and a subsequent synchronous challenge-based part (DESIGN). These two main elements were delivered as part of a presentation day dedicated to launch the challenge through a brief, company presentations. At the end of the event the students formed groups.(DEFINE). Students were asked to develop a solution and make concept prototypes of developed new products / processes / services (DELIVER). The structure and the contents of the learning experience have been condensed and presented within the Fashion-Tech Interline Syllabus *(2022).*

Brief indicative contents

The contents of the theoretical part (DISCOVER) were delivered through lectures, preparatory exercises and applicative sessions to level the knowledge of students in the five different disciplinary domains of the project: design, material management, engineering, product management and business development. A series of lectures conceived as theoretical pillars of the learning experience focused on:

- Fashion-Tech definition,

[6]Digital fashion was defined as the visual representation of clothes made with computer technologies, particularly 3D software. Examples of the clothes made digitally are in fact designed on computers, fed into a 3D printer and printed exactly as they looked in the computers.

[7]Virtual fashion was defined as the design and sale of fashion items for virtual platforms and avatars. Virtual garments are designed digitally with high photorealistic features but rather than be produced, they remain virtual and are used online, for their social media, their avatars, on life simulation video games.

- Near future trends and far future scenarios,
- Design Methodology of 3D modelling and virtual prototyping of garments,
- Digitalizing Materials for 3D Modelling,
- Simulating and rendering for digital Fashion Experiences,
- Advanced Manufacturing techniques in the digital fashion,
- Advanced 3D Modelling for Additive Production,
- Sensors and actuators for application in smart textiles,
- Digital value chain and business model development/ experimentation,
- Circularity and Industry 4.0.

In the challenge-based part of the course (DESIGN), students worked in groups to develop a virtual capsule collection made of one to three products of outerwear, whose aesthetics and functionalities could range from extremely fashionable to extremely technological. They should develop a comprehensive solution, tackling design, material management, engineering, project management including a business model. The following activities and tasks required teamwork: (i) Concept definition and design of the collection/products, (ii) 3D modelling and prototyping the collection/products, (iii) Fitting and Ergonomics modelling, (iv) Materials digitalization, visualization and simulation, in both style and functional perspectives, (v) Business development and business model innovation, and (vi) Project management innovation. Students were asked to work in groups and deliver contents to be accessed during the tutoring and mentoring sessions on a visual on-line collaborative board (MIRO) during the DESIGN phase toward the final presentation (DELIVER). Coupled with Microsoft Teams and Beep, this digital space gave the students the opportunity to collaborate as a team, setting a remote team culture, managing and delivering the project and also giving the possibility to work together in a digital classroom to allow every student to see other students' deliverables, reaching a peer-to-peer learning and eventually provide proactive/constructive feedback.

Course materials

For the Discover part (asynchronous theoretical part), the learning experience developed:

- An in-depth series of 24 video lectures and multi-media presentations with high-quality graphics & detailed descriptions (total 840 minutes);
- High-detailed examinations of the topics through digital documents, and readings (texts, documents, presentations) to achieve enhanced digital literacy;
- 5 comprehensive set of quizzes as assessment tests delivered via Google modules providing direct feedback on the learning outcomes;
- 12 practice-based propaedeutic exercises on the software CLO3D,
- 3 assignments with a peer-review activity among students via the online forum.

For the Define and Design parts (Brief Launch and Challenge based part), the learning experience delivered:

- 5 industry talks from industry experts from Pespow, Pangaia Grado Zero (PGZ), Thrill Digital, Wearfit and Il3x,

A set of specific templates and other document materials related to the challenge-based group project, that included: scenario board canvas, trend analysis canvas, moodboard canvas, Persona-target and lifestyle canvas, Concept and Sketches board, Market analysis canvas, Competitor analysis board, technical drawings canvas, materials and colours board, 2D pattern canvas.

Learning Experience Objectives

The general purpose of the learning experience was to train professionals who will become able to employ the potentials of digital technologies in the domain of fashion, and to drive design processes in interdisciplinary contexts. Through an innovative way of teaching, students achieved knowledge on useful tools to critically interpret the project dimension within the broader context of social, cultural, and technological contemporary shifts (new lifestyles and needs, new typological configurations and innovative technological scenarios).

The Discover part aimed to transfer student's knowledge on how fashion and digital technologies are interconnected, highlight the potential as well as the limitations of this interconnection to the entire value chain, from ideation to production, and from retail to communication. The challenge-based part of the course (DESIGN+DELIVER) aimed to explore the potential of interdisciplinary teamwork practices with students developing a project (a capsule collection of outerwear) that interfaces with the complexity of product ideation, design and engineering phases, and business model strategy development. Thus, it is aimed at training adaptive professionals to collaborate in delivering a project in the field of Fashion-Tech, requiring the combination of a creative attitude and deep understanding of technical/technological issues, and to allow

interdisciplinary interaction with other professionals.

Learning Experience Outcomes

Upon the successful completion of the learning experience, students are expected to improve their knowledge and understanding, as follows:

- demonstrate in-depth knowledge of the implications of digitalization and virtualization of the design process in relation to the entire product life management cycle, referring to the impact in terms of different structures of costs;
- demonstrate in-depth knowledge of the implications of digitalization and virtualization of the design process in relation to the innovation of the garment product in the design process, in communication, selling and commercial side;
- demonstrate in-depth knowledge of the implications of digitalization and virtualization of the design process in relation to business management.

They are expected to develop the following skills and abilities:

- to research and understand innovation and methodological processes;
- to develop 3D models from 2D technical drawings of fashion garments;
- to digitize, visualize and simulate materials for the digital fashion application;
- to identify and critically evaluate 3D software tools in textile and garment design;
- to develop an innovative business model related to digital/virtual design processes and products;
- to handle and understand digital/data-driven sustainable supply chains;
- to handle, plan and direct innovative and complex project management;
- to dialogue with other disciplinary contexts;
- to synthesize interdisciplinary contributions into possible innovation tracks and solutions;
- to Learn by doing.

Students also should achieve critical evaluation abilities such as:

- Identify and critically describe the limits and opportunities of 3D software tools in textile and garment design in all the phases of value chain: ideation, prototyping, visualization, communication, distribution, showcase, selling and retailing,
- Identify and critically describe the economic, environmental, and societal impacts of implementing a completely digital/virtual design and product development process,
- Reflect on complexities associated with virtual/digital implementation of a 3D collection /business,
- Critical skills and awareness of the ethical dimension of the profession,
- Co-Learning and co-working abilities in an international community.

2.3 METHODOLOGY

Learning Experience Structure and Outline

The learning experience was delivered over 8 weeks, from January to March 2021. It was developed in 50 hours in 8 weeks, delivering the knowledge and understanding of new ways to design a fashion product that integrates and interfaces with the digital and virtual dimension through a preliminary theoretical part (DISCOVER). A presentation of the challenge-based part and industry partners (DEFINE) both aimed to level the knowledge of the students and introduce them real-challenges as a prerequisite for the practical part of the course (DESIGN + DELIVER) (Fig.6).

THEORETICAL PART

0 WELCOME + INTRODUCTION + SYLLABUS

WELCOME (Week 1)

Teaching staff shared the syllabus of the course with the students, providing the project overview with objectives and guidelines, introducing the course structure, and contents related to digital prototyping which aims to set the expectations for student use. In addition, students were familiarized with the digital platform of the course and the software to be used for the DISCOVER part of the course: Beep platform containing all the theoretical pillars, and the licensed CLO3D software.

1 DISCOVER

DESIGN THEORY IN BRIEF MODULE | DESIGN METHODOLOGY MODULE | 3D MODELLING MODULE | MATERIALS & SENSORS MODULE | ADVANCED 3D MODELLING AND MANUFACTURING MODULE | SIMULATION AND VISUALIZATION MODULE | BUSINESS MANAGEMENT MODULE

THEORETICAL PILLARS

FLEXIBILITY: FREE CALENDAR + HOURS/ETC (SUGGESTED TWO WEEKS)

DISCOVER (Week 1-2)

The theoretical part of the learning experience aimed to become familiar with the technology and its implications from the design, business management and engineering perspectives. To achieve this, lectures about theory, methodology and application examples were provided. To familiarize students with 3D modelling technology, lectures about tools and software were accompanied with preparatory applicative exercises about digital modelling and prototyping, materials digitalization (including smart and eco-sustainable materials), garment's style and functions simulation, advanced manufacturing, integration of wearable sensors and actuators. Students were asked to work individually and asynchronously in an individual and self-paced modality, following the lectures and carrying out small tests, assignments and exercises to assess their achievements and preparation on the specified topics. This preliminary preparation was delivered to all the students from the different HEIs due to a deadline. In this phase, students were also required to participate to different activities of interaction such as chat, blogs, forums throughout curated online discussions aimed at communicating with course peers to exchange information, insights, results of the assignments and to start to know each other.

2 DEFINE

CHALLENGE LAUNCH
DIGITAL COMPANY VISIT
MODULE

CONTENT SPECIFIC

SYNCHRONOUS: ESTABLISHED CALENDAR

DEFINE (Week 3)

Students were briefed about the contents of the challenge –based part and the expected outcome of this practical assignment of the learning experience, aiming to experience the process and the methodological approach of a project development activity that includes design, engineering, product life management, costing and pricing, research and materials management. Companies delivered introductory lectures related to the topic of the challenge, allowing students to gather direct information and ask questions / interact with industrial partners. Students were also guided through ice-breaking exercises to allow acquaintance among team-members.

FIGURE 6 LEARNING EXPERIENCE STRUCTURE AND OUTLINE

PRACTICAL CHALLENGE-BASED PART

3 DESIGN

RESEARCH AND CONCEPT CREATION | CONCEPT DEVELOPMENT | PROTOTYPING CONCEPT | USER TESTING SIMULATING

TUTORING COACHING AND REVIEWING ACTIVITIES

SYNCHRONOUS: ESTABLISHED CALENDAR

DESIGN (Week 3-7)

Week 3 - Tutoring session about Research, Trend and Concept

Students were required to approach the interdisciplinary research, to analyse context and trends in social, technological and sustainable terms. The scope was to define the scenario and user lifestyle along with starting to design the project value proposition.

Week 4 - Tutoring session about Concept and Product Development, 3D Modelling and Virtual Prototyping, and Business Management and Innovation

Imagining to be a small fictitious start-up company to launch a capsule collection using digital and virtual design and prototyping processes in post COVID19 or the «Next Normal» situation, students were instructed to apply a design-driven innovation approach to ideate and conceptualize the capsule collection of three outerwear garments, starting with a traditional fisherman raincoat pattern varying the concept, occasion of use, style and aesthetical qualities, functionality and performances, materials, and manufacturing processes. They presented concepts and sketches, technical drawings, 2D patterns, materials and colours selection. Also, they started working on the software CLO3D, setting up their avatar, including the 2D pattern and starting the 3D modelling, annotating misunderstandings, and incurred problems. In the meantime, they also prepared an initial business innovation strategy, presenting two key ideas/elaborated business model canvas related to the SDGs and corporate sustainability strategy. Students were instructed to conduct interviews/surveys with their key users/stakeholders to have feedback on their project ideas.

Week 5 – Presentation and mid-term review about Project development Follow up tutoring sessions about 3D Modelling and Virtual Prototyping and Business Management and Innovation

Students were asked to share a presentation to show the advancement of their project. The reviewer committee had mixed expertise from fashion design, technical, digitalization and business sectors. The tutoring sessions about CLO3D was focused on 3D modelled outerwear, materials and colours selection and digitisation, rendering and visualization processes. In the meantime, students had to show data derived from interviews/focus groups and/or surveys undertaken with users/stakeholders and to deliver their proposed Business model for the project.

DESIGN (Week 3-7)

Week 6 – 7 Tutoring session on Service Development, 3D Modelling and Virtual Prototyping and Project Finalization and presentation

Students presented the mock-ups of their digital/physical services connected to their capsule collection. In addition to this, they presented their capsule collection through advanced modelling of the digital outerwear, checking materials integration, the import/export of 3D models, the rendered images and video frames of the outerwear.

4 DELIVER

FINAL PRESENTATION

RESULTS

SYNCHRONOUS: ESTABLISHED CALENDAR

DELIVER (Week 8)

Students were asked to prepare a pitch presentation, a video, a design report and a business development and innovation report. They presented their project to an interdisciplinary committee of tutors, professors and company members, and also got feedback also from peers.

FIGURE 6 LEARNING EXPERIENCE STRUCTURE AND OUTLINE

Participants

The classroom was composed of 47 interdisciplinary and international students and 15 teaching staff, collaborating with 5 professionals from Fashion-Tech companies, both internal and external to the FTalliance consortium (Fig. 7).

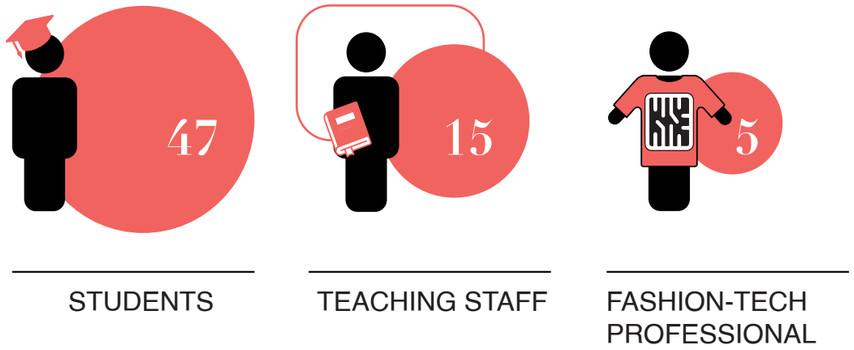

FIGURE 7 LEARNING EXPERIENCE PARTICIPANTS.

Teaching Staff

Teaching staff members were involved in delivering the learning experience as follows (Fig.6):

- 5 professors from Politecnico di Milano, School of Design (Italy) focusing on Computational Design, Virtual Prototyping, Fashion and Fashion-Tech Design;
- 3 professors from University of the Arts London – London College of Fashion (UK) focusing on Trend, Fashion and Speculative Design;
- 3 professors from Hogskolan i Boras - The Faculty of Textiles, Engineering and Business The Swedish School of Textiles (Sweden) focusing on Circular economy, value chain innovation, Fashion-Tech value chains and business models;
- 3 professors from TU/Delft - Industrial Design Engineering Faculty (The Netherlands) focusing on Smart materials and textiles;
- 1 professor from Ecole supérieure des Technologies industrielles avancées (France) focusing on Robotics.

The 80% (12 professors) were involved in delivering theoretical lectures during the theoretical part and the 40% (6 professors) was involved in delivering the challenge-based part of the learning experience.They were also available during the project design through a series of mentoring and tutoring activities covering different topics such as Computational Design, Virtual Prototyping, Fashion and Fashion-Tech Design, and Fashion-tech value chains and business models.

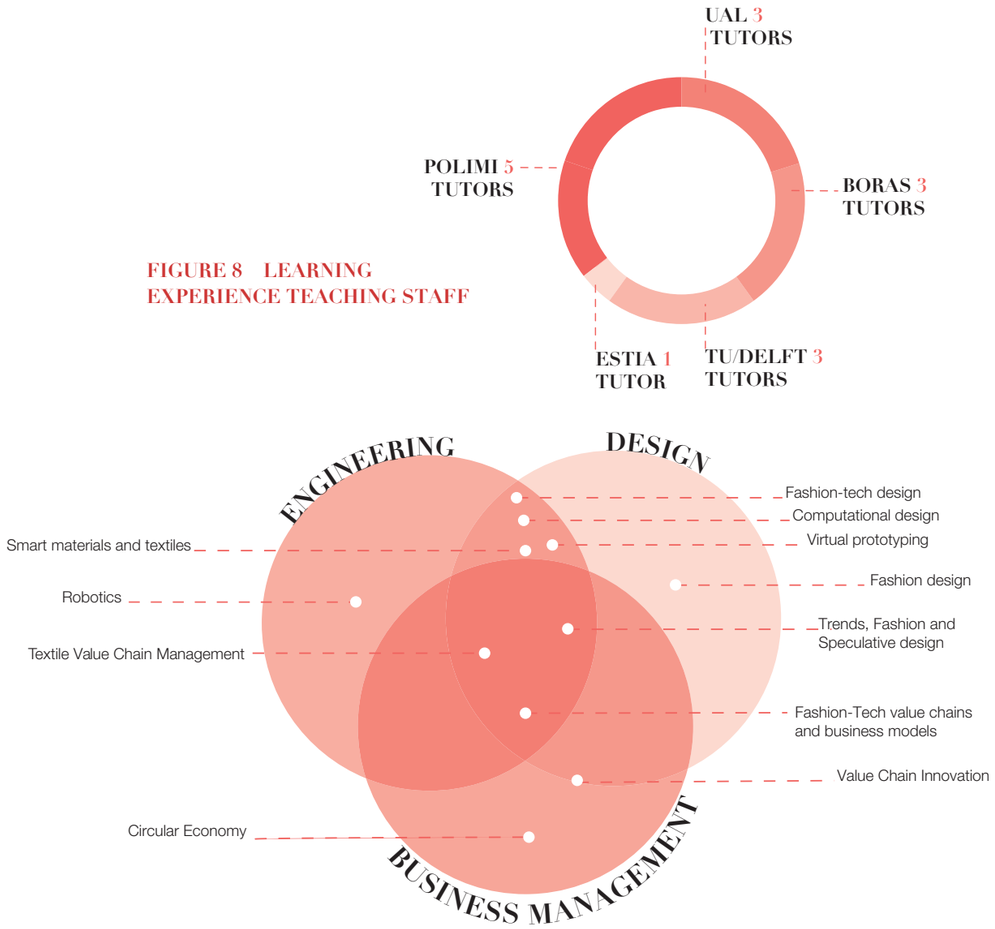

FIGURE 8 LEARNING EXPERIENCE TEACHING STAFF

Students

Students have been selected and participated to the learning experiences, as follows (Fig.8):

- 11 students from Politecnico di Milano, School of Design (Italy) (first and second year MA in Design for the Fashion System),
- 14 students from University of the Arts London – London College of Fashion (UK) (first year MA in Innovative Fashion Production),
- 9 students from Hogskolan i Boras - The Faculty of Textiles, Engineering and Business -The Swedish School of Textiles (Sweden) (First and second year MSc in Fashion Marketing and Management, Industrial Ecology, Textile Value Chain Management, Textile Management, Business Administration and Textile Management)
- 3 students from TU/Delft - Industrial Design Engineering Faculty (The Netherlands) (MA in Design for Interaction, Integrated

Product Design, Industrial Design),

- 10 students from Ecole supérieure des Technologies industrielles avancées (France) (first, second and third year BA Bachelor of Technology).

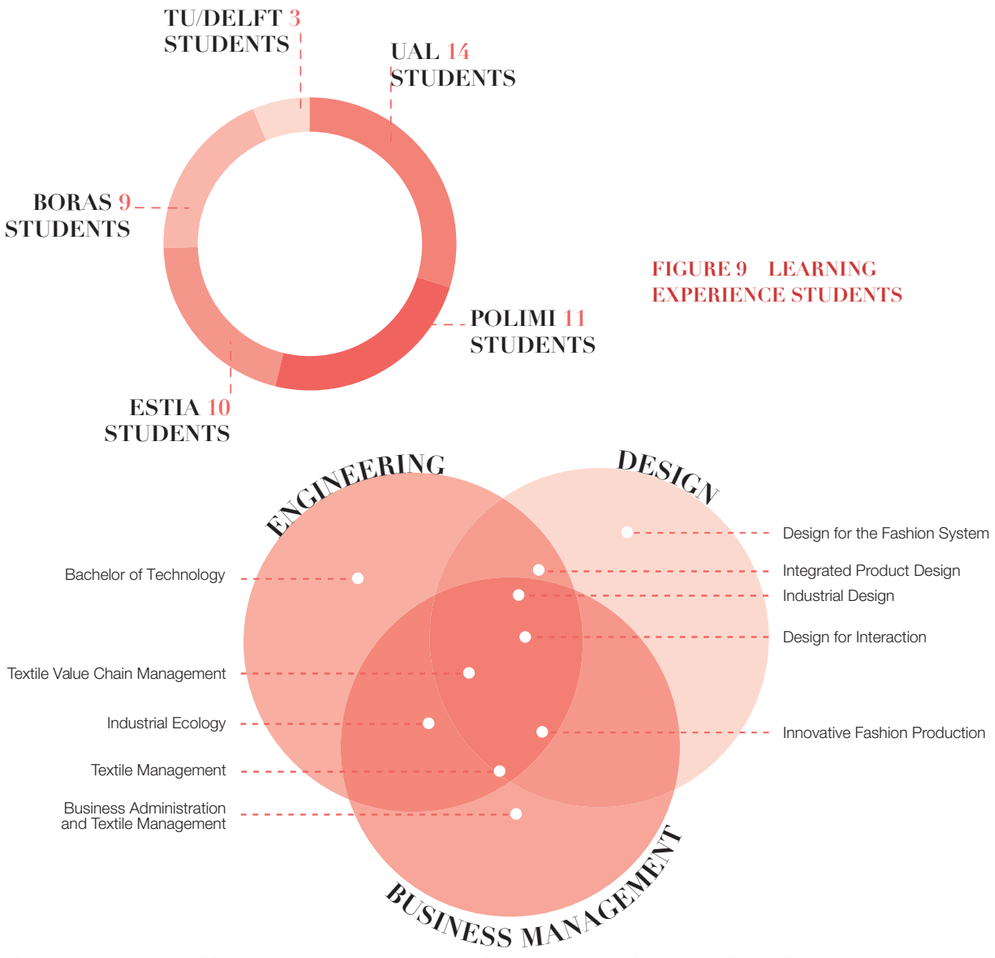

FIGURE 9 LEARNING EXPERIENCE STUDENTS

Students worked in 10 teams of 4/5 members each, with interdisciplinary background and similar abilities. Groups selection has been defined from the teaching staff, considering skills that students presented by answering to an initial survey.

The learning experience has been collaborating with two (2) Italian companies leading the sector of Fashion-Tech and partner of the FTalliance project: Cinzia D'Agostino from Pespow and Enrico Cozzoni from Pangaia Grado Zero. In addition to this, three (3) International Fashion-Tech start-ups active in the field of digital and virtual fashion design has provided their perspective on the topic: Alex Delz Erinle fromThrill Digital, Lukasz Rzepecki and Katarzyna Gola from Wearfits, and Erika Lamperti from Il3x.

2.4 RESULTS

The learning experience has been able to implement a series of the Subject-specific Skills as resulting from the three focus group and integrated into the E4FT project (see Chapter 1). Subject specific skills related to Fashion-Tech Design process and methodology and Fashion-Tech project management were implemented in order to allow students to collaborate from different disciplinary domains and to produce Insights into multi-disciplinary area of Fashion-Tech and its industrial applications. In particular, this learning experience focused on design, engineering and business management aspects related to the digital transformation of the entire supply and value chain, focusing on the use of digital technologies in the transformation of creative and operational processes and practices along with implication in the business creation and on sustainability from an holistic perspectives (Fig.10).

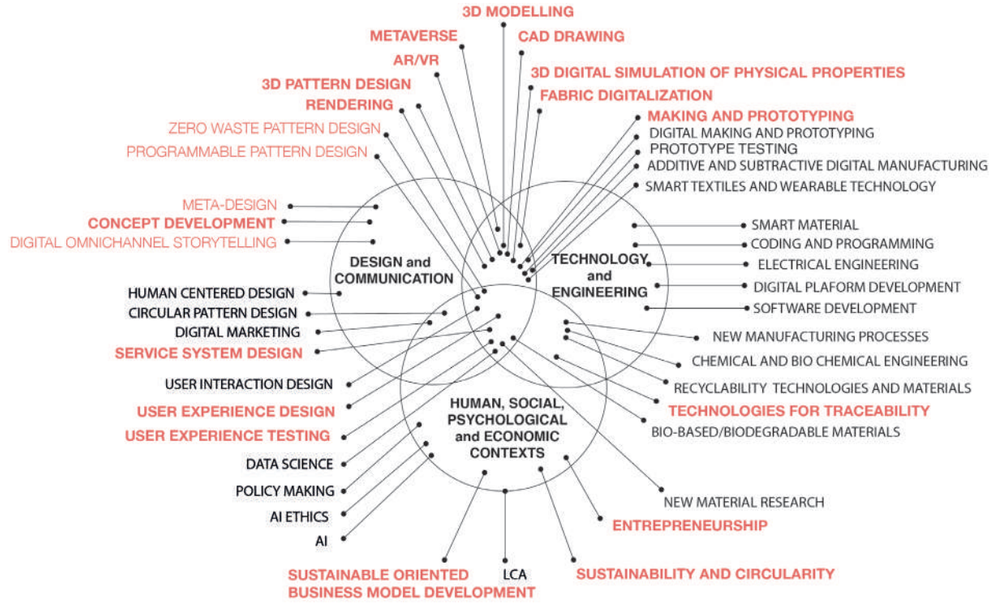

FIGURE 10 SUBJECT SPECIFIC SKILLS IMPLEMENTED IN THE LEARNING EXPERIENCE

Lesson learned from hybridizing design, engineering, and business management education

The examination of the didactic experience has identified opportunities and challenges when designing market-oriented solutions. These solutions explore and experiment with the virtual/digital dimension of fashion, hybridising design, engineering, and business management education. Lessons learned are extracted from a thematic analysis of the project documentation delivered by students during and after the didactic experience. The findings are clustered according to the projects' topics (trends and drivers, product and service interaction, contribution to sustainability) and elements influencing the process development (design and making of, skills and competencies, concept validation).

Reflections on projects' trends and roles of digital/virtual fashion solutions

All the groups identified emerging, timely, and critical issues to tackle, grounding the project in reality These issues included the COVID-19 pandemic related health and mental wellness crisis; sustainability, pollution and climate change; technology development, digitalisation and digital transformation; social media and digitally-mediated show-off culture; live experiences and show business; circular and sharing economy; political and social justice; customisation and personalisation; the sense of community, connectedness, and togetherness. Students demonstrated great sensibility of current issues and awareness of being in a time of transition, facing wicked problems with fashion assuming new roles to contribute actively. Specifically, the designed solutions aimed to raise awareness around psychological, societal and environmental issues [Follow the rabbit, Azzurro, Ahorn&Efeu, IPv6]; foster sustainable production and consumption behaviours [Ahorn&Efeu, TCP, Flow]; empower designers and consumers' creativity and self-expression [Brave New World, Ahorn&Efeu, Flow]; connect individuals within communities of like-minded people [IPv6, Azzurro]; engage in novel and alternative phygital experiences, virtual worlds, and digital twins [Proteus, Inspired, TCP]; educate consumers about care, heritage and culture [The Past to Remember]. The projects' outcomes ranged from social networks and/or co-creation platforms to AR/VR applications and experiences, digitalisation services and digital libraries. Interestingly, in many of the proposed solutions, the garment/capsule collection – whether in a physical or virtual format - was conceived as one of the "touchpoints" along the user journey part of broader experiences, as a means to access additional services, contents and experiences, beyond the clothing itself. For example, the project 'Follow the Rabbit' includes a limited number of lifestyle coaching and mindset consultations together

with purchasing the ready-made garment. 'The Past To Remember' project "takes physical garments as starting point" to attract consumers to the platform and lets them access and explore digitised vintage and historical garments and educational content. 'Azzurro' considers virtual garments as a medium to address mental health and wellbeing by communicating with friends, family, and health-related stakeholders the user's own feelings, through AR filters, based on the analysis of his/her social network activity. 'IPv6' platform aims to support activism and sensitise users around social justice and environmental-related news by offering individuals the possibility to personalise, wear digitally and share with the community a garment as a manifesto, considering literally "fashion as a means of expression".

Interaction between the physical In Real Life (IRL) and digital (URL) dimensions

The teams explored how the design of digital/virtual fashion solutions could act as enablers for value creation, exploring different interaction modalities and combinations of the physical and digital dimensions in phygital solutions. On one side of the spectrum, physical and digital can be conceived as inseparable and intertwined elements of the experience, where the former justifies the existence of its counterpart and vice-versa. On the opposite side, they could act as co-existent but experiential standalone components of broader service architecture. A transversal analysis of the students' projects offers an interesting outlook of innovation trajectories experimenting with diverse combinations of In Real Life (IRL) and URL ("Universal Resource Locator" standing for an item on the web) solutions.

From IRL to URL for valorising heritage

The opportunities offered by digitisation and digitalisation in transforming IRL garments to URL have been mainly investigated in the heritage preservation and valorisation scope. The project 'The Past to Remember' leverage 3D scanning technologies and reverse engineering to develop highly detailed digital twins of historical and vintage clothing. The digital nature of the selected pieces, together with a detailed description concerning historical, construction and material information, extends their lifetime, accessibility, and geographical reach, serving multiple purposes: from educational and archival to commercial ones.

Simplify IRL and signify URL

Many projects addressing the phygital dimension of fashion showed a particular tendency to simplify IRL garments favouring several and more complex "digital skins" and virtual experiences [Ahorn & Efeu, Proteus,

Flow]. The simplification of the IRL is rendered with expressions such as basic, neutral, and minimalistic design; simple, limited-edition and pure-functional clothes; sustainable, high-quality and performative materials. On the other side, the signification of the virtual dimension through digital skins, digital twins and the virtual world is conveyed through customised, augmented/virtual reality, surreal, endless and "limitless experiences of fast-evolving trends" (Ahorn & Efeu). From a business standpoint, the dynamic and ever-changing virtual skins are considered core elements of subscription-based business models, supporting users' long-term engagement and emotional attachment, thus impacting sustainable behaviours in terms of more durable and long-lasting experiences.

IRL experiences propelling URL dimension

In the case of inseparable counterparts, activities performed in the physical domain can be the propeller of the experience in the virtual world, activating positive, sustainable/healthy behaviours as in the case of 'Ahorn&Efeu'. While the brand sells simple physical garments and "virtual skins", the evolution and dynamic nature of the digital graphic pattern of the virtual outerwear is enabled by the user's activities in real life when they wear the garment. The more the user walks on the outside with it, the more the digital pattern evolves from seed to flowers.
Proteus develops made-to-measure and customisable garments updated every month through digital skins that enable new aesthetics or functionalities to enhance digital experiences in an alternative virtual world connected to the same physical garments.

Personalization and customisation of URL and IRL fashion

Digital fashion has exceptional potential to foster personalisation and customisation by offering its customers – whether they are designers or consumers – platforms to combine and give a personal touch to garments. The virtual domain enables various degrees of customisation from static/interactive prints, photos, and texts to be applied on a standard garment as canvas [IPv6] to modular patternmaking systems to further personalise with static/dynamic visuals [Brave New World, Proteus] as well as multimodal input (i.e. sounds), beyond the visual dimension [Flow]. Several projects [Flow, Brave new world, TCP, Proteus] also investigated the opportunities offered by digital garment customisation platforms for the on-demand production of physical garments. However, the results showed that at this stage of concept development, students underestimated the implications of such systems since the degree of freedom allowed to the consumer in the customisation process highly affects the logistic challenges the brand will need to face with respect to supply chain, inventory, manufacturing facilities, etc. Micro urban digital factories in a distributed manufacturing logic could support reducing pressure in centralised production sites; however, while theoretically sound, its practical feasibility is still challenging (Singh Srai et al., 2016).

URL gender-neutral collections

The virtual domain seems to stimulate designers to overcome traditional binary genres, letting the development of hybrid virtual identities surpass the limits of the physical and empowering imagination beyond the distinctions between male and female, young and elderly. Most of the projects released gender-neutral, unisex, genderless garments, using those terms as synonyms [Brave New World, Proteus, Azzurro, Ipv6]. The choice of developing a gender-neutral collection appears to be driven by multiple reasons: the widening of the catchment area of the service, addressing universal needs such as self-expression, and demonstrating sensitivity to the current discourse around gender identity. Due to the limitations of the CLO3D software, projects could not succeed in the technical implementation of a gender-neutral collection, creatively exploring the limitless possibilities of designing avatars beyond the female and male dimensions. Additional software should have been used to design complete customisation of the avatar beyond the human dimension. To be able to design for these kinds of experiences, designers should acquire additional skills and knowledge and find the appropriate software allowing them to design and implement otherworldly aesthetics.

Reflections on sustainability

Sustainability has been a relevant component of many stages of the learning experience challenge-based phase. It was directly addressed in the theoretical lectures (see paragraph 2.2), and was part of the design and Business Management Innovation brief. Students addressed the following sustainability issues with their phygital fashion solutions: overproduction and over-consumption, materials and manufacturing transparency, resources exploitation, social justice, inclusion, and human wellbeing. Below, an overview of the objectives and strategies developed within the projects is offered.

Phygital fashion solutions contributing to the SDGs

The most cited Sustainable Development Goals recognized to be highly affected by digital fashion solutions are Industry, Innovation and Infrastructure (SDG9) and Responsible Consumption and Production (SDG12). This is due to the change of paradigm in designing, prototyping samples, producing and communicating fashion garments, potentially affecting the supply chain entirely and limiting the exploitation and consumption of resources, thus reducing material waste.

Gender Equality (SDG5) and Reduce Inequalities (SDG10) were also frequently addressed by the projects through the development of genderless/unisex/gender-neutral collections. However, the link between these SDGs and the actual contribution of the projects seems marginal and demonstrates an oversimplification of the complexity of such a contemporary and relevant topic. Guidelines to address this topic should be more thoughtfully explored in the teaching and learning activities to understand how phygital fashion solutions could actually give their contribution.

Limiting the environmental impact of the physical dimension

Designing phygital solutions drove many of the groups to consider not only the role of the physical counterpart of the experience but its environmental impact as well. Many strategies have been identified on how to achieve this aim. For example, [TCP] proposed a service where the physical garment had a digital counterpart and the physical was delivered in a limited edition only. Some groups presenting physical collections [Flow, Follow the Rabbit, Brave New World, Proteus] proposed a made-to-order and on-demand production service to limit over-production and over-consumption. These solutions were mainly related to business models founded on customization and co-creation.

A core topic that was discussed by all the groups was the choice of materials as vehicles of sustainability. While IPv6 included a materials search tool in the platform to offer a tactile option to its customers, Ahorn & Efeu's collection comprised biodegradable fabrics and Inspired and Flow privileged second-hand materials not necessarily coming from the fashion industry.

Finally, all projects presented the students' biases about the sustainability of digital solutions due to the product dematerialisation that makes virtual fashion items pollution-free and sustainable by nature. In contrast, the footprint of the digital fashion system accounts for the invisible infrastructure that is behind programming, rendering, and digital consumption of 3DVD products (Andrae, 2017), including the energy consumption of data centres, networks, and blockchain transactions (Sedlmeir, Buhl, Fridgen et al. 2020).

Designing for longevity

Another relevant approach visible in the proposed solutions are the different ways the teams designed to extend the lifespan of the physical products/services. The proposed "design for longevity" strategies leverage both physical and psychological aspects.

Among the main tactics for "physical longevity" there are the selection of durable, long-lasting and quality materials [Flow, Proteus, Inspired], the design of modular, transformative and multi-purpose products [Inspired], as well as services and educational materials related to garment's maintenance, repair, care, and re-use [Flow, The Past to Remember], were explored. On the other side, tactics to foster "psychological longevity" were enacted through customisation and co-creation platforms and services [Brave New World, Flow, Proteus], transparency of information around the product lifecycle, materials and production facilities to augment the trust and commitment to the brand [IPV6], emotional attachment [Azzurro, Inspired, Ahorn&Efeu], digitalisation of heritage and historical garments [The Past to Remember], interactive phygital experiences through gamification and the possibility to access endless virtual skins over time [Proteus, IPV6, Ahorn & Efeu].

Sustainability at-all-cost for unsustainable phygital solutions

The desire to address micro aspects of the project through a "sustainable" lens led to overcomplicated and complex systems, failing to be sustainable overall. For example, providing high degrees of virtual customisation, plus on-demand garment manufacturing using recycled fabrics from sails, including the repair and swap services [Flow], shows little awareness of the logistic and economic effort of these services. The desire to be sustainable at all costs made the solutions highly unsustainable from a different perspective.

An accurate analysis of the projects reveals an "all or nothing" and over-positive approach when dealing with sustainability. Students were asked to reflect on the possible negative impacts of their proposed solutions concerning the sustainability and circularity of their business models. Half of the groups stated only the positive impacts [Flow, Follow the Rabbit, Azzurro, IPV6, Inspired, TCP] and three groups [Proteus, The Past to Remember, Inspired] did not address the question at all. Only two groups [Brave New World, Ahorn & Efeu] out of ten demonstrated a thorough awareness of what was required at that stage, exploring the risks and impact of their designed solution. Five groups [Azzurro, Follow the Rabbit, Brave New World, Proteus, IPV6] stated to support five or more SDGs, demonstrating a limited understanding of many of them. Removing negative implications and throwbacks demonstrates that students achieved poor critical thinking and evaluation skills.

Reflections on phases of the didactic experience

Design. Phase 1-2: Research, trend and concept development

The first phases of the challenge-based part of the didactic experience was characterised by research, trend and concept development. In addition to the asynchronous lectures (see par. 2.3), students were provided with actionable tools to support the project reasoning (scenario building template, lifestyle board, value proposition, and business

model canvas). In this initial phase, materials assisting the exploration of near and future trends were particularly relevant in helping students unpack an emerging phenomenon by identifying the innovators, drivers, present-day impact, consequences, and short-term/long-term future developments. The trend research and scenario building aimed to inform the value proposition development. The request to frame an initial value proposition seemed to guide students to ground their project further, detailing what solutions they were offering, the target consumer and pains they were addressing, benefits deriving from the adoption of the solution and differentiation factors concerning competitors. While some groups succeeded in performing this step, others experienced difficulties transitioning from a macro/general to a micro/applicative perspective. The request to fill the business model canvas at this stage was probably premature. The groups attempted to fill in the canvas, but the results were often questionable. Detailing all the business model components before a thorough definition of the value proposition could have compromised the tool's efficacy. In addition, several projects addressed more than one value proposition simultaneously; this led to the presentation of ever-complex product-service systems to deal with, considering the "start-up" stage students were asked to simulate.

Design. Phase 3a: 3D Modelling and virtual prototyping

The opportunities offered by CLO3D software have been well received by students, even if some problems emerged during their use. In general, students from fashion design adapted with a certain difficulty to a new virtual modality of prototyping cloths, but the learning curve increased very rapidly. All projects could be realised through the software application, although with different levels of accuracy and different results in terms of quality and complexity achieved. According to the students, CLO3D software limitation and basic students' skills in using the software affected the brand image and "coherence of the project itself" [The Past to Remember]. Among the difficulties encountered with respect to manual/analogue fashion design and patternmaking, students quoted technical problems (i.e. manipulating multi-layered garments, Brave New World, difficulties in controlling the silhouette in the digital setting [Brave New World], and the difficulty of achieving photorealistic images [The Past to Remember]. Before and during the virtual prototyping, all the groups developed and refined the collections (CLO3D, Illustrator, Photoshop) digitally to support idea generation and decision-making processes. One group [Inspired] realised the physical prototype of the multifunctional garment to support the reasoning on its functioning and implement the virtual prototyping that was not allowed via CLO3D software. In this regard, virtual prototyping allowed students

to experience the opportunities and limitations of the technology, compare the analogue and the digital modalities, and find creative solutions to issues identified along the path. Proteus, Inspired, and Azzurro combined the collection development in CLO3D with additional software to craft particular effects foreseen by the concept (Blender and Unity) were adopted to include unconventional materials, dynamic effects and Augmented reality features. However, due to the lack of time and skills, students found it very challenging and seldom simulated the concepts in other ways to render the idea. In addition, due to time limits and the novelty of the software, the virtual collections developed during the course with CLO3D did not present a high level of detail from a technical perspective. However, from the students' reflections on the collection realisation process emerges a deep awareness of the wealth of transversal and varied skills in virtual prototyping necessary to achieve a realistic account of the designed solution.

Design. Phase 3b: Business Management and innovation

This phase of the learning experience comprised of the three following sub-phases:

1) Business model ideation via sketching possible business model design with help of business model canvas templates. At this step students were asked to sketch at least three ideas of business models at the higher level of abstraction, without detailed elaboration on all building blocks of the business canvas. This deliverable was reviewed in a preliminary session with students.

2) Furthermore, a selection and development of two key ideas with detailed elaboration of two business model canvas based on desktop research and reference to specific SDG targets was asked. It was followed by discussion of the method to test the suggested ideas with potential users and key stakeholders. The preferred method applied by all students included interviews and surveys. Tutoring and feedback on this step was implemented during the review session dedicated exclusively to business management and innovation;

3) Presenting results from interviews and surveys and refining the developed business model canvas based on collected data, followed by critical reflection of how selected business idea positively and negatively affects the initially targeted SDGs.

The final deliverable on business management and innovation phase comprised of the 2500-3000 words report, with detailed reporting template being provided to students.

Reflecting on implementation of the business management and innovation phase, it should be mentioned that diversity of business model ideas was proposed by students based on the application of diverse

digital technologies in different parts of the value chain, leading to novel practices of product development, design, manufacturing, distribution, consumption and reinventing the user's experience. These models aim to support transition towards more sustainable & circular fashion system, e.g., by enabling 'servitization', reduction in wastes and consumption levels, and more sustainable lifestyles. However, while sustainability was treated from diverse perspectives (including environmental, social and cultural dimensions), majority of groups didn't go in the details of the specific targets under the selected SDGs. Moreover, in some reports very broad range of SDGs was related to, instead of focusing on few goals but in more detail.
Although students have succeeded with empirical data collection as part of business model testing, findings were not always sufficiently reflected upon in presenting the final solution. Some groups provided the final visuals of the business model canvas without much reflection and elaboration on each element and how it is supported by collected data. Moreover, given the short period of time to administer interviews and surveys, rather limited data sets were collected to allow for comprehensive validation of business idea in all student's projects. Future learning experience should allocate more time for business model testing activities providing students with opportunity to develop and implement rigorous methodologies for data collection and analysis.

Design. Phase 4: Service Development, experimenting, testing

Contemporary to product development, students were asked to design the product-service definition at a mock-up level. The design of the user experience, even if interesting and sound on a theoretical level and from a simulation perspective, was not allowing students to grasp the limits and opportunities of the technology. Since a real simulation of the service (through interactive and functioning platforms) was not implemented in the educational units, students developed very complex and conceptual product-service systems that will be very difficult to work out in real contexts. Lacking this reality check, the conceptual account of the designed system does not allow students to conceive the actual effort necessary for its technological realisation, limiting their awareness of the actual challenges.
Students were asked to perform a reality check of their business idea, adopting qualitative and quantitative methods learned during the asynchronous course phase as tools for concept validation. Including a "reality check" during the project progress proved highly beneficial to let students discover the relevance of involving users as sources of inspiration, information and concept validation. Most of the groups selected online surveys as the privileged method, and a few included initial sketches of the proposed solution in the survey.
However, from an accurate analysis of how the different groups deployed their research, a few limitations have been identified and need to be addressed. Many groups disseminated the survey among personal contacts, friends, and university colleagues for time-related issues. However, they stated afterwards that the participant base of the study was not or partially representative of the target using their product/ service aimed to address. This led to several issues, among which an arbitrary and biased choice of the findings impacted the project's evolution. On the one hand, many groups changed their design and business-related assumptions based on the survey findings, besides the non-representativeness of the study participants; on the other hand, some answers considered contradictory with respect to the project statements were labelled as "not applicable" because of the non-representativeness of the target group. This means that in case the survey is not thoughtfully crafted and the participants' base is not well-founded, it could lead to misleading actions and decisions. In addition, asking students to perform user research to validate an already defined and advanced project could make it difficult to pivot and integrate feedback.

Reflections on the tools of the didactic experience

Miro Board set-up for team collaboration, iterative reviews and presentations

The access to a well-structured shared platform allowed all group members to contribute in real-time to the project's iterative updates. It guided the students through the project development phases, aligning the groups' advancements by marking key dates and materials required. However, many students felt under pressure for the weekly reviews on the projects' advancements based on predetermined templates because of the complexity of applying the teachers' feedback and suggestions to all the different aspects of the projects, from the product and service design to the business and sustainability innovation strategy.
The possibility of hosting the entire project development for several groups on the same board was rated as positive since it allowed to record the evolution of the project, facilitate peer-to-peer learning, and ease the review process of the different phases with the course teachers. However, the organization of the board in disciplinary silos may have strengthened the students' perception of not having learned skills belonging to different disciplines. The results of the projects and the observation of the students' paths allow the teachers to affirm effective contamination of knowledge and basic skills among the different members of the group.

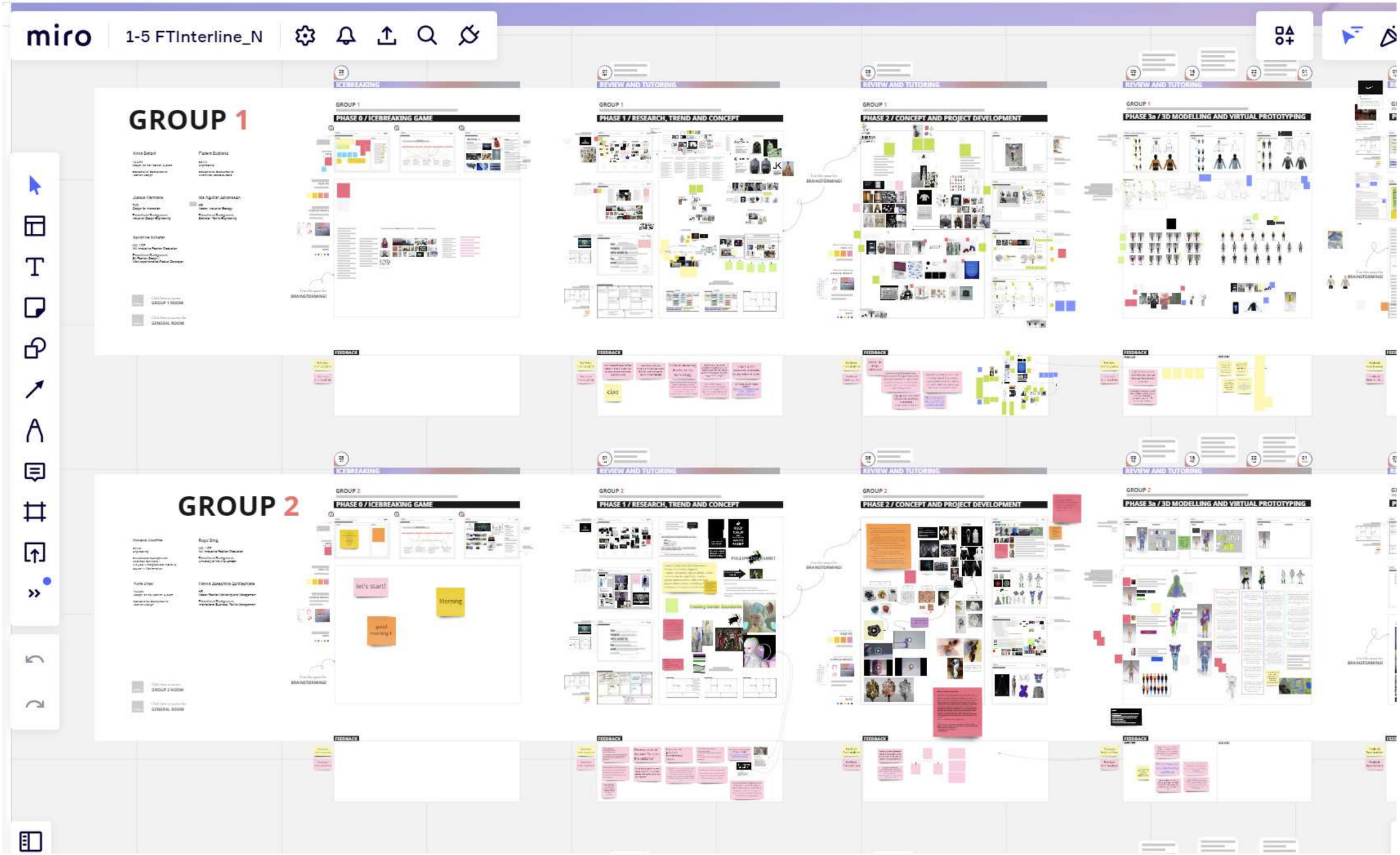

FIGURE 11 - MIROBOARD FOR COLLABATIVE DIGITAL CLASSROOM

Opportunities and limitations of the case study

Being a case study with many participants, this study was not without limitations. The current sample of participants was based on convenience sampling techniques, so this prohibits generalising the findings. In addition to this, the specific brief and the used software defines certain limitation and borders to the achieved results that limit their abstraction and universal application. However, the findings provide directions for future research in understanding opportunities and limitations in 3D digital and virtual modelling learning processes for developing subject-specific skills and soft skills derived from the interaction among students from different disciplines. This could offer educators and teaching staff insights, designers willing to upskill or reskill toward the digital and virtual fashion, and software designers and developers for more user-friendly and practice-based interactions with the software. Possible future research could replicate this study implying larger samples, and assessing different learning processes, comparing different software for 3D modelling of fashion garments in fashion design courses. The learning experience results bring out several lessons, opportunities, and suggestions for future implementation.

The **innovation trajectories** emerging in the concepts developed by students, whereas not exhaustive of all the opportunities offered by phygital solutions, outline interesting accounts requiring research and educational effort to be further investigated. The following topics should be further explored through practice-led/driven/based research, and theoretical design, engineering, and business foundations should be developed to support students in developing phygital solutions:

- the relations between and roles of the physical and the digital;
- how to design garments that co-exist in multiple realities;
- the logistical, technological and manufacturing challenges emerging from the development and delivery of phygital solutions;
- Business Models and innovation strategies;
- the holistic perspective of the sustainability of virtual fashion products/services;
- the new communication paradigm that virtual fashion can play.

In this regard, fashion has always been considered “a means of” communication of status and self-expression beyond its very functional and protective properties. By adding a digital and virtual layer to the traditional physical experience of apparel, virtual fashion design is extending its reach, embracing and playing an active role in new communication paradigms.

In order to help students to deep inside problem definition at a micro-level during product-service concept definition, staging gradually from general issues to be addressed to more specific needs to be solved, additional tools could be designed/included. These should increase step-by-step the granularity of details as part of the research and concept development path. Additionally, requiring a structured competitor analysis could be helpful to support the project’s reality check and as an inspiration. At this stage, it could be beneficial to break down the filing of the Business Model Canvas over time, along with the project development.

In terms of **sustainability**, it could be helpful to gradually approach SDGs through case study applicative sessions in which existing brands’ practices are analysed and synthesised to tackle the goals. This could be done as exercises during the asynchronous or the synchronous part of the learning experience. The challenge-based session could be productive to select and focus on a maximum of three SDGs to increase the deepness and understanding of how they can actually contribute to their realisation. To allow a real sustainability check of the implemented product/service solutions, students should be provided with sustainability assessment tools and dedicated exercises to inform the evaluation process, helping to boost their critical and analytical skills in research and identification of risks, barriers and unintended impacts. This could be beneficial to let them develop relevant competencies, and further ground their solution in reality, support raising their awareness around this topic.

To support the understanding of **virtual and physical prototyping** opportunities for fashion designers, future courses should focus on exploring the iteration of physical/virtual to grasp interactions, interconnections, and differences in terms of meaning, functionality, and sustainability. Working on a short–time course was detrimental to the complex and high-quality visualisation of the products. To obtain photorealistic and sophisticated IRL/URL products without blowing up the computer, designers are required to possess advanced skills and high-powered computational equipment and demonstrate problem-solving capabilities, putting into play tweaks and tricks to negotiate simplification and complexity according to the desired outcome. A second stage course with higher-level competencies could follow up on this one for deepening the complexity of garments and the photorealism of the solutions. In terms of services, instead, future courses could include lectures on the development and functioning of applications and platforms to support their eventual realisation in order to allow higher awareness of technological potentialities and limitations.

The reality check is crucial in many stages of the **project implementation**, particularly during the idea generation and concept design. Future

courses should anticipate the involvement of the target group in the early stages of the process, providing theoretical pills on Human-Centred qualitative methodologies to gather insights to inform the project development. An interesting addition could be designing and letting the target group interact with a Minimum Viable Product, an essential and simplified version of the product/service with enough features to allow potential users to give feedback on its future development. In this way, questionnaires, interviews, and observation methods would not be adopted only as ways to understand if the proposed solution takes root, but as tools to explore users' needs and wills and unintended uses and behaviours. Instructing students on how to integrate the insights coming from these research methods at a different stage of the project development without hiding uncomfortable feedback could help them root their solution into reality further.

To boost **interdisciplinary activities**, it is desirable to design digital tools and learning experiences as shared and collaborative paths, guiding the interdisciplinary process and making it evident to all stakeholders (students, teachers, and companies). Some actions that could be implemented are: include reflection moments on disciplinary contamination along with the project development, designing the board so that the individual and discipline-specific contributions are manifest and guide the decision-making process towards their integration in a joint agreement (i.e. design-oriented, business-oriented and engineering-oriented mood boards, research through specific disciplinary lenses, idea generation and creativity map, etc.).

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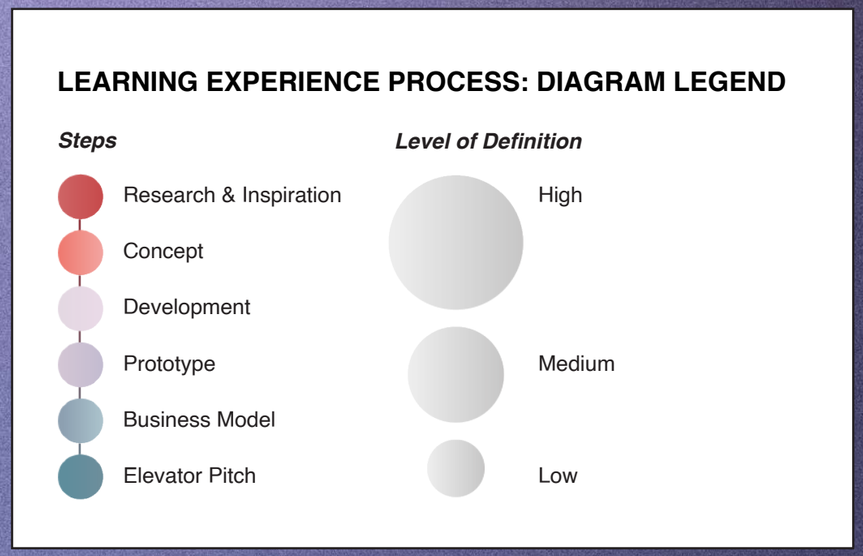
FIELD EXPERIENCES
The portfolio of innovative fashion-tech concepts of product and services

FLOW
FOLLOW THE RABBIT
BRAVE NEW WORLD
PROTEUS
AZZURRO
THE PAST TO REMEMBER
AHORN & EFEU
IPV6
INSPIRED
TCP



FLOW

Anna Baroni, Design for the Fashion System (POLIMI)
Florent Dublanc, Engineering (ESTIA)
Justus Hermans, Design for Interaction (TUD)
Ida Aguilar Johansson, Industrial Ecology (TUD)
Sandrine Schäfer, Innovative Fashion Production (UAL-LCF)

#CUSTOMIZATION **#ON-DEMAND LOCAL PRODUCTION**

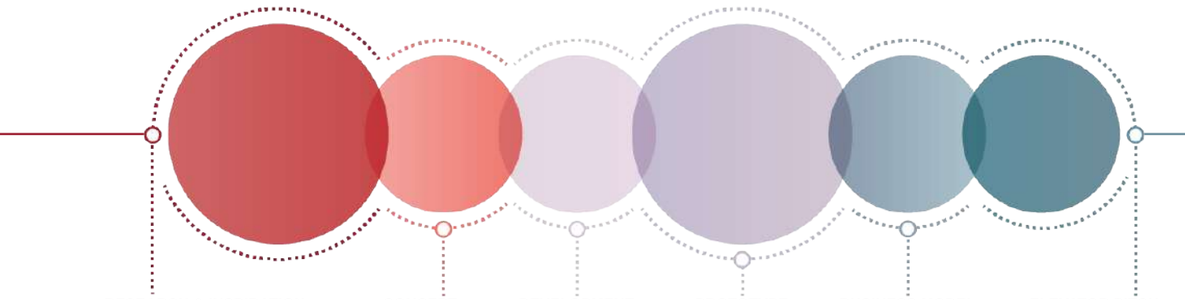
ABSTRACT
Flow develops customisable modular jackets based on sound and imaginary, to help the proactive generation (25-35 years old) to express and create consumption awareness. It aims to create an immersive customer involvement, reduce passive consumption behaviours, increase a proactive community, and enable a change of attitude. Growing service and experience design market are the focus of Flow, that combines the virtual with the analogue dimension.

LEARNING OUTCOMES

Soft Skills
Knowledge exchange
Research and critical thinking
Time management

Subject Specific Skills
Business model development
Virtual prototyping via CLO3D
User journey mapping

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Scenario building, target audience & lifestyle board, value proposition

CONCEPT
Phygital jackets to raise consumption awareness

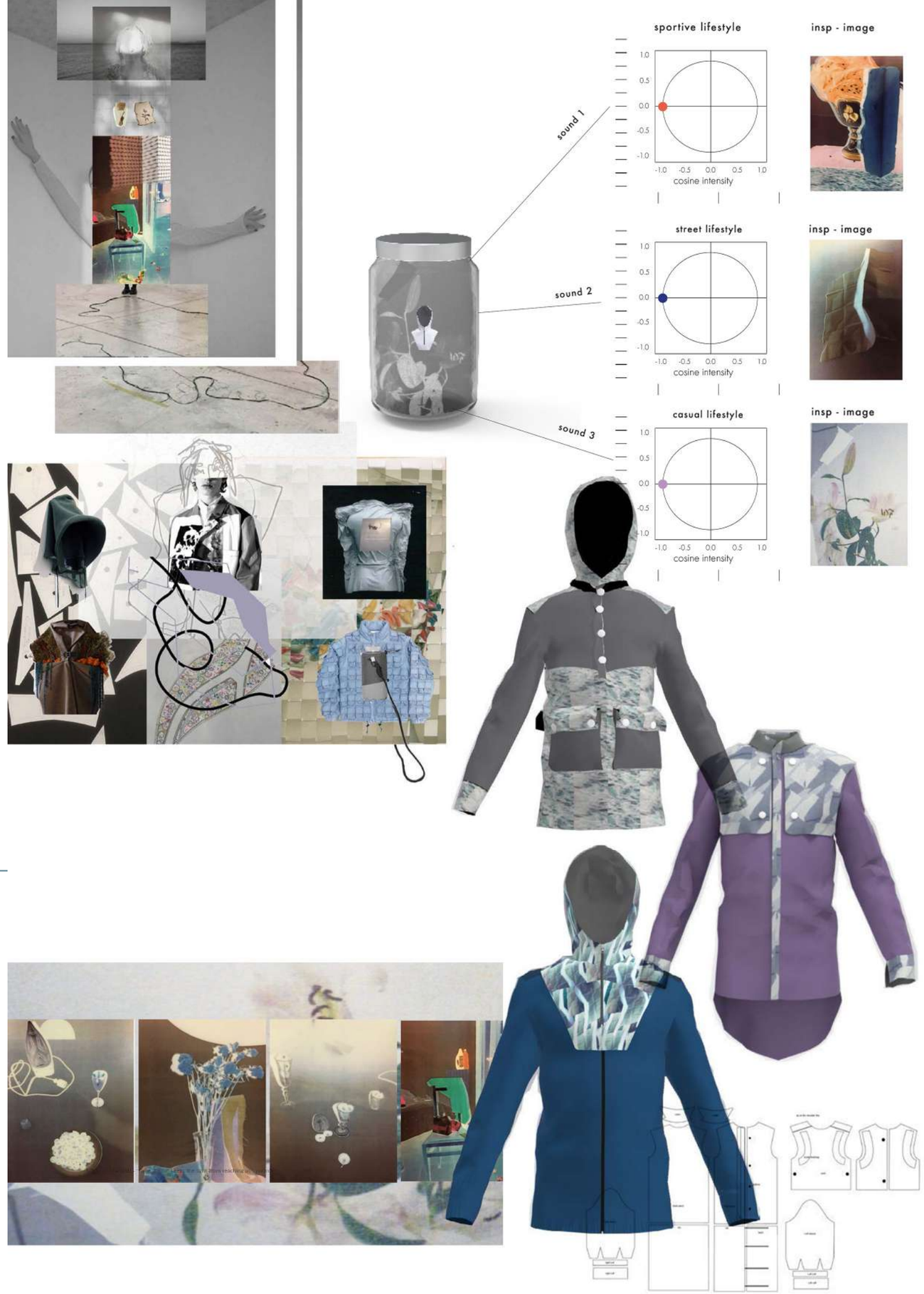
DEVELOPMENT
Virtual and physical materials, moodboard, technical drawings

PROTOTYPE
3D model, collaboration with artists mockups

BUSINESS MODEL
BM canvas, circular model canvas & user testing via survey

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS
Target 12.5



FOLLOW THE RABBIT

Roxane Couffitte, Engineering (ESTIA)
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Hanna Josephina Schliephake, Fashion Marketing and Management (HB)
Yuhe Zhao, Design for the Fashion System (POLIMI)

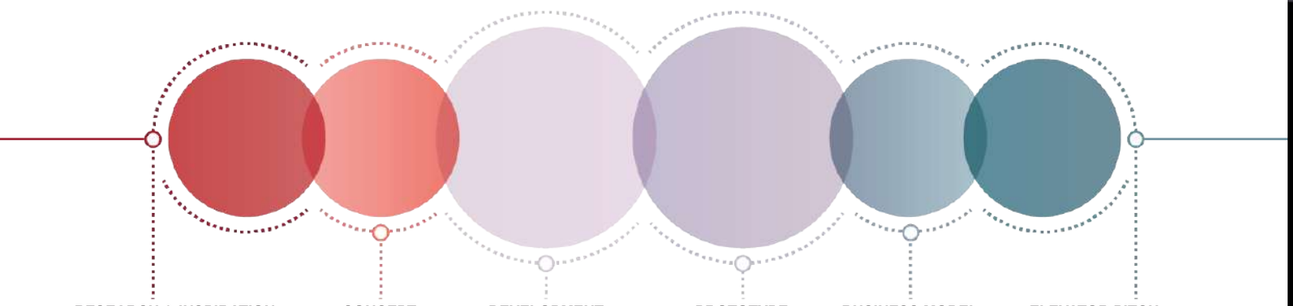
#EMOTIONS **#FUTURISTIC** **#SHAPE-CHANGING**

ABSTRACT
Follow the Rabbit developed a jacket capsule collection called “eMotion”. It invites everybody (ageless, genderless, technology enthusiast) to experience negative feelings in order to become aware of them and actively let them go, with the aim of creating one’s very own power to gain strength and self-esteem. Competing in the growing e-health market, the brand proposes digital and physical jackets that change in shape according to specific emotions and feelings, which are detected by sensors included in the garment.

LEARNING OUTCOMES

Soft Skills	***Subject Specific Skills***
Multidisciplinary collaboration	Shape-changing animations
Knowledge exchange	Avatar design
Real company project	User journey mapping
New design methods	Business model development

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Scenario building, lifestyle board, value proposition

CONCEPT
Shape-changing, emotion-detecting garments & app

DEVELOPMENT
Materials & sensors definition, moodboard, sketches board

PROTOTYPE
Special avatars design, 3D model, dancing animations

BUSINESS MODEL
BM canvas & user testing via survey

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS

BRAVE NEW WORLD

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#HIGH FASHION **#OPTIONS** **#COMMUNITY VOTING**

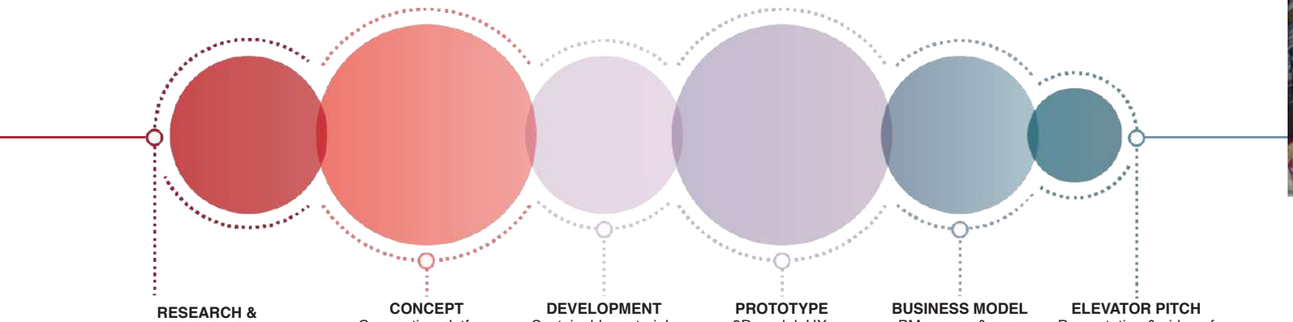
ABSTRACT
Brave New World is a subscription based, fully transparent co-creation platform that helps fashion pioneers connect and create together, providing an innovative and transparent approach to the fashion design process and giving a voice to every member of the community, with particular attention to ethic and sustainability. On this platform, users are guided through the fashion design process while providing full details about materials, suppliers, manufacturers, costs. The platform offers two modes: expert mode and story mode. The former is designed for people with advanced skill sets who are comfortable with sketching and using software freely, while the latter is more accessible and allows users to modify the 3D visualization of garments developed directly on the website.

LEARNING OUTCOMES

Soft Skills
Experimental process
Overcoming technical difficulties

Subject Specific Skills
Website design
UI/UX

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Future scenarios, lifestyle board, innovative services research, value proposition

CONCEPT
Co-creation platform for sustainable garments design

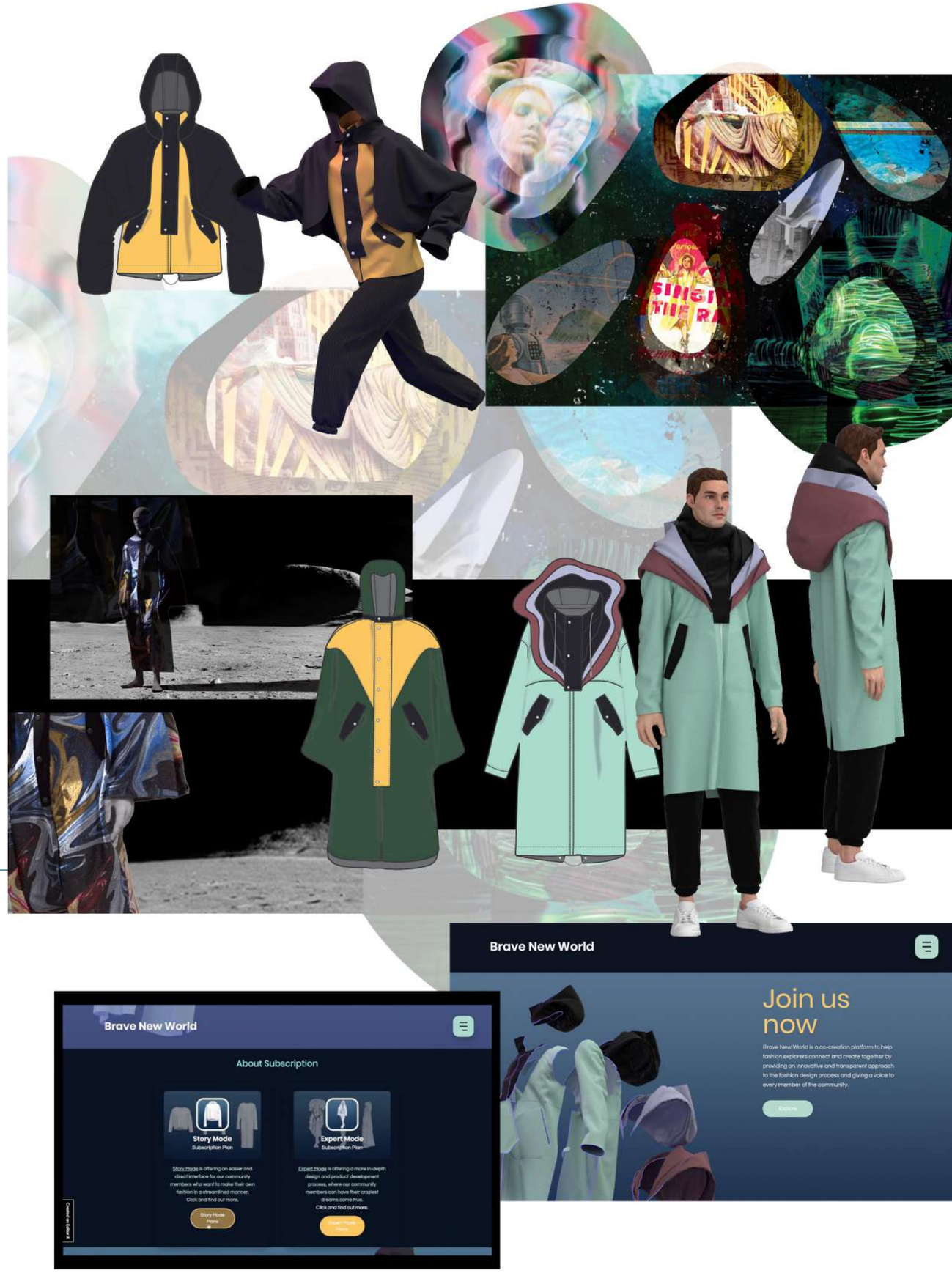
DEVELOPMENT
Sustainable materials research, moodboard, sketches board

PROTOTYPE
3D model, UX, website mockup and development

BUSINESS MODEL
BM canvas & user testing via survey

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS



PROTEUS

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#EXPLORE **#HYBRID** **#AI** **#NEW WORLDS**

ABSTRACT

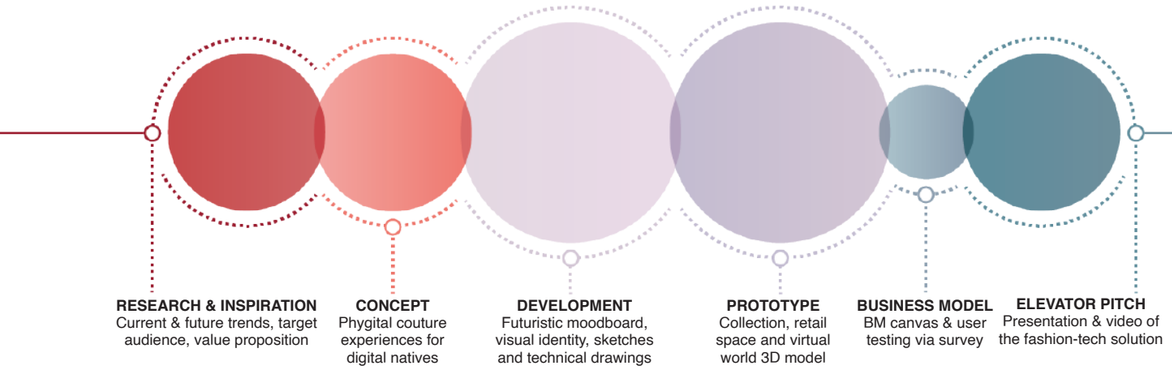
Proteus develops made-to-measure and customisable garments that come with new digital skins every month. They are inspired by a monthly theme that is showcased using V.R. technology to create new worlds to explore. Competing in the growing hybrid and digital fashion market, the aim is not only to provide Gen Z with long-lasting, sustainable, and customisable perfect fitting garments, but also to offer digital garments to overcome the overbuying caused by social media.

LEARNING OUTCOMES

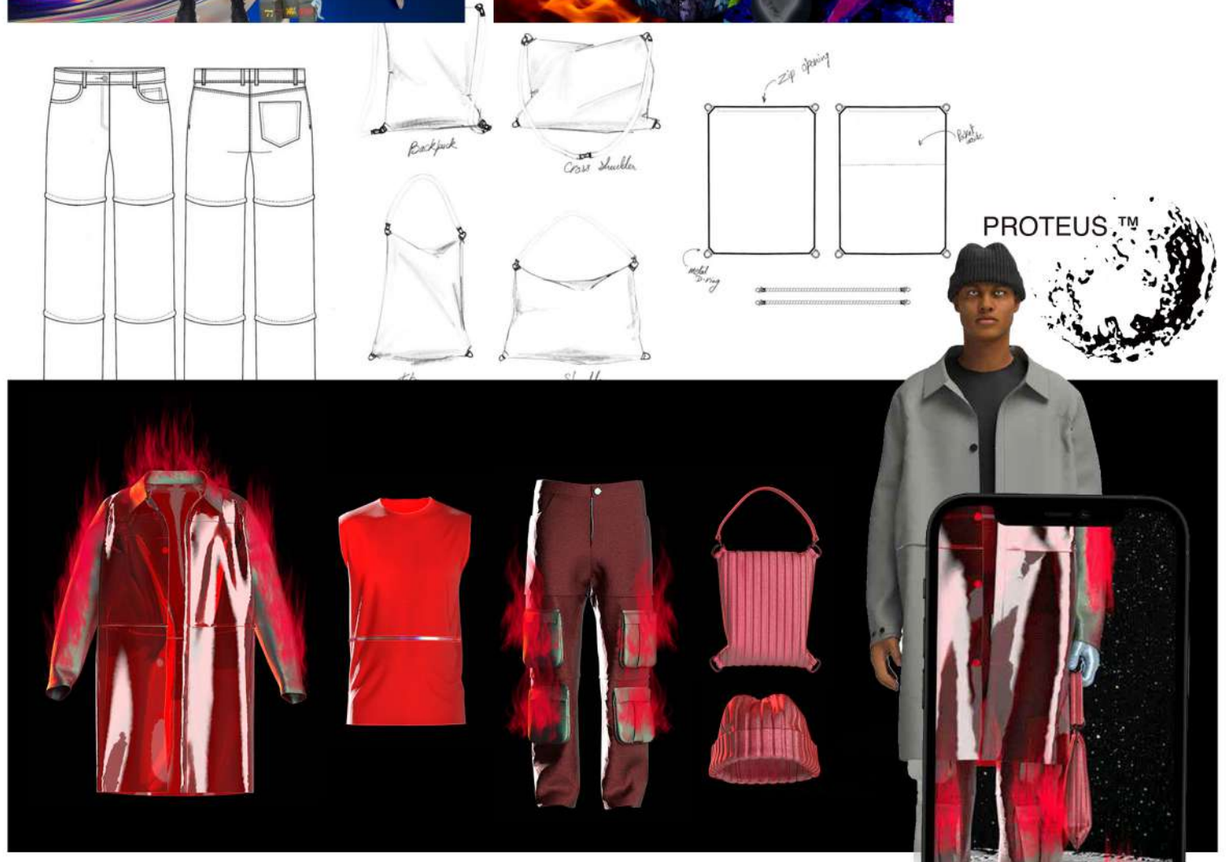
Soft Skills
Multidisciplinary collaboration
Real life challenges
Remote teamwork

Subject Specific Skills
Product service system design
Pattern-making
Animations and 3D modelling

LEARNING EXPERIENCE PROCESS



IDENTIFIED SUSTAINABILITY IMPLICATIONS



AZZURRO

Laura Dittmann, Textile Value Chain Management (HB)
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Fatima Miftahul Jannah, Innovative Fashion Production (UAL-LCF)
Firas Zaarouri, Engineering (ESTIA)

#FEELINGS **#EXPERIENCE** **#SEE-THROUGH**

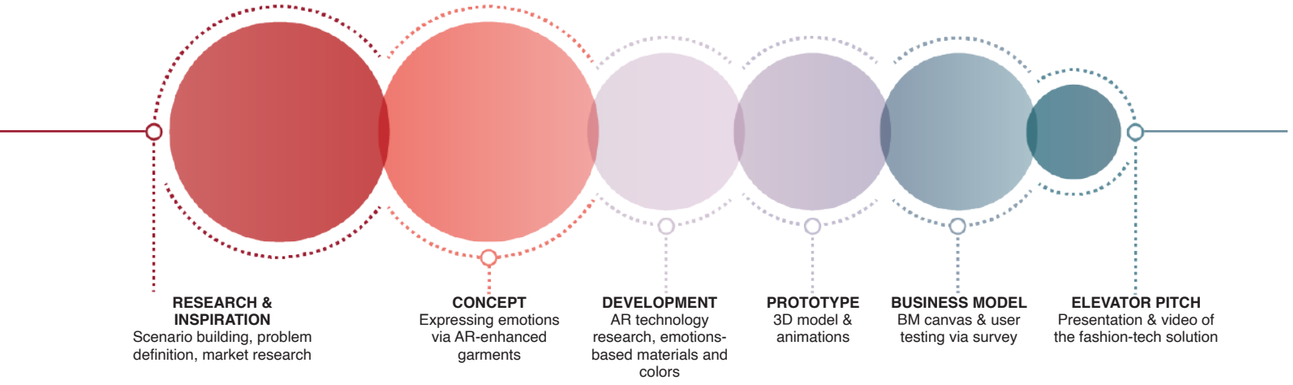
ABSTRACT
Azzurro aims to be the leader in digital emotional fashion by creating a unique experience through the combination of feelings and fashion design. Important goals are the empowerment of social sustainability and the implementation of design innovation. It aspires to support mental health well-being through the expression of feelings and thoughts with the AR technology. The raincoat is the main product of the first collection. Thanks to its connection to the mobile app, it is able to showcase feelings and thoughts through Augmented Reality technology to offer unique and immersive digital experiences.

LEARNING OUTCOMES

Soft Skills
Group development
Contextual learning
Working within tight deadlines

Subject Specific Skills
F-tech research and state of art
Fashion business management
Managing consumer demand

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Scenario building, problem definition, market research

CONCEPT
Expressing emotions via AR-enhanced garments

DEVELOPMENT
AR technology research, emotions-based materials and colors

PROTOTYPE
3D model & animations

BUSINESS MODEL
BM canvas & user testing via survey

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS

78

THE PAST TO REMEMBER

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Awad Issilame, Engineering (ESTIA)
Tianzi Lu, Innovative Fashion Production (UAL-LCF)
Maria Antonieta Sandoval Ramirez, Design for the Fashion System (POLIMI)

#VINTAGE #DIFFERENT AGES #EDUCATIONAL

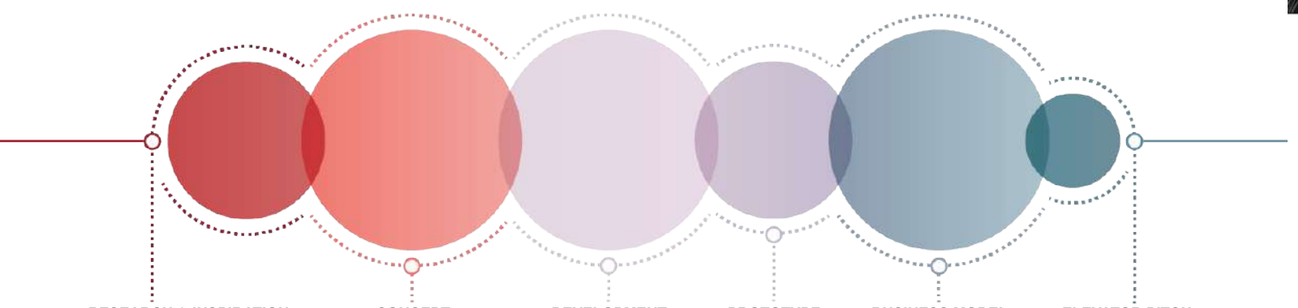
ABSTRACT
The Past to Remember is a history archive database and website that provides digitalized vintage garments for educational purposes. Fashion professionals can subscribe to a membership to access full information in the history archive database, including material information, time and era, pattern construction, etc. There are three ways to collect the garments: collaborating with the vintage shop, taking donated garments, collaborating with museums and educational institutions and creating digital collection. The website also offers the creation of virtual exhibitions for museums and educational institutions, accessible by the public.

LEARNING OUTCOMES

Soft Skills
Knowledge exchange
Pitching

Subject Specific Skills
Design methodology
Virtual prototyping via CLO3D

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Scenario building focusing on vintage clothing, value proposition

CONCEPT
Educational archives providing digitalized vintage garments

DEVELOPMENT
Moodboard, visual identity, sketches and technical drawings

PROTOTYPE
3D model & digital platform mockup

BUSINESS MODEL
BM canvas & user testing via survey

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS

AHORN & EFEU

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Camille Labazuy, Engineering (ESTIA)
Lucas Stollenwerk, Innovative Fashion Production (UAL-LCF)
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#ADVENTURER **#BOTANIC EUTOPIA** **#ECO-ACTIVISM**

ABSTRACT
Ahorn & Efeu develops a biodegradable product with its digital twin to help environmental activists with an affinity to technological advancement to be conscious buyers while living limitless experiences of fast-evolving trends. This will support the purpose to reduce overconsumption waste and increase emotional attachment through interactive experiences. Due to the connection between both, sustainable functionality and digital fast fashion, users seek will wear functional gear for escapism and individual development. Every costumer can choose a seedling that will gradually grow as pattern on the virtual version of the garment. The raincoat can develop in the digital sphere with every physical step and lived experience.

LEARNING OUTCOMES

Soft Skills
Research and critical thinking
Time management

Subject Specific Skills
Business model development
Virtual prototyping via CLO3D

LEARNING EXPERIENCE PROCESS

RESEARCH & INSPIRATION
Scenario building, raincoat market & trends research, value proposition

CONCEPT
Physical garment with a metamorphosing digital twin

DEVELOPMENT
Regenerative materials, print evolution, sketches and technical drawings

PROTOTYPE
avatar, 3D model, animations, website & app mockup

BUSINESS MODEL
BM canvas, user testing via survey, expenses plan

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS

82

IPV6

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Hai Ly Pham, Fashion Marketing and Management (HB)
Matilde Voltolini, Design for the Fashion System (POLIMI)

#YOUNG ACTIVISM **#MANIFESTO AWARENESS**

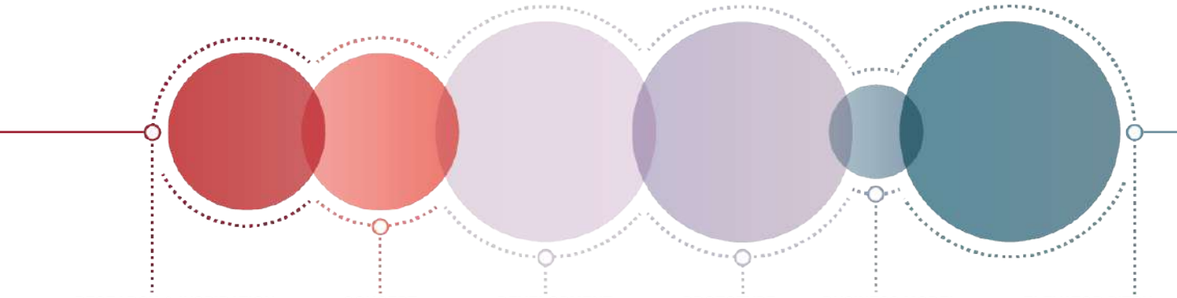
ABSTRACT
IPv6 aims to work as an intermediary channel between different individuals and the surrounding world through a digital platform, in which people can communicate about current global issues. On the IPv6 platform, users will find a safe place where they will be part of a community with which to share thoughts and ideas through discussions. They have the possibility to use fashion as a means of expression thanks to a section where individuals or groups can edit a canvas capsule collection of raincoats by adding manifesto prints and statements representing different themes to make their voices heard.

LEARNING OUTCOMES

Soft Skills
Multidisciplinary collaboration
Remote teamwork
Overcoming technical difficulties

Subject Specific Skills
Virtual prototyping via CLO3D
Dealing with complex aesthetics
F-tech research and state of art

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Scenario building focusing on protest signs, trend cartogram, value proposition

CONCEPT
Digital fashion co-creation platform to encourage self-expression

DEVELOPMENT
Sustainable materials research, moodboard sketches, visual identity

PROTOTYPE
3D model, website architecture & mockup, UX/UI

BUSINESS MODEL
BM canvas & user testing via survey

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS

INSPIRED

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Dione Leeger, Integrated Product Design (TUD)
Sarah-Leigh Roberston, Innovative Fashion Production (UAL-LCF)
Zhewen Yan, Design for the Fashion System (POLIMI)

#TRANSFORMATIVE **#PHYGITAL** **#MULTI-FUNCTIONAL**

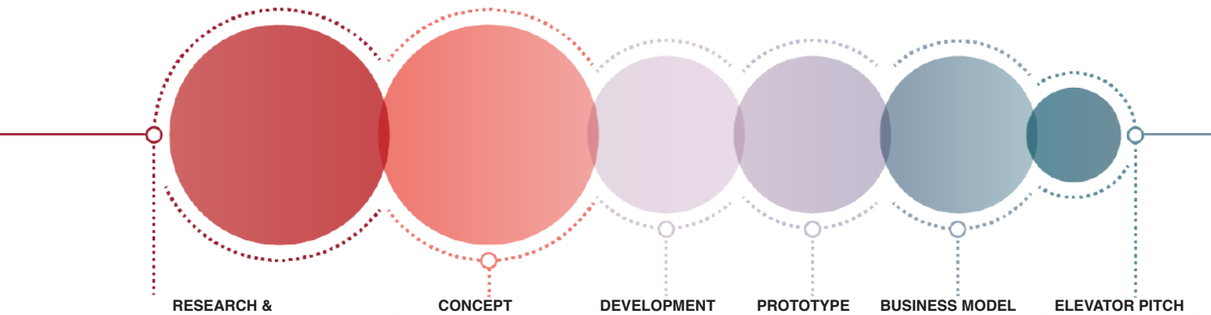
ABSTRACT
Inspired develops multifunctional and transformative (from jacket to bags) fashion products for physical and digital events to feel connected to their chosen event irrespective of how they attend them. These products help reduce the one-time use of event merchandising while also creating a sense of connection between physical and digital event attendees. Physical consumers will purchase a product which has multiple uses outside the event meanwhile digital consumers will purchase a transformative skin which can be used during immersive events alongside digital games partners platforms.

LEARNING OUTCOMES

Soft Skills
Time management
Overcoming technical difficulties

Subject Specific Skills
Virtual prototyping via CLO3D
Animations and video

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Scenario building focusing on festivals & sustainability, value proposition

CONCEPT
Digital & transformative merchandising for more sustainable events

DEVELOPMENT
Transformative product research & sketches

PROTOTYPE
3D model & website mockup

BUSINESS MODEL
BM canvas & user testing via survey

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS

Target 12.4
Target 12.5
Target 12.8

Target 13.2

TCP

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Dejin Chen, Design for the Fashion System (POLIMI)
Bilel Khanouch, Engineering (ESTIA)
June Kin, Industrial Design (TUD)
Victoria Ponieman, Innovative Fashion Production (UAL-LCF)

#OVERSIZED #BOXY #DIGITAL & PHYSICAL

ABSTRACT

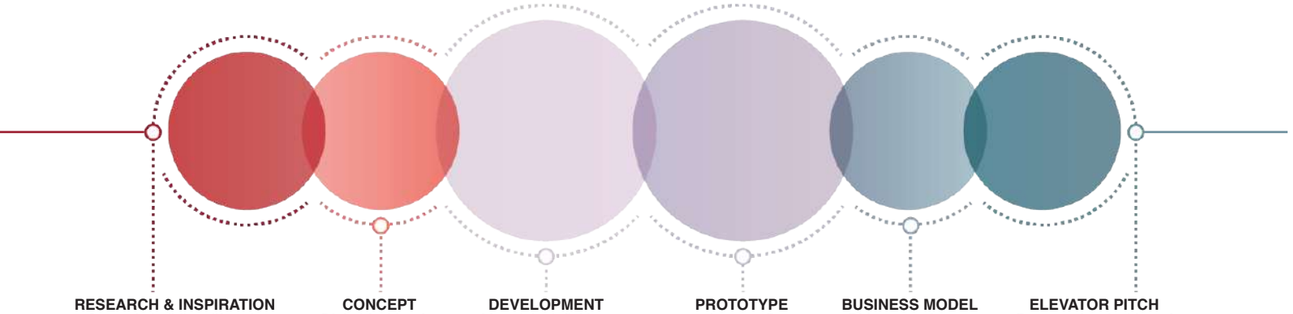
TCP is a digital platform that can provide solutions for waste generated by the occasional use of clothing products due to on-site activities. By creating digital fashion products in the form of interactive filters, TCP combines digital aircraft with physical clothing through limited edition apparel designed by artists and TCP's creative team to create unique event products that can be collected. The clothing not only fits perfectly with the theme of the event, but also incorporates augmented reality features to enhance the customer experience and create unique travel experiences that can bring the audience closer to other participants and artists during the event, strengthening the sense of community and belonging and improving the overall event experience.

LEARNING OUTCOMES

Soft Skills
Lateral thinking
Multidisciplinary collaboration

Subject Specific Skills
Design methodology
Business model development

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Scenario building, lifestyle board, value proposition

CONCEPT
Digital fashion for performers and fans

DEVELOPMENT
Materials definition, moodboard, sketches & technical drawings

PROTOTYPE
Avatar, 3D model, app & AR filter mockup

BUSINESS MODEL
BM canvas & user testing via qualitative interviews

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS