PILOTING FASHION-TECH EDUCATIONAL STRATEGIES

PROOF OF CONCEPT FOR INNOVATIVE FASHION-TECH PRODUCTS AND SERVICES

edited by
Daria Casciani, Chiara Colombi

FTalliance

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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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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).

1. INTERPRETING THE FASHION-TECH PARADIGM IN DIDACTIC RESEARCH

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1.1 UNPACKING FASHION-TECH: DESIGN-DRIVEN PRODUCT, SERVICE AND PROCESS INNOVATION

The fashion sector, being both a socio-cultural and industrial system has been invested by the potentials of the "Forth Industrial Revolution" *(Schwab, 2016)*, conceived as the combination of emerging technologies such as electronics, and Information and Communication Technologies (ICTs) that allow the generation of cyber-physical systems (CPS) where physical, digital, and biological boundaries fade along the whole supply and value chain. The technologies at the base of the implementation of Industry 4.0 (I4.0) systems are the Internet of Things (IoT), Big Data and Artificial Intelligence (AI), advanced manufacturing (AM) and digital fabrication (DF), virtual reality (VR) augmented reality (AR), mixed reality (MR), and collaborative robotics (CR) *(Alcàcer & Cruz-Machado, 2019)*. These technologies are entering the fashion industry and enabling fashion brands to develop market intelligence strategies that endeavour to completely change fashion paradigms. The list of technologies further includes Radio Frequency Identification (RFID) & Near Field Communication (NFC) technologies, Blockchain, and Cryptocurrencies that show the potential to develop in the sector at a fast pace due to the digital transition and trackability for transparency.
In this context, Fashion-Tech has emerged and keeps growing as a pervasive, fragmented and transdisciplinary sector, missing a unanimous definition due to the complexity and transversality of the field. There are several different terms that address the phenomena, and approach it from multiple perspectives that provide different meanings and specifications. Few emerging scientific studies *(Bertola & Teunissen, 2018; Noris et al., 2021; Nobile, 2021)* and industry reports *(CB Insights, 2022; ETP, 2016)* have tried to provide a broad overview of the I4.0 implementations and development in the textile and apparel industry, with the aim of deeply anticipating the Fashion-Tech potentials and trends offering a clear framework on Fashion-Tech potentials and criticalities/limitations before its mainstream application. For example, the concept of "Fashion 4.0" has extended I4.0 in the fashion and textiles industry, defining a model of smart products, smart factories, and smart networks that affects fashion products, services, and processes toward innovation via decentralization, modularity, interoperability, real-time capabilities, virtualization and service orientation *(Bertola & Teunissen, 2018)*.
The concept of "Digital fashion" from Noris et al. *(2021)* and Nobile et al. *(2021)* attempts to develop a framework for the emerging sector through a taxonomic classification that reflects its interdisciplinarity complexity. Based on the adoption of ICTs in the fashion sector, the analysis frames the phenomena in three categories: (i) Communication and Marketing strategies in the digital era allowing the development of systems, methods, and models for shopping experiences and mediatization of communication; (ii) Design and Production focusing on automatization and digitalization of practices, processes, and tools involved in product, services and systems' implementation along with new business models and improved decision-making processes through effective and efficient structured workflows; (iii) Culture and Society with implications of digital fashion in terms of culture, education, and societal development.
ETP *(2016)* elaborates on the impact of the "fourth industrial revolution" on the European clothing and textile industry in relation to (i) digitisation of products, processes, factories, workplaces, supply chains, distribution, and retail, (ii) sustainability, circularity and resource efficiency of materials, processes and overall business operations and (iii) the proliferation of new business and consumption models based on sharing of productive resources and final products, servitisation, pay-per-use or subscription models. Therefore, the report conceives the future research topics on the fashion and textile industry impacted by technologies such as: (a) smart, high-performance materials, (b) advanced digitised manufacturing, value chains and business models, (c) circular economy, eco-innovation and resource efficiency, and (d) high-value-added solutions for attractive growth markets. For these four topics, it provides information of key collaboration partners for its successful development, the Technology Readiness Levels, and the expected time frame toward industrial deployment of technology.
An important aspect emerging from all these studies is the focus on sustainability and digitalization that together are expected to drive the parallel transition of the European fashion eco-system, increasing the application of a responsible approach to the technological innovation and promoting positive and more sustainable goals at the medium and long term *(Bertola and Vandi, 2021).* Being early positioned as the encounter of technologies, computer science and engineering and fashion, Fashion-Tech nowadays encompass social and behavioural sciences (e.g. psychology, sociology, anthropology, ethnology, economics, business and management), natural sciences (e.g. biology, chemistry), environmental science, addressing also specific sustainable challenges and constantly redefining its boundaries in this hybrid field of inquiry.
Considering this wide perspective that encompass bio-nano-info technologies and cognitive science, thus having an impact on society *(Roco et al., 2013),* the Fashion-tech paradigm could lead to open-innovation trajectories, both activating short terms opportunities and long-term effect, bringing the promise of deeply changing the industry, along with economies, and professionality's skills, thus impacting further the required educational models. At the same time, it raises ethical

implications and unpredictable impacts, widening the boundaries of the research. Therefore, a hybrid pedagogical approaches and the inclusion of transdisciplinary domains that pertains not only technological and engineering disciplines, but also social and natural sciences have the objective to shape future professionals able to navigate the complexity of new sustainable and societal challenges, changing the way people define their identities, make sense, live, produce and consume.

The innovation potential of Fashion-Tech can be activated by multidisciplinary, interdisciplinary, and transdisciplinary collaborative practices among different professionals of different disciplinary fields and professional backgrounds from industry, research centres, and training institutions, thus contributing to open knowledge in the sector toward a wider uptake, and application.

An important emphasis of the research is required for the development of a highly skilled and appropriately qualified workforce for the European future fashion, textile and clothing industry. EPT *(2016)* foresees an important generational shift in 2025 that should be accomplished by preserving specialized traditional skills and know-how and at the same time acquiring the current subject-specific skills that are deriving from the hybridization of the Fashion-Tech sector. In order to succeed, European Higher Educational Institutions (HEIs) and Vocational Education and Training (VET) institutions should support and further develop a world-leading Fashion-Tech education and training infrastructure in the widest sense and application. Therefore, it is important to boost didactic research about Fashion-Tech in terms of learning content and outcomes, pedagogy and learning environment, teaching methodologies and pedagogical practices, educational models and formats to be tested and piloted to inform new potential curricula for future-proof Fashion-Tech professionals. Digitalization, business innovation, sustainability, and societal impact / social challenges has been found to deeply affect the future profession in the Fashion-Tech sector.

Digitalization

Digitalization is defined as the adoption or increase in the use of digital technologies that affect the economy, society, and culture and enable a business transformation in operations, functions, models, processes, and activities *(Brennen and& Kreiss, 2016)*. Industrial digitalization involves structuring, shaping, and influencing a multidimensional transformation in the economic, societal, and cultural sense *(Brennen &and Kreiss, 2016)*. Digital transformation is associated with a wide alteration of value-creation paths that allow offering new products and services while managing the structural changes and barriers in the transformational process *(Vial, 2019)*. The European strategy toward

the digital transformation combines sustainability to guide the positive development of its industrial ecosystem toward a twin transition. In the aftermath of COVID-19 crisis, the European Commission has included resilience as an additional element toward the positive transition to include lesson learned from the crisis to re-establish a balance in a change-shifting global paradigm. The European efforts are also driven by a digital education agenda for the European citizens and professionals, whose scope is the achievement of universal digital skills, integrating all subjects and disciplines with computer science and information technology *(2030 Digital Compass: the European way for the Digital Decade, 2021; Digital Education Action Plan (2021-2027), 2021)* in the upcoming years.

Sustainability

Despite the United Nations has called HEIs to focus on education for sustainability in their higher education curricula, research activities, physical operations, and student lifestyle *(UNESCO, 2005)*, the indeterminacy of the term sustainability has challenged the real implementation of curricula towards the Education for Sustainable Development (ESD) *(DuPuis & Ball, 2013)*. Therefore, the adoption of the 2030 Agenda for Sustainable Development under the Sustainable Development Goals has provided a favourable environment to scale up the implementation of ESD, to “ensure inclusive and equitable quality education and promote lifelong learning opportunities for all”. Target 4.7 states that sustainability encompasses environmental preservation and includes sustainable human rights, gender equality, promotion of a culture of peace and nonviolence, and appreciation of cultural diversity *(UNESCO 2020)*. Thus, ESD in the Fashion-Tech sector aims to develop skills that enable and empower the future professional to reflect on their design actions, taking into account current and future social, cultural, economic and environmental impacts with local and global perspectives. In addition to provide contents on social, cultural, environmental and economic impact of the Fashion-Tech sector, ESD pushes toward interactive and learner-centred teaching and learning settings, toward a reflexive and action-oriented transformative pedagogy whose features are: self-directed learning, participation and collaboration, problem-orientation *(UNESCO 2018)*, to understand the “how” of sustainable Fashion-Tech practice, process, and design, while allowing the “what” of sustainability to emerge from interdisciplinary group interaction in a collaborative context.

Business Innovation

Even though, the digital technologies are in the early phase of commercialization, and existing research primarily explores the technological advancements allowed by its adoption *(Papachristou &and Bilalis, 2015; Spahiu et al., 2021)*, it is crucial exploring and gaining knowledge on new Fashion-Tech business models, revenue streams opportunities, and values creation, capture, and delivery within digitalization *(Parida et al. 2019)*. Digitalization determines structural changes at the front-end of business operations not only because of new products, but also because of the provision of services, that results in the transformation of the logic of business and value chain with new business models emerging from the co-creation with customers, the servitization, and the product monitoring/traceability. These new business opportunities and approaches require a shift and update of professional roles and skills inside the Fashion-Tech companies to support their sustainable and feasible development *(Chkanikova et al, 2021)*.

Societal impact / Social challenges

Technologies in fashion have particular impact on specific elements of society, since fashion is not just a material matter but also involves immaterial aspects mainly linked to culture, education and society. The different technologies that are changing the material fashion toward virtual one, as well as the communication technologies that enable connection, and mediatization are having a deep effect on how individual and communities shape their own identity through different social media channels. In addition to this, technologies in fashion can contribute to culture, education, and societal development *(Noris et al, 2021)*, addressing ethical aspects such as data management, privacy, safety, and surveillance linked to digital fashion and smart wearables, and configuring more inclusive and sustainable approaches in the fashion industry, in terms of awareness of sustainable consumption *(Collins, 2019)*, ethical behaviours *(Creangă, 2019)* and sustainable design and manufacturing processes.

1.2 EXPLORING DISCIPLINARY CONVERGENCES IN FASHION-TECH EDUCATION

ETP *(2016)* estimated that by 2025 the European fashion jobs market would face a generational turnover seeking for a qualified number of young professionals in the Fashion and Textile industry associated with the digitalization and emerging technologies across the operational, technical, managerial, creative and scientific sectors. To face the change, industry, higher educational institutions and research centres should strengthen their collaboration on accessing, delivering and developing scientific and advanced technological research and educational projects. It is important that future professional will be equipped with flexibility and multiple, transversal skills to face the paradigmatic shift of the Fashion-Tech industry toward digitalization of factories, and supply chain along with sustainability, and circularity, new business models and value-chain management.

The Fashion-Tech job is transformed in the convergence of skills between science, technologies, humanities and social sciences, reflecting the complexity and fluidity of modern reality where those areas are intertwined *(Carnevale et al., 2011)*. Convergent education allows knowledge to emerge beyond the borders of conventional academic disciplinary domains to fuse and integrate them toward a common interdisciplinary interest *(Casciani et al. 2021)*. The convergence of two or more disciplinary fields, majors, and subjects in education *(Nissan and Niroomand, 2006)* aims to cultivate future-proof talented professionals with enhanced specific disciplinary domain mindset and broader interdisciplinary knowledge that increases creative problem-solving abilities and responds to interdisciplinary labour demand *(Baek, Cho and Kim, 2019)*.

Convergence means widening disciplinary perspectives, empowering knowledge encounters, and integrating specialties with the purpose of generating new knowledge *(Hong, 2012)* to remain competitive in the work market and also to accomplish flexibility. In this rare savoir-fare, specialized expertise of traditional manufacturing and craft techniques, and unique design skills must be preserved through generational transfer allowed also using digital technologies and tools.

If the first discourse on convergence education emerged in the 70s at a seminar hosted by the OECD that classified it as multidisciplinary and interdisciplinary, Klein et al. *(2001)* also included the transdisciplinary category as a collaborative way of combining and redefining problems, it would contribute to incorporate concepts and knowledge across various fields. The Bologna Process in 2005 attempted to foster the adoption of convergence between European HEIs by establishing comparable

criteria and standards toward quality assurance in the European Higher Education Area, to achieve convergent educational curriculum, practices, and models at the organisational and instructional level.
In this context, the development of methodologies allowing the cooperation of students and professionals from different disciplines in the Fashion-Tech is based on systematic assignment division, collaborative problem-solving, critical reflexivity, experimental creative thinking, communicative and practice-based teaching/learning approaches to help the students dialogically converge toward one integrated product/service/system solution, and to produce intersubjective knowledge where disciplines from science, art, humanities, and technology entail a multi-perspective development.
The goal of Fashion-Tech convergent education is to allow students to get out from their disciplinary comfort zone to widen references and methodologies from others' disciplinary expertise, draw big pictures of the phenomena by linking different contexts, and explore the complexity equipped with a multidisciplinary vocabulary, and collaborative, participative interactive working modalities.
This tension toward transdisciplinary ways of knowing in the Fashion-tech sector should allow students from different background in humanities, social sciences, design, engineering and management to work on real-life problems through research methods allowing to acquire instrumental skills, to design new solutions that reflect the speed of the development of technology and lead new reflexive research with a systemic approach, including also sustainable implications in economic, environmental, societal and cultural terms.

1.3 DEFINING GUIDELINES AND APPROACHES OF A POSSIBLE CONTEMPORARY FASHION-TECH EDUCATIONAL MODEL

Considering the emerging crucial demand for the evolution of educational models towards the convergence of disciplinary fields and diffusion of new knowledge in the mutable sector of Fashion-Tech, the team of Politecnico di Milano, Dipartimento di Design in collaboration with the other HEIs involved in the FTalliance project has defined a series of guidelines and approaches for convergent education in order to test and pilot a proposed Fashion-Tech educational model. The teaching/learning method has been developed taking into account (i) the E4FT MA Fashion-Tech curriculum[1] *(Colombi and Teunissen, 2020)*; (ii) the recommendations taken during a cycle of three focus groups organised between HEIs, Fashion-Tech companies and research centres of the FTalliance consortium[2]; (iii) desk research about innovative pedagogical approaches such as Challenge-based learning *(Nichols and Cator, 2009; Nichols et al., 2016)*, Flipped Classroom *(Mazur, 2009; Berrett, 2012)*, and Social Learning *(Bandura, 1997)*. (Fig.1)

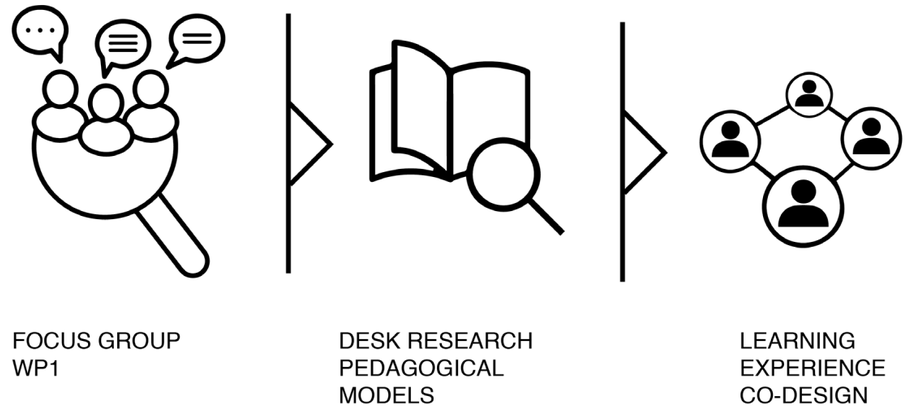

FIGURE 1 METHODOLOGICAL APPROACH TO DEFINE THE FORMAT/ EDUCATIONAL MODEL

The new integrated Fashion-Tech educational model would allow navigation and selection of the learning units to enhance the learning flexibility and personalization, advancing the learning modality from multidisciplinary to interdisciplinary and transdisciplinary. In addition to this, interactivity, participation, and direct companies' involvement was recommended to allow solving real-world problems and enable students to acquire instrumental skills and the development of critical and reflective thinking.

Three (3) pilot learning experiences[3] were planned and implemented within the FTalliance project duration to test the new educational principles and guidelines as follows[4] (Fig.2):

- **interaction and engagement** between different contents, sectors, disciplines, and HEIs and through both traditional (e.g. students learning from teaching staff) and non-traditional interactions (e.g. student learning from professionals and from peers in interdisciplinary teamwork project-based activities).
- **teamwork activities allowing learning from multidisciplinary to interdisciplinary and transdisciplinary** toward the "integration and modification of the disciplinary contribution" *(Stember, 1991)* allowed by more and deeper negotiations across the various disciplinary perspectives *(Choi & Pak, 2006)*.
- **personalized learning experiences** to address individual student's distinct learning needs, interests, aspirations, or cultural backgrounds, increasing students' level of choice as well as learning path responsibility.
- **learning flexibility** to accommodate differences of HEIs in organisational and instructional terms and to use subject-specific pedagogical techniques adequate for the Fashion-Tech areas across a variety of learning environments.
- **real world challenges** to achieve long-term retention of material, developing 'replicable' skills, and improving students' attitudes towards learning;

[1]The E4FT Fashion-Tech Curriculum, was developed as a two-year MA Fashion-Tech Design program with a modular and flexible structure. Divided into 3 Educational Sections of Focus (Design and Multimedia Communication, Technology and Engineering and Human Social, Psychological and Economic context) and consisting of 18 units in total, the MA program offered the option of levelled education for learners with a different background in education and experience. More information via this link: https://www.e4ft.eu/

[2]The integrated Fashion-tech Curriculum model is fully described in the D1.1 of the Fashion-Tech Alliance project available and fully downloadable at this link: https://fashiontechalliance.eu/images/reports-and-publications/D11_Integrated_industry_relevant_Fashion-Tech_Curriculum_Model_V3.pdf

[3]The learning experiences are conceived as cross-universities, international and interdisciplinary courses held digitally with a flexible timing and modular credits attribution, accounting for different academic calendars and structures. The asynchronous modules are delivered at the beginning of the course to share theoretical pillars as multidisciplinary contents for common knowledge and will last from 2 to 3 weeks, meanwhile, the synchronous challenge-based part will last from 6 to 8 weeks. Accordingly, the course will deliver from a minimum of 6 ECTS to a maximum of 7.5 ECTS, depending on each University.

[4]The educational model/format along with guidelines specifically applied to Fashion-Tech education are included in the D2.1 Project Based Learning Modules https://fashiontechalliance.eu/images/reports-and-publications/D2_1_Project_based_Learning_Modules.pdf

- **industry perspective inclusion and companies' involvement** in the definition and development of the courses.
- **open knowledge and accessibility of resources** provided by different entities, but also collected, curated toward the creation of a repository for the open digital literacy of students and professionals.
- **digital education approach**.

FIGURE 2 EDUCATIONAL MODEL GUIDELINES

Due to Covid-19 sanitary situation (2019-2022) and travel restrictions among European countries, the digital on-distance approach was mandatory to make the learning experience possible all around European HEIs (Politecnico di Milano - School of Design; ESTIA École Supérieure Des Technologies Industrielles Avancées; Högskolan I Borås; University of the Arts London - London College of Fashion; Technische Universiteit Delft) involved in the activities of the FTalliance project. However, the need to transform the educational experience into digital has been transformed into a teaching opportunity in order to test new collaborative digital tools, learning activities and outcomes developed at distance between learners and teachers.

The digitalization of education and the use of more interactive and collaborative components within higher educational e-learning is already a trend *(Richert et al., 2016)*. However the implementation of an effective e-learning system able to hybridize knowledge among multi-agent teams which are completely interconnected among themselves and their environment and allow interaction has to be still tested and understood in terms of learning outcomes and student engagement.

This aspect is central in the academic experience *(Tinto, 2006)* so

that it could result in student success, improved learning and better achievement *(Kahn, 2014; Zepke, 2014, Hoskins, 2012; Sinatra, Heddy, & Lombardi, 2015)*. Engagement is particularly important in distance and online educational contexts where dropout is a problem. In the FTAlliance learning experiences, engagement between learners-learners, and learners-educators was allowed through the use of several digital tools, such as discussion forums, chats, digital classrooms, and collaborative digital boards. The discussion forum is an essential tool to share and discuss assignments, exercises, and reflections among all participants (students, teachers, experts from companies), showing work and giving/receiving feedback. Collaborative digital boards (e.g. Miro, Mural, Conceptboard, Ziteboard, Whiteboard fox, Stormboard) allow students' to co-create a shared and meaningful body of knowledge, to interact, brainstorm, and to creatively co-design a product/service/system. The visual digital whiteboards are helpful as project management tools (i) in the phase of the learning experience preparation (from the interdisciplinary teaching staff and companies professionals) to converge and integrate different perspectives on teaching/learning activities as well as (ii) for students during the challenge-based part activities to control the workflow of activities, to map and visualize ideas in early creative stages, and as co-design tools, allowing groups to modify output and edit in real-time or asynchronously to facilitate transdisciplinary consensus buildings.

In organisational terms, the misalignment of calendars of each HEI has been arranged in order to allow students to participate to the learning experience with the least possible overlap with other courses of their study plan. To do so, an atypical calendar structure was structured to allow students with different backgrounds to participate and gain personalised learning experiences about the Fashion-Tech sector, with a synchronous and asynchronous modality.
The main structure is as follows (Fig. 3):

• a kick-off synchronous introductory lecture (WELCOME) aimed to welcome students, explain the learning experience by sharing the Syllabus

• a theoretical asynchronous part (DISCOVER) focusing on theoretical pillars conceived as contents, knowledge, and information in emergent subject areas of Fashion-Tech (e.g., concepts, theories, principles, methodologies, methods, and tools) about design, engineering, business management.

• An initial synchronous lecture (DEFINE) to brief the students with a challenge-based project delivered in collaboration with the companies involved in the learning experience;

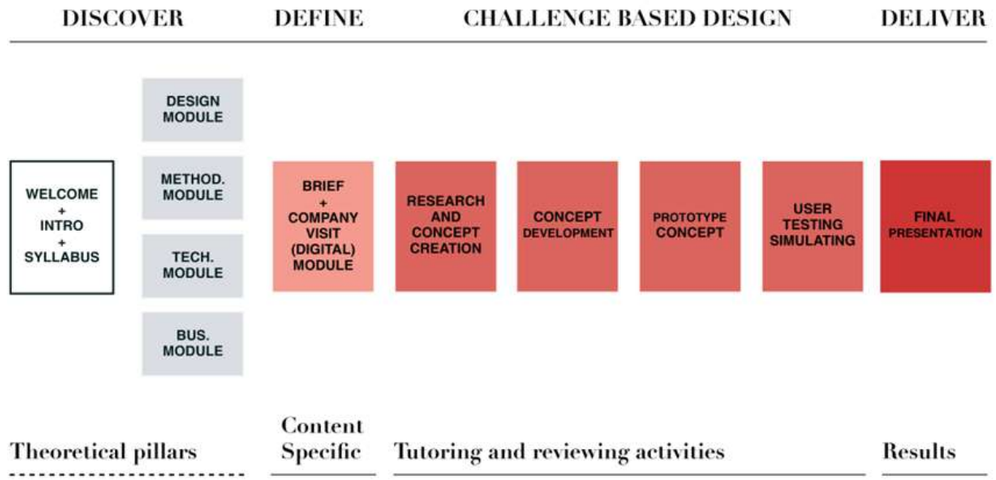

FIGURE 3 SCHEDULE OF THE LEARNING EXPERIENCES FROM WELCOME, DISCOVER, DEFINE, DESIGN AND DELIVER PHASES

• A synchronous challenge-based Learning-by-doing part (CHALLENGE-BASED DESIGN), where students from different disciplines approach a real-world challenge, while exploring and analysing the topic from their own subject specialism and discipline. Companies' contribute to the real-world challenge briefs, as well as through teaching and coaching activities co-implemented with teaching staff.

• A final synchronous delivery part (DELIVER) where students will be pitching their ideas and developed concepts toward an interdisciplinary committee made of teaching staff of different HEIs and professional experts from the Fashion-Tech companies

Each learning experience is expected to deliver:

• video lectures across different disciplines and subject-areas (e.g. design, engineering, and business management) that are released as Open Educational Resources (OERs) *(Miao, Mishra and McGreal, 2016).*
Each learning experience is expected to deliver:

• A portfolio of proof of concepts as learning outputs that do not focus on well finished Fashion-Tech end results but on proof of concepts and solutions with an emphasis on the process focusing on problematizing, reframing, and iterating in design, engineering, and

business management domains *(Cross, 2010)*.

As a result of the learning experiences, students are also expected to learn general soft-skills (e.g., communication, teamwork and interpersonal abilities, creativity and cooperation, serendipity, and an open and innovative mindset) as well as wide variety of Fashion-Tech Subject-specific skills *(Colombi and Casciani, 2021)* (Fig. 4).

FIGURE 4 - OVERVIEW OF THE SUBJECT-SPECIFIC SKILLS AS RESULTING FROM THE THREE FOCUS GROUPS AND INTEGRATED INTO THE THREE PILOT LEARNING EXPERIENCES OF THE FTALLIANCE (COLOMBI & CASCIANI, 2021)

1.4 PUBBLICATION'S OVERVIEW AND CONTENTS

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 lesson learned from the testing and piloting of the three innovative Fashion-Tech learning experiences in order to discuss opportunities for the Fashion-Tech (i) Strategic Innovation, (ii) applied Research for the Education Agenda and (ii) cooperation, networking and partnership opportunities.

The work has been organised and synthesised by the 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. Specifically, this project 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.

The publication consists of five chapters in which the didactic research is summarized presenting the research assumption, evaluation and implementation of case-studies as learning experiences in Fashion-Tech and results, conclusions and future perspectives.

Chapter 1 presents the premises of the Fashion-Tech educational research, aiming at unpacking the Fashion-Tech paradigm as a new, emergent and mutable sector for research and education to define new products, services and processes toward innovation and sustainability. This new domain is in need of new educational approaches to grasp the complexity of the sector and to implement new skills for the future Fashion-Tech professionals. For this reason, the chapter briefly covers the importance of convergence education in the Fashion-Tech sector as an introduction to define educational guidelines and approaches that were designed and implemented in three (3) learning experiences that involved teaching staff from five (5) European HEIs and nine (9) Fashion-

Tech professional experts, along with ninety-seven (97) interdisciplinary and international students.
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.
In particular, chapter 2 covers the learning experience about fashion digitalization and virtualization of the fashion processes that affect concept development and prototyping, production, supply chain operations, and business model innovation toward faster, smarter, more efficient and sustainable garments, products, and correlated services. Chapter 3 outlines the learning experiences focusing on Fashion-Tech value chains, aiming on identifying future sustainable development challenges to be solved by developing inter-disciplinary and scalable Fashion-Tech solutions from a social innovation perspective. Chapter 4 presents the learning experience about fashion wearable technologies, reflecting upon data ethics, and economic, environmental, and social sustainability through a process of research-informed design ideation.
Each of these chapters is followed by visual charts presenting the results of each learning experience collected in form of a portfolio of innovative Fashion-Tech concepts of products/services. Each concept is presented through its contents (e.g., short abstract, representative keywords, and visualizations) and interdisciplinarity of the team, the learning outcomes (e.g. soft and subject-specific skills) achieved by the students, and the learning experience process, highlighting the level of contribution and focus of the team in the different steps of the learning activity (e.g. research and inspiration, concept, development, prototyping, business model definition, and pitching) (Fig. 5), and the identified sustainability implications as the SDGs.

FIGURE 5 KEY DIAGRAM OF THE LEARNING EXPERIENCE PROCESS: ON THE LEFT SIDE THE PHASES DIVIDED BETWEEN RESEARCH AND INSPIRATION, CONCEPT, DEVELOPMENT, PROTOTYPING, BUSINESS MODEL DEFINITION AND PITCHING; ON THE RIGHT SIDE THE AMPLITUDE OF EFFORTS OF THE TEAM.

Finally, chapter 5 sets out the findings and future trajectories about Fashion-Tech education and collaboration, reflecting an encapsulated moment in time and challenges for Fashion-Tech educators and professionals, as well as students into Fashion-Tech studies. The provided lesson learned lead to set the premises for prospective scenarios of the Fashion-Tech education which serve as an invitation to open up a discussion on the future of Fashion-Tech educational models, collaborative engagement between different stakeholders of the sector, all concerned about the skills of future Fashion-Tech professionals.

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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).

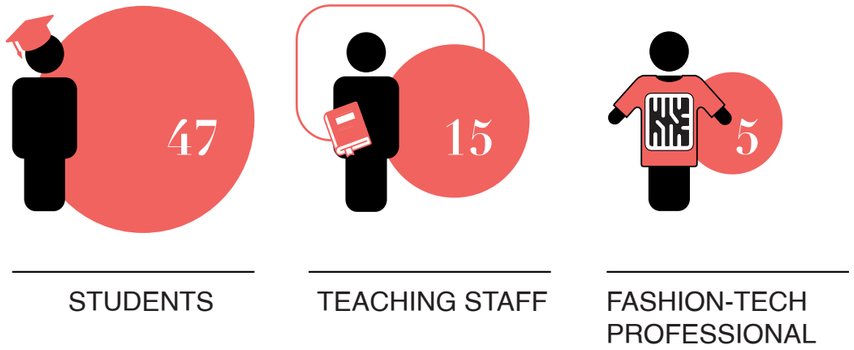

FIGURE 7 LEARNING EXPERIENCE PARTICIPANTS.

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.

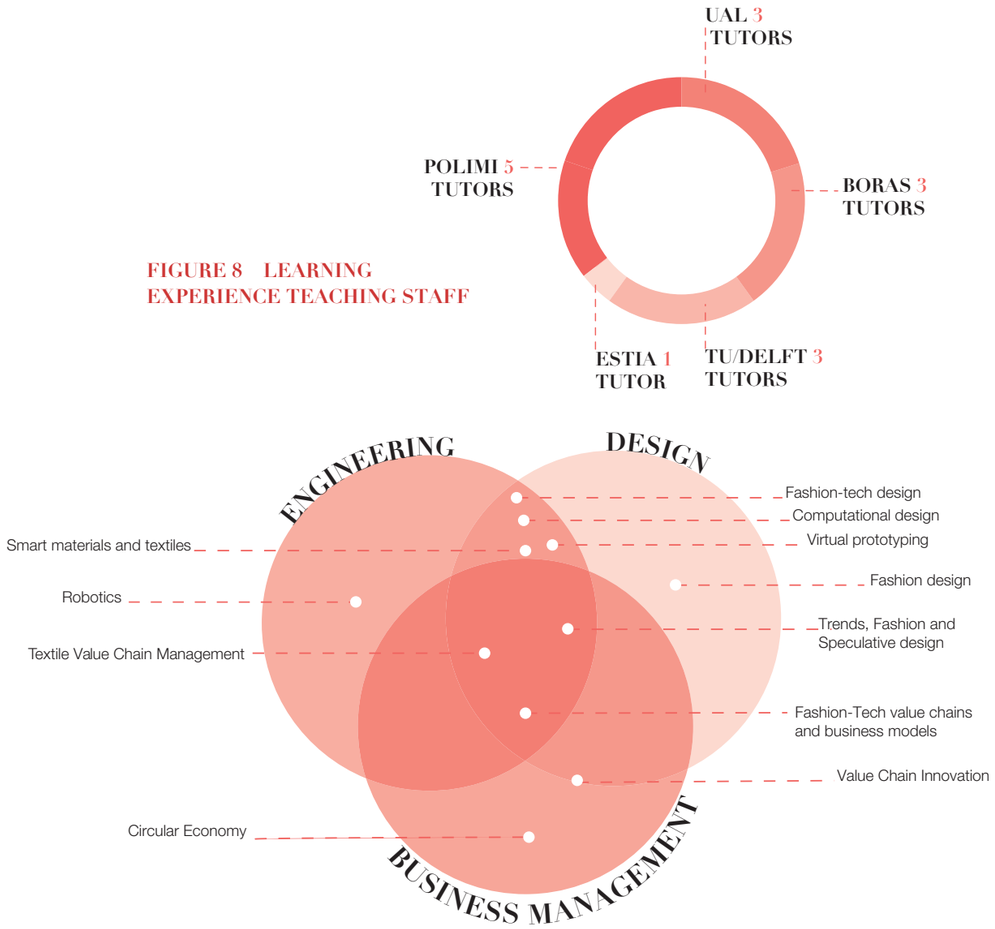

FIGURE 8 LEARNING EXPERIENCE TEACHING STAFF

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).

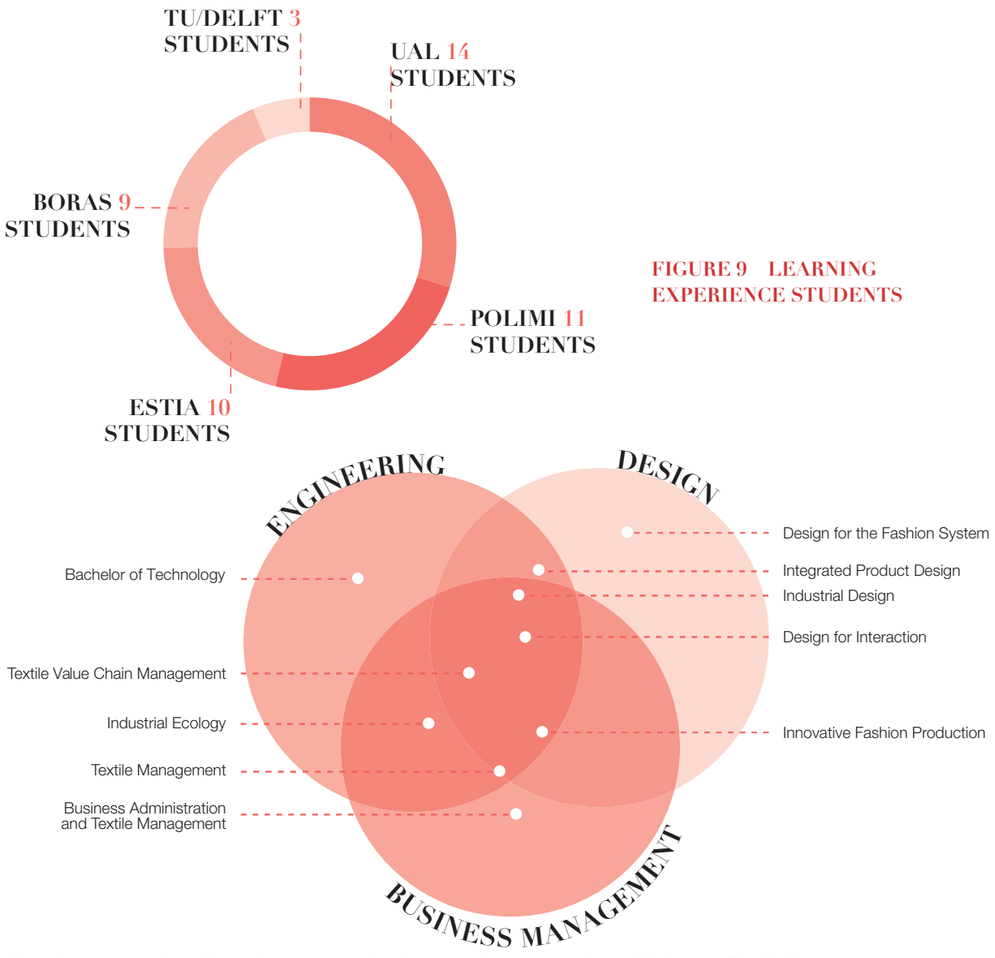

FIGURE 9 LEARNING EXPERIENCE STUDENTS

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).

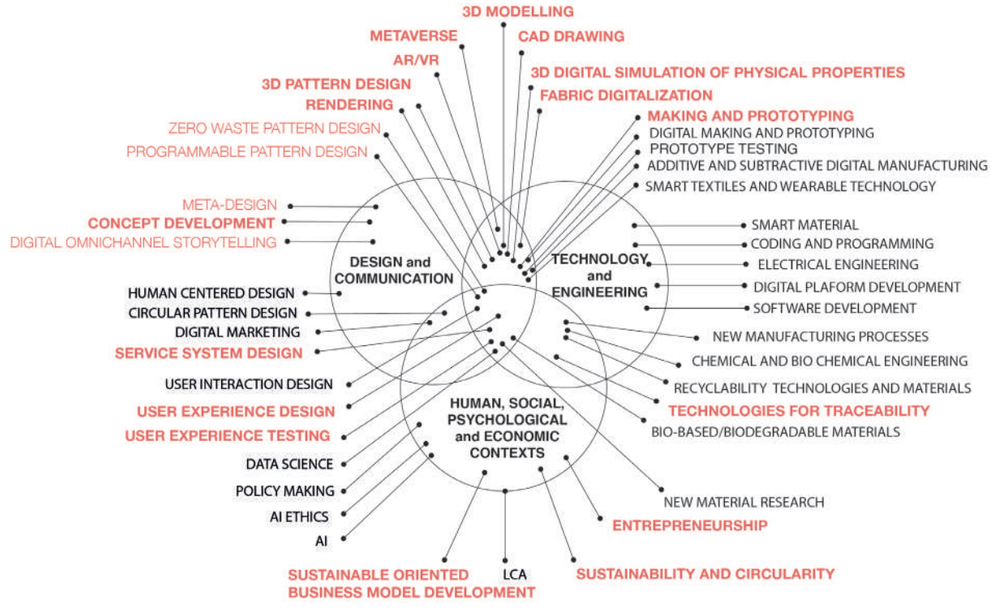

FIGURE 10 SUBJECT SPECIFIC SKILLS IMPLEMENTED IN THE LEARNING EXPERIENCE

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.

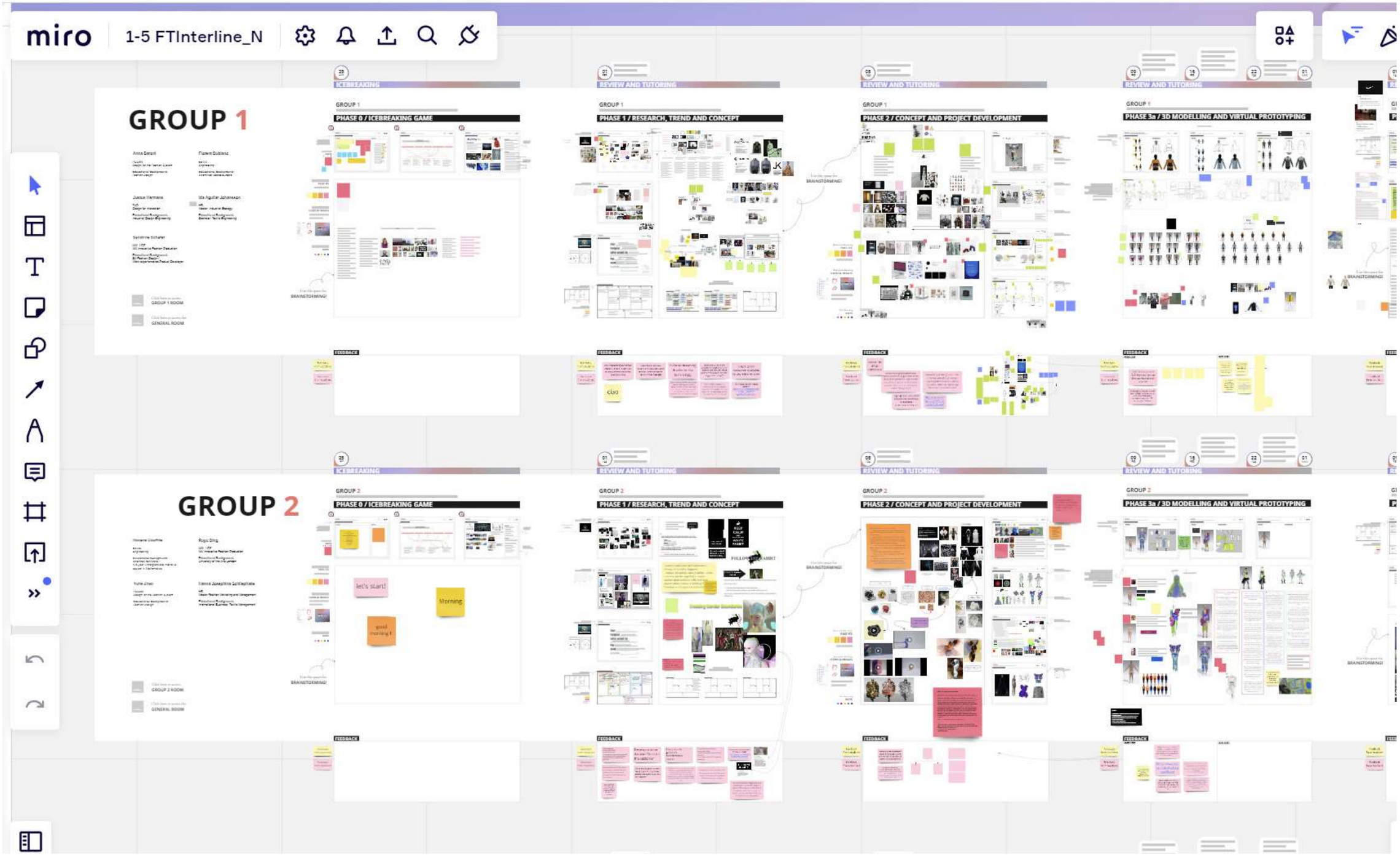

FIGURE 11 - MIROBOARD FOR COLLABATIVE DIGITAL CLASSROOM

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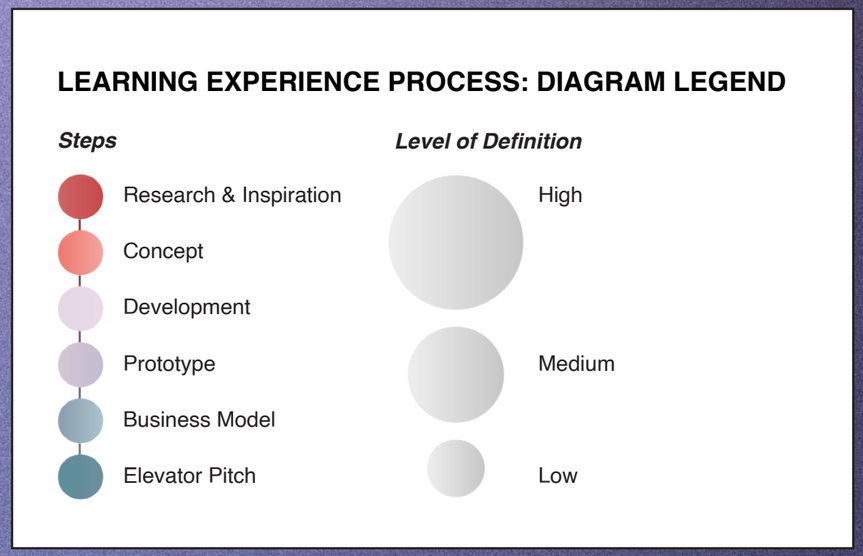
FIELD EXPERIENCES
The portfolio of innovative fashion-tech concepts of product and services

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



FLOW

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

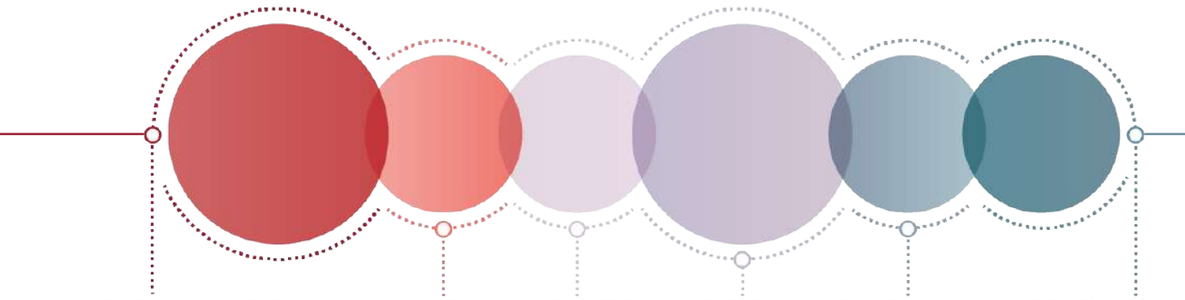
ABSTRACT
Flow develops customisable modular jackets based on sound and imaginary, to help the proactive generation (25-35 years old) to express and create consumption awareness. It aims to create an immersive customer involvement, reduce passive consumption behaviours, increase a proactive community, 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

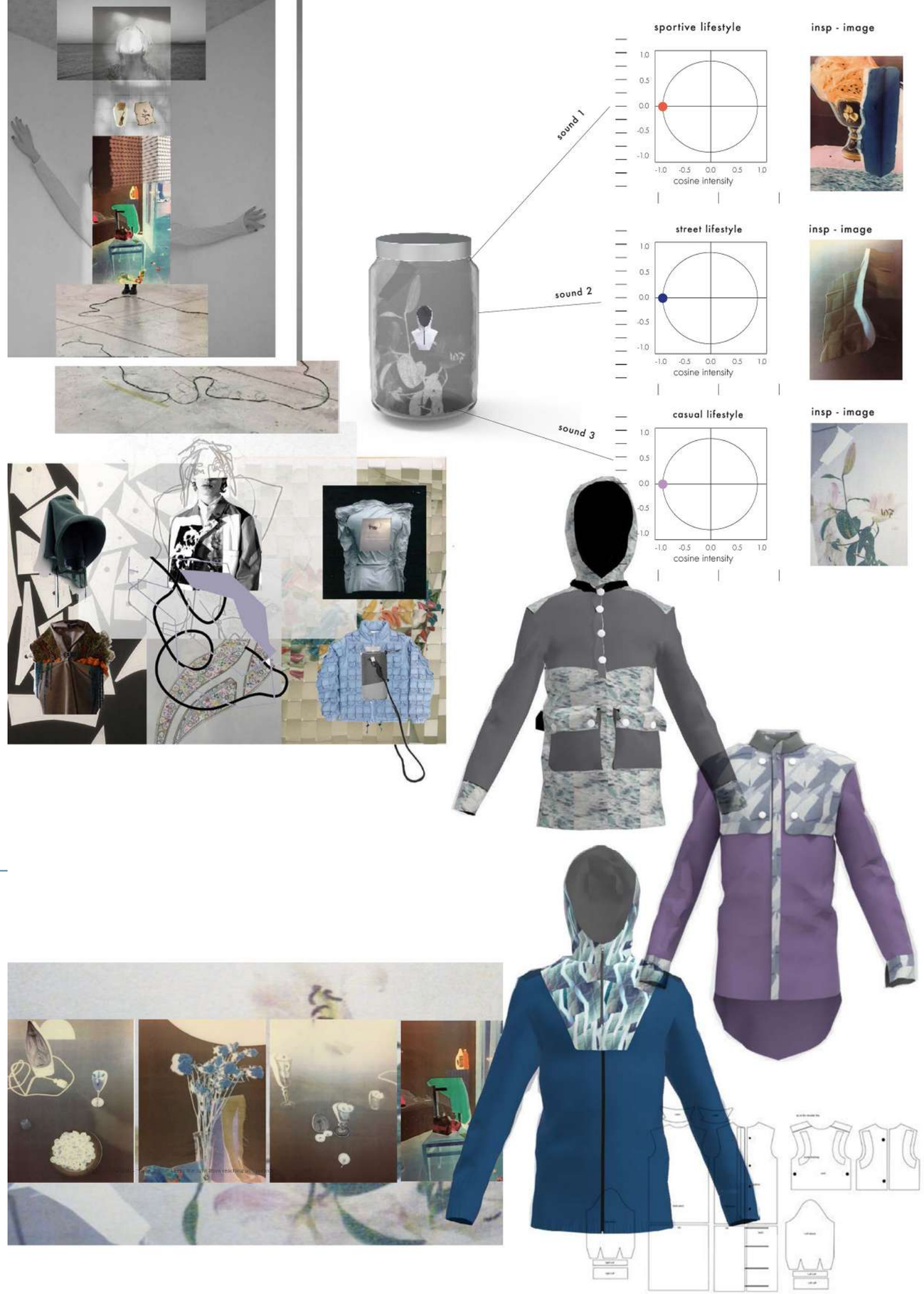
DEVELOPMENT
Virtual and physical materials, moodboard, technical drawings

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

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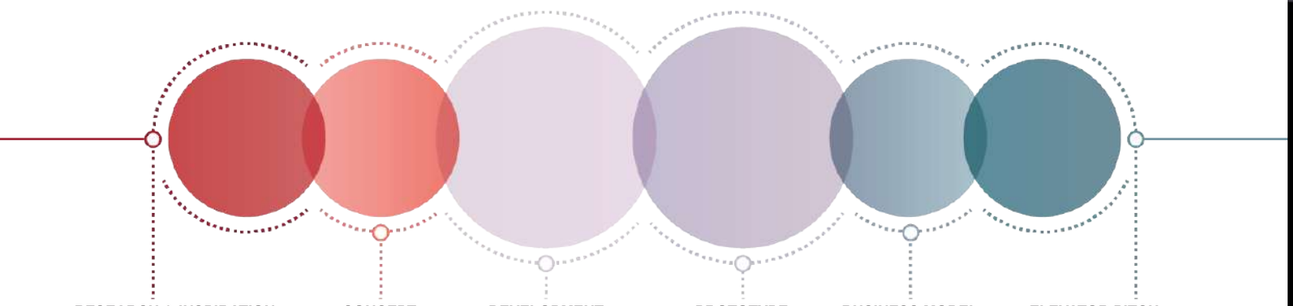
#EMOTIONS **#FUTURISTIC** **#SHAPE-CHANGING**

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**

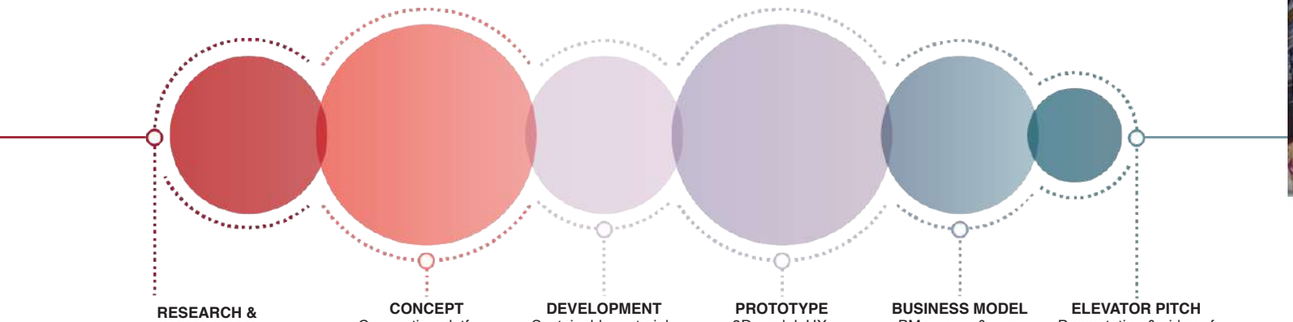
ABSTRACT
Brave New World is a subscription based, fully transparent co-creation platform that helps fashion pioneers connect and create together, providing an innovative and transparent approach to the fashion design process and giving a voice to every member of the community, with particular attention 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

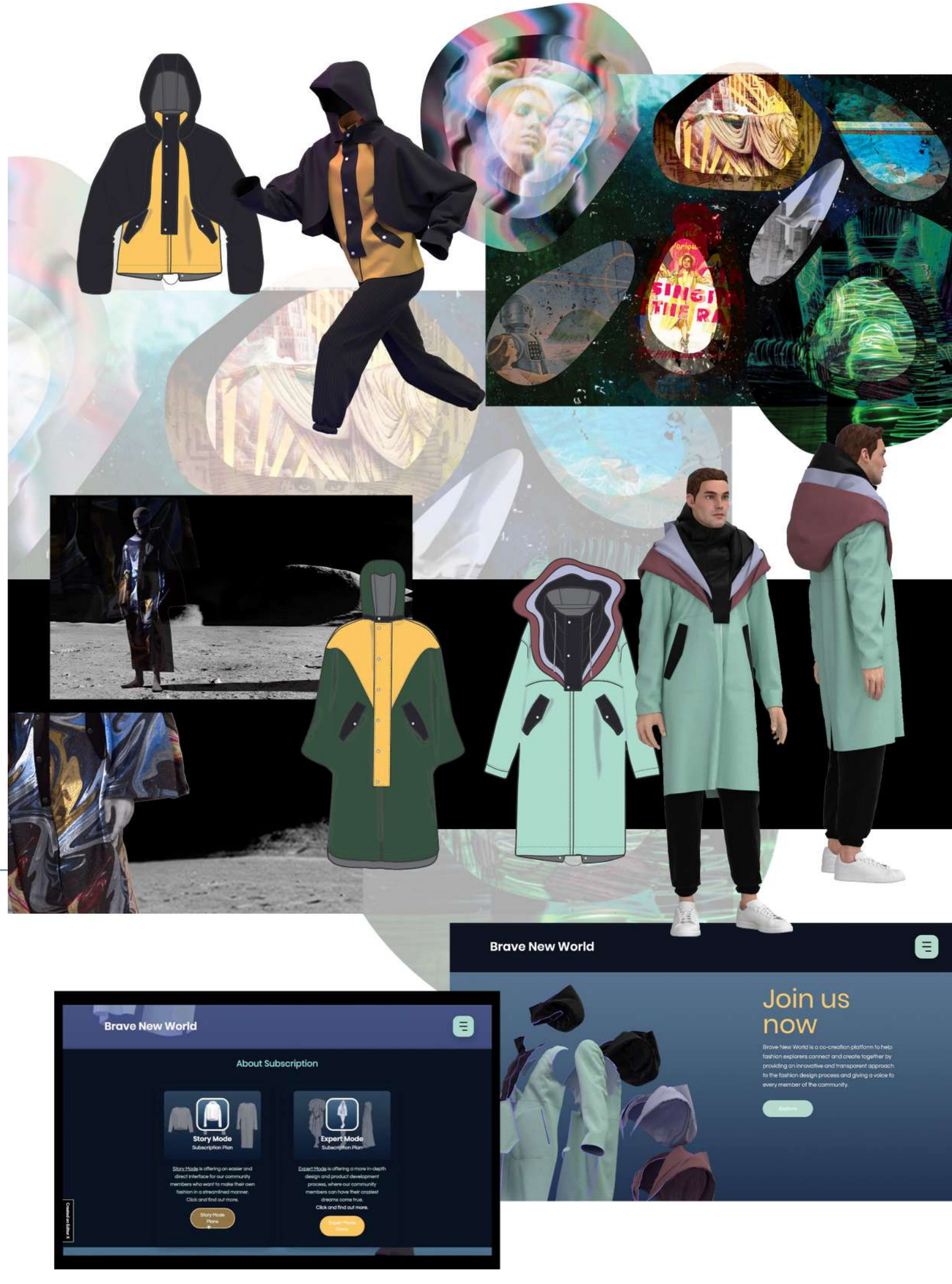
DEVELOPMENT
Sustainable materials research, moodboard, sketches board

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

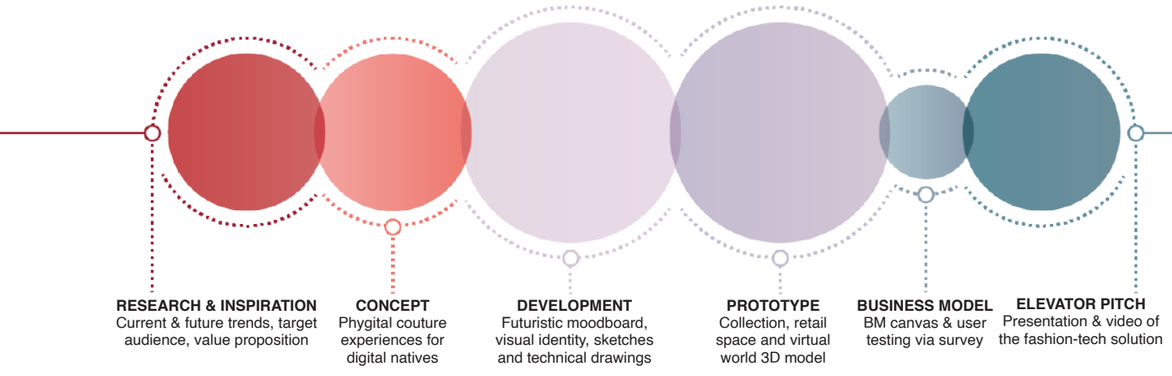
Proteus develops made-to-measure and customisable garments that come with new digital skins every month. They are inspired by a monthly theme that is showcased using V.R. technology to create new worlds to explore. Competing in the growing hybrid and digital fashion market, the aim is not only to provide 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

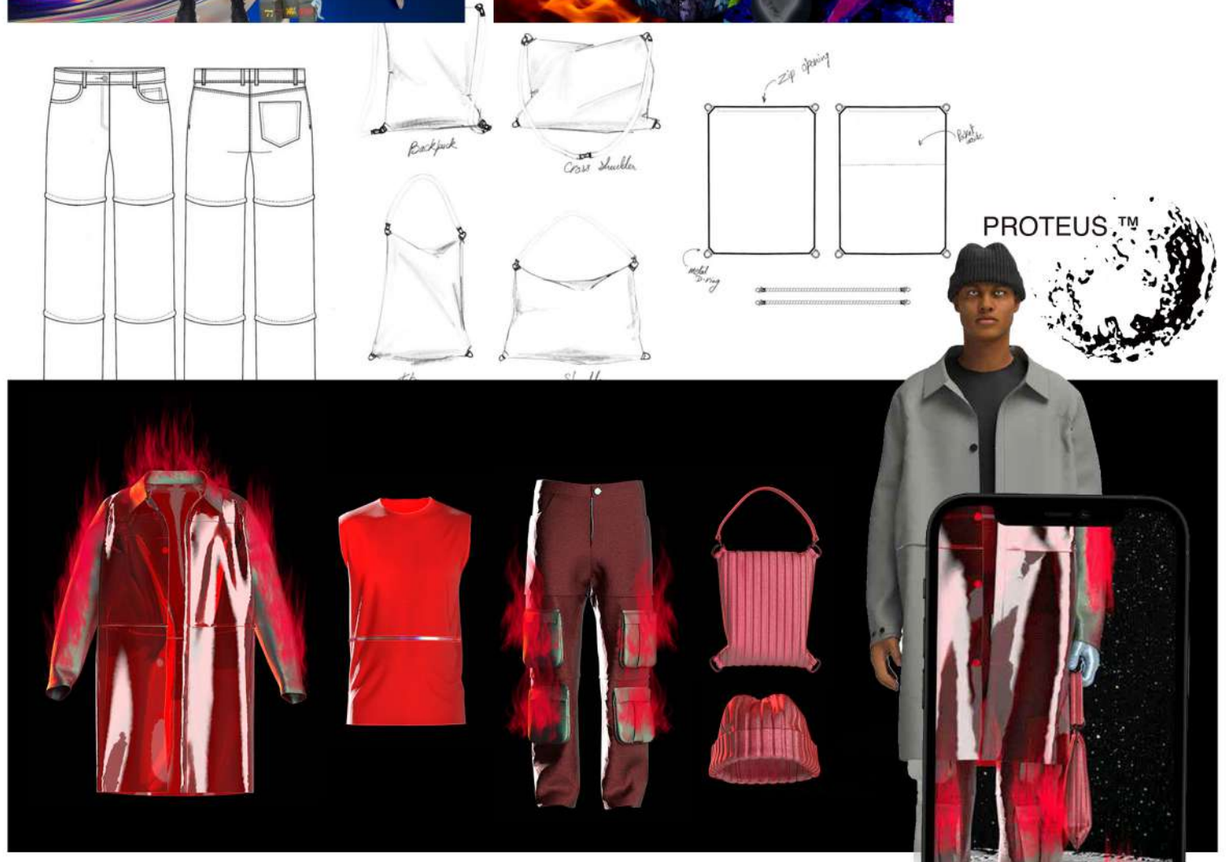
Soft Skills
Multidisciplinary collaboration
Real life challenges
Remote teamwork

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

LEARNING EXPERIENCE PROCESS



IDENTIFIED SUSTAINABILITY IMPLICATIONS



AZZURRO

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

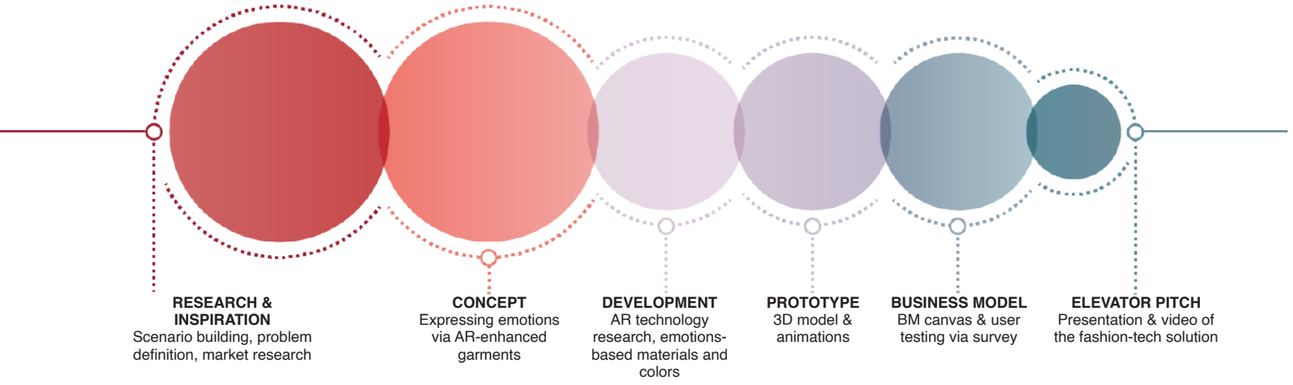
ABSTRACT
Azzurro aims to be the leader in digital emotional fashion by creating a unique experience through the combination of feelings and fashion design. Important goals are the empowerment of social sustainability and the implementation of design innovation. It aspires to support mental health well-being 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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Tianzi Lu, Innovative Fashion Production (UAL-LCF)
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#VINTAGE #DIFFERENT AGES #EDUCATIONAL

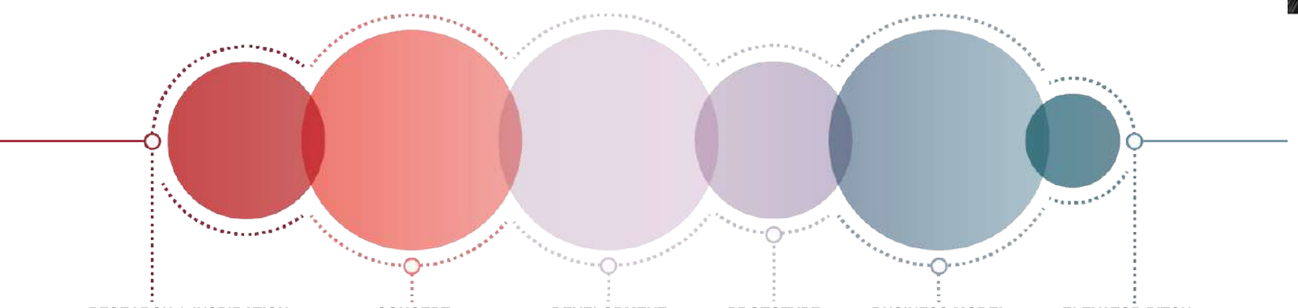
ABSTRACT
The Past to Remember is a history archive database and website that provides digitalized vintage garments for educational purposes. Fashion professionals can subscribe to a membership to access full information in the history archive database, including material information, time and era, pattern 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

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IPV6

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#YOUNG ACTIVISM **#MANIFESTO AWARENESS**

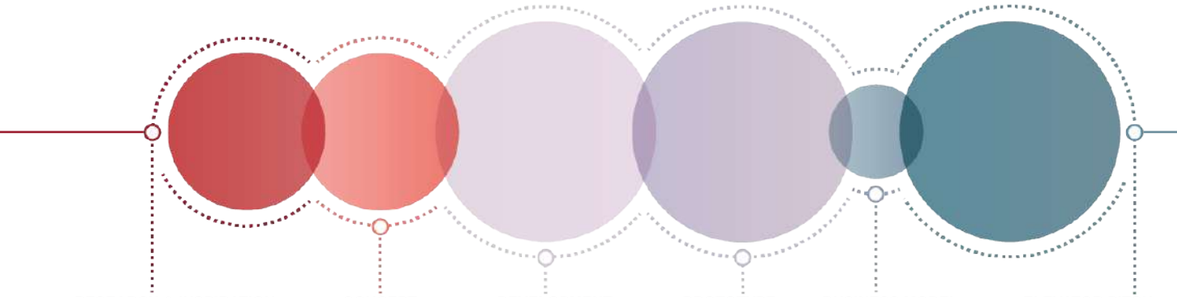
ABSTRACT
IPv6 aims to work as an intermediary channel between different individuals and the surrounding world through a digital platform, in which people can communicate about current global issues. On the IPv6 platform, users will find a safe place where they will be part of a community with which to 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**

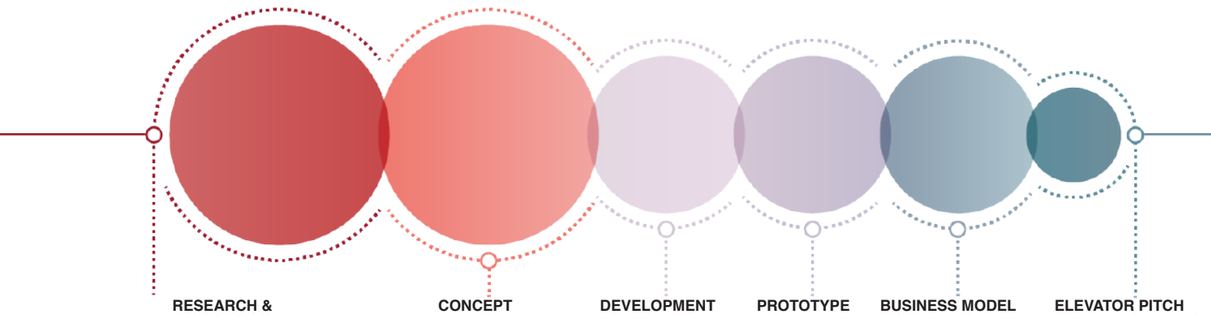
ABSTRACT
Inspired develops multifunctional and transformative (from jacket to bags) fashion products for physical and digital events to feel connected to their chosen event irrespective of how they attend them. These products help reduce the one-time use of event merchandising while also creating a sense 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

Fanny Byhmer Svensson, Business Administration in Fashion and Textiles (HB)
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

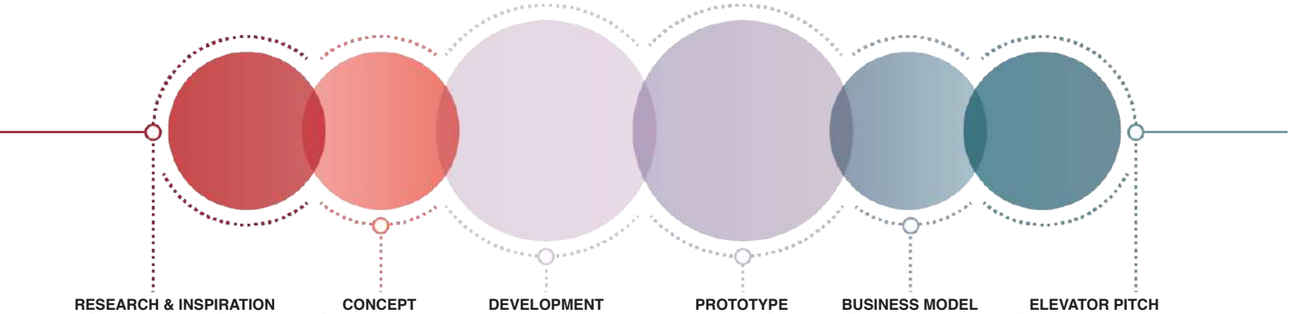
TCP is a digital platform that can provide solutions for waste generated by the occasional use of clothing products due to on-site activities. By creating digital fashion products in the form of interactive filters, TCP combines digital aircraft with physical clothing through limited edition apparel 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

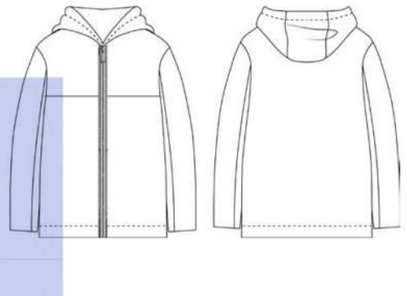
DEVELOPMENT
Materials definition, moodboard, sketches & technical drawings

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



3. CASE STUDY SCALABILITY OF MULTIDISCIPLINARY FASHION-TECH SOLUTIONS

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3.1 ADDRESSING FUTURE SUSTAINABILITY CHALLENGES

Currently we live in a world that is often described by narratives, such as ecosystems in decline, species loss, water scarcity, climate chaos, spread of diseases coupled with the resultant social and economic turmoil *(Aneja & Pal, 2015).* This situation is largely contributed by accelerated trends, such as growing volumes of world trade (volume index has grown by nearly 45 times since 1950) and proliferation of world population (set to increase from 1.8 billion in 2012 to 4.8 billion by 2030). Tracking the exponential growth of the effects of human activity upon the Earth, in terms of 12 socio-economic and 12 earth system parameters, since 1950, these trends mark the period of "great acceleration". Macy and Johnstone (2012) terms this as the "The Great Unraveling" while Rockström and Klum *(2012)* term this as the quadruple squeeze on humanity's ability to secure long-term sustainable development on planet. Overall, the consequences are marked by economic decline, resource depletion, climate change, social division, war, and mass extinctions; thus, rapidly eroding resilience of the earth, where we have so far undermined 60% of the key ecosystem services in support of human well-being *(Aneja and Pal, 2015).* At the current rate of growth, this will rise to 2 Earths by 2030 and 2.5 Earths by 2050—a clear impracticality *(Global Footprint Network 2014)*. To combat the situation, sustainability has become an important catchphrase and a movement meaning "meeting the needs of the present without compromising the ability of future generations to meet their own needs" *(Brundtland Report 1987)*.

The aim of this section is to situate the learning experience 'Scalability of Multidisciplinary Fashion-Tech Solutions' in relation to existing literature on fashion industry impact on sustainability from a holistic multifaceted perspective, tto give an understanding about the importance of educating students toward this thematic area through innovative teaching methods and digital educational tools.

The textile and clothing industry with a global trade worth US$807 billion in 2019 and employing more than 70 million people worldwide is considered to be one of the most polluting industries *(United Nations, 2019)*, with 10% of global greenhouse gas (GHG) emission *(Saha et al., 2020)*. It is the fifth-largest contributor to GHG emission accounting for around 4% of the secondary carbon footprint of an individual in the developed world *(Dev 2009).*

Water pollution is also rampant due to effluents such as fertilizers and pesticides from cotton farming and dyeing units *(Haque, 2017)* and the industry discharges are estimated to be nearly 20% of the global industrial water pollution. Water consumption due to extensive cotton cultivation has led to major environmental degradation and habitat loss (as was observed in the Aral Sea region). Apart from that, the industry has been a major source of fossil fuel-based pollutions for energy generation purposes.

Besides, in a fashion system where only around 20% of clothing is recycled or reused, huge amounts of clothes and textiles ends as waste in landfills or is incinerated *(Global Footprint Network, 2017),* estimated to be worth US$3 billion. The scale of the problem is increasing in-line with increasing demand for clothing, and McKinsey and Company *(2016)* estimates that the global production which reached 1 billion items annually in 2014, will further rise owing to the dominance of the fast fashion as the overall consumption is predicted to increase by 63% from 62 million tons today to 102 million by 2030 *(Pulse of Fashion Industry, 2017).* Fashion logistics, forecast-driven overproduction, irresponsible consumption and uninformed consumers are responsible for the sustainability gap in the textile, clothing and fashion industry *(Strähle & Müller, 2017; Pal 2014).* Thus, climate impacts of textile production, consumption and use present huge challenges, causing climate change and resource depletion. Such environmental challenges stemming out from textile, clothing and fashion industries is topped by social challenges facing the textile industry, and the potential for interventions linked to achieving social sustainability targets *(Huq, Chowdhury, & Klassen, 2016)*. The social hotspots of these industries have been found to relate to significant social risks such as low wage levels, child labour and exposure to carcinogens in the workplace. Therefore the future of textiles, clothing and fashion, much like other industries, is facing problems of limits to natural resources, global warming, sustainability issues, and social and political upheaval. To become sustainable, the industry needs a dramatic change at all levels starting with design, production, marketing, sales, and promotion *(Pal 2014).* With growing awareness, sustainability has gained traction in the textile, clothing and fashion industries and today is becoming even more important. There are several sustainability issues — along the three pillars of the triple bottom line approach—that specifically relate to the components of the supply chain for meeting the challenges of fashion logistics, overproduction, unsustainable consumption behaviour, and social irresponsibility, hence cannot be ignored *(Pal 2014).*

The global textile, clothing and fashion industry is transforming rapidly owing to the impact of the current COVID-19 outbreak with a massive contraction in global revenues. However, this has simultaneously opened up new opportunities for driving a paradigm shift of the industry powered by digital technologies and virtual connections with the promise of enhancing innovation and sustainability along the entire value chain *(Brydges et al. 2020, Gonzalo et al. 2020);* believed to be resulting in faster, more intelligent and more efficient processes, products, services, and

business models. Furthermore, the digital shift in the industry promises not only to drive profitability but also significantly improve sustainability across all value chain stages. Digital technologies are found to have significant impact in driving dematerialization of resource-intensive processes in traditional supply chains. For instance, clothing companies that have started using digital technologies such as 3D design, virtual sampling and prototyping can optimize material consumption for physical sampling which can ultimately reduce carbon footprints *(Cobb et al. 2017; Xiong 2020).* In the production stage, digitally enabled on-demand production allows elimination of unsold clothes, and when combined with digital tools such as 3D virtual fitting can be used to manufacture made-to-measure garments, thus eliminating both pre- and post- consumer wastes. Other technologies, for example adding digital tags or RFID in garment-making stage can reduce the level of safety stocks needed, enable supply chain traceability, thus increasing the lifecycle of clothing by reducing pre-consumer waste *(Denuwara et al. 2019, Östlund et al. 2020).* However, the application of digital technologies in the textile, apparel and fashion industry is in its exploratory phase; and existing technological advancements require widespread adoption and scale to attain. Even though digitalization is a 'silver lining' that offers opportunity to re-imagine the textile, apparel and fashion industry, create operational and financial stability, and underpin focus on sustainability and circularity. The learning experience proposed in the following section attempts to address the identified needs in current Fashion-Tech pedagogy research and aims to investigate design and business innovation possibilities of technology applied to fashion to address societal challenges and deliver sustainability-related improvements.

3.2 FOCUSING ON THE LEARNING EXPERIENCE

Learning experience contents description

The learning experience, 'Scalability of Multidisciplinary Fashion-Tech Solutions' focused on the field of Fashion-Tech and its value chains. The aim was to advance students' knowledge on identifying future sustainable development challenges and to focus on how these can be solved by developing interdisciplinary and scalable Fashion-Tech solutions (covering design, technology, and management aspects). In this context, scalability was discussed from a social innovation perspective in terms of scaling-out, scaling-deep and scaling-up dimensions *(Moore et al., 2015; Sandberg and Hultberg, 2021)*. The course further discussed the link between management, design, innovation, technology and customer to enhance Fashion-Tech industry competitive advantages across the triple bottom line: economic, environmental, social and cultural sustainability. Content, structure and specific information about the learning experience has been included in the 'Scalability of Multidisciplinary Fashion-Tech Solutions' Syllabus *(2022).*

Brief indicative contents

The digital course was delivered with a preliminary theoretical part assigned in an asynchronous way (Discover) aimed to level the knowledge of the students as a prerequisite for the subsequent practical challenge-based part of the course (Define, Design and Deliver) that was delivered synchronously. The contents of the theoretical part were delivered through lectures, preparatory exercises and applicative sessions to level the knowledge of students in the three different disciplinary domains of the project: sustainable design, Fashion-Tech interventions and Fashion-Tech business & impacts. The challenge part started with a kick-off through a brief launch and interactive brainstorming (Define). Students were then asked to develop a comprehensive scalable Fashion-Tech solution to a critical sustainability/societal challenge, by creating a sustainable business model blueprint of a fictitious project company (Design). In the challenge-based part students were formed into interdisciplinary and international groups to experience the process and the methodological approach of a project development activity that includes design, engineering, business management, research & development. The value proposition, and means to create, deliver and capture such sustainable solutions were addressed from a systemic perspective, by developing (where necessary) mock-ups of product design, technical specifications, engineering solutions and value chain. Different strands of the project among a series of thematic options, were:

- Circular Fashion-Tech solutions for resource effectiveness and climate positive impacts;
- Traceability solutions for improved provenance, circularity and due diligence;
- Smart textiles solutions for eco/sustainable materials;
- Innovative manufacturing and/or assembling processes for climate-smart solutions;
- 3D experience for simulation and personalization.

Finally in the Deliver module, students were asked to produce the results of the project in different formats. Students were also introduced to innovative ways of teaching that are based on digital tools used both to deliver the course and to develop project work and group collaboration between teammates. Therefore, the course was delivered totally digitally in a Virtual Learning Environment (VLE) using tools, such as Pingpong,

Zoom and Miro.

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

- An in-depth series of video lectures and multi-media presentations with high-quality graphics & detailed descriptions (13 video lectures)
- A list of required course textbooks, texts and other readings indicated at the end of every lecture in the videos, pdf files of the presentations and also as extra material. These are intended as optional materials to be read and studied to complete the learning objectives.
- High-detail examinations of the topics produced through digital documents, readings)
- A comprehensive set of quizzes and assessment tests

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

- 6 industry talks from experts from Centexbel (CTB) and WeLoveYou (WLY)
- A set of specific templates and connected reading materials related to the 3 phases of the challenge-based group project, that includes business plan, sustainable business model canvas, value mapping tools, scaling models, and template for final deliverables (group report and presentation).

Learning Experience Objectives
The general purpose of the course was to train professionals who are able to employ the potentials of digital technologies in the domain of fashion, to drive development of Fashion-Tech solutions covering technology, management and design aspects, to address sustainable development or societal challenges.
The course, through an innovative way of teaching, aimed at providing students with useful tools and skills to critically interpret the project dimension within the broader context of sustainable and societal developments contemplating diverse social, cultural, and technological contemporary shifts (new lifestyles and needs, new typological configurations and innovative technological scenarios). The digital theoretical lessons, preparatory exercises and applicative sessions were aimed to transfer students' knowledge of how fashion and digital technologies are interconnected, and their potential as well as limitations towards addressing sustainability related challenges in the entire value chain. From product/service ideation, design and engineering stages, to business model strategy development, students were asked to explore and exploit the potential of Fashion-Tech tools, as well as the implications of digitalization and virtualization of the value chain processes in relation to scaling opportunities for sustainability innovation.
The course also contained a challenge-based phase that was designed to nurture adaptive professionals with the ability to collaborate in delivering a project in the field of Fashion-Tech, as well as pitch their product and business ideas in a professional manner.

Learning Experience Outcomes
Upon successful completion of the course students were expected to gain the following learning outcomes:

- Knowledge and understanding
- Describe and explain scaling and scalability in fashion-tech value chains;
- Understand the role of fashion-tech solutions (covering design, technology, management aspects) in the context of future sustainable development risks and challenges;
- Identify the implications of developing inter-disciplinary and scalable fashion-tech solutions in addressing societal trends and sustainability demands.

Skills and abilities
- Apply innovative research and methodological approaches in the multidisciplinary Fashion-Tech context;
- Develop insights into fashion-tech tools and how to scale them in order to solve specific sustainable development challenges related to circularity, personal safety and health, climate change, social cohesion, etc.;
- Develop innovative business model scalability approaches to accommodate the fashion-tech solutions related to products, processes and value chain;
- Engage in dialogue and co-produce knowledge and innovation with various stakeholders across multiple disciplinary international contexts.

Evaluation ability and approach
- Critically reflect from the SDG perspective on the economic, environmental, and societal impacts of implementing scalable fashion-tech solutions;
- Critically reflect on complexities associated with scaling fashion-tech value chains, and demonstrate awareness of the negative impacts of it.

3.3 METHODOLOGY

Learning Experience Structure and Outline

The learning experience was delivered over 12 weeks, from September to November 2021. It contained both theoretical and practical activities that stretched over 50 hours of frontal teaching/tutoring (synchronous and asynchronous) and about 80 hours of student work, i.e. asynchronous self-learning and teamwork interaction. The number of quantified hours are approximate and an average from the different HEIs involved in the course. The activities included lectures, instructions, assessments, peer interactions and the delivery of a final project. The course was broadly divided into 5 modules as shown in Figure 12.

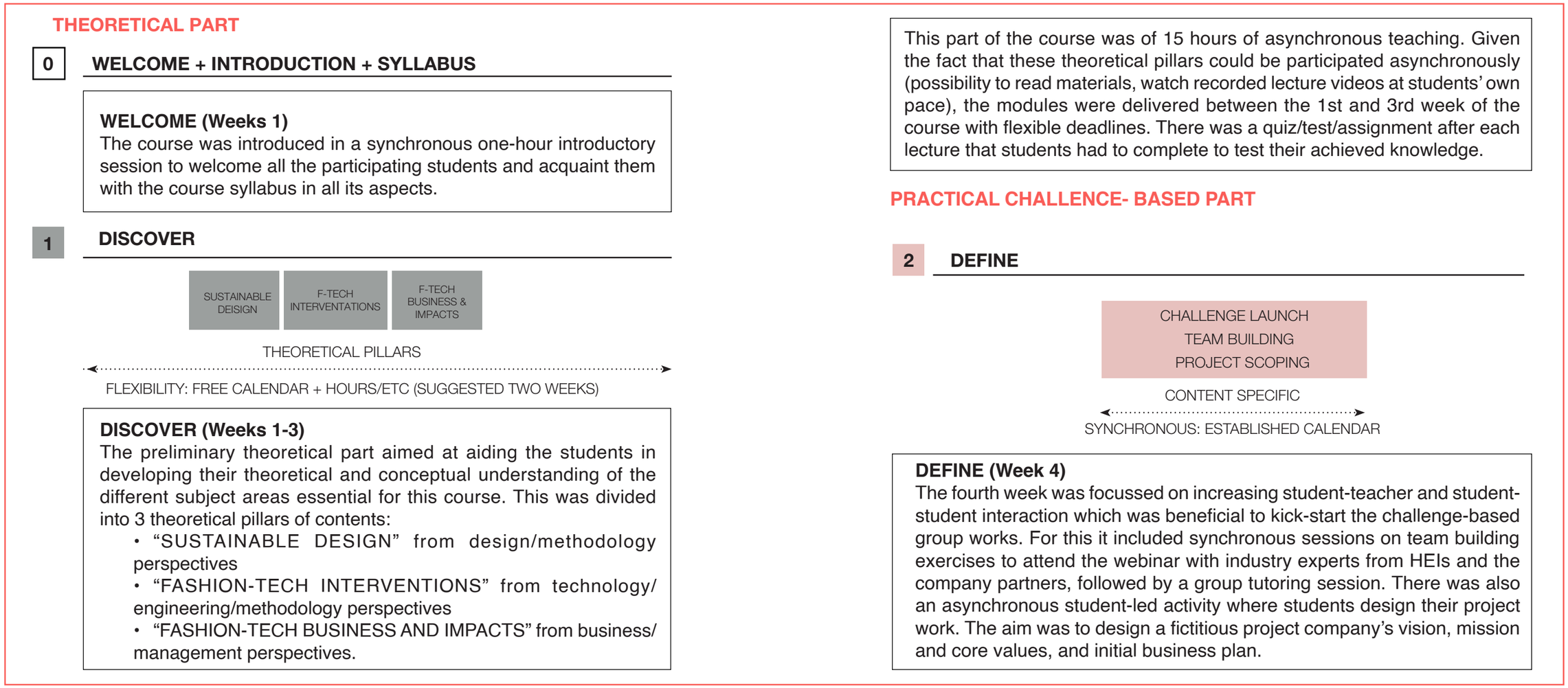
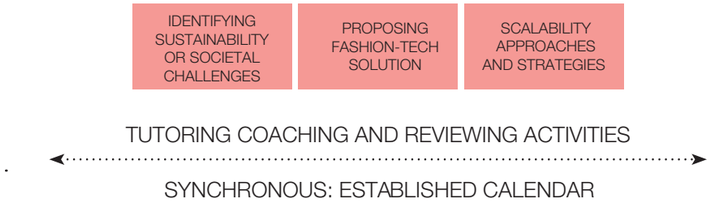


FIGURE 12 LEARNING EXPERIENCE STRUCTURE AND OUTLINE

3 DESIGN



DESIGN (Weeks 5-10)
The next part of the course was practice and challenge-based and was divided in three chronological phases of two weeks each. The challenge-based part of the course had students from the different HEIs working in their student groups to develop a comprehensive scalable Fashion-Tech solution to a critical sustainability/societal challenge. The goal was to create a sustainable business model blueprint of a fictitious project company. The value proposition, and means to create, deliver and capture such sustainable solutions was also addressed from a systemic perspective, by developing mock-ups of product design, technical specifications, engineering solutions and value chain. The three phases were as follows:

Weeks 5-6: Identifying sustainability or societal challenges.
In this context, student groups had to:

- Identify a critical societal/sustainability challenge that their company pivots on,
- Prepare initial elevator pitch on how this company is guided by the SDGs and what challenges it critically targets to solve through its business.

In this phase, there were three synchronous sessions; first dedicated to industry talks on "Sustainability/Societal challenge-driven Innovation in Fashion-Tech arena", the second organised as a group-wise preliminary concept pitching, and the final one as feedback and interaction session on the work-in-progress status of the group projects.

Weeks 7-8: Proposing Fashion-Tech solution.
In this context, student groups should:

- Locate the Fashion-Tech solution rendered by the project company,
- Map the value profile (proposition, means to create, deliver and capture these) for the project company,
- Make sustainable business model blueprint with detailing technology, design, process and value chain dimensions.

In this phase, there were two synchronous sessions; first dedicated to industry talks on "Fashion-Tech solution space amidst sustainability/societal challenges", while the second was a feedback and interaction session on the work-in-progress status of the group projects.

Weeks 9-10: Scalability approaches and strategies.
In this context, student groups had to:

- Locate the current scalability challenges and scaling opportunities in the solution provided by their project company,
- Identify approaches/strategies for scaling impacts based on systemic innovation perspective,
- Reflect on scaling outcomes on SDGs.

In this phase, there were two synchronous sessions; the first dedicated to industry talks on "Fashion- Tech scalability and its impact", while the second one as a feedback and interaction session on the work-in-progress status of the group projects.

Based on the specific disciplinary background, each component of the interdisciplinary groups took care of the following activities and tasks in order to complete the project and the final assignment:

- Concept Pitching, and presenting project company's vision, mission and core values, and initial business plan
- Societal/sustainability challenge-driven innovation
- Sustainable Development Goal alignment
- Sustainable business modelling and value mapping with detailing on technology, design, process and value chain dimensions.
- Approaches/strategies for scaling impacts and systemic innovation.

Teamwork was tutored and supported by a team composed of teaching staff and tutors from each HEIs to review the work of the students from different disciplines and perspectives.

FIGURE 12 LEARNING EXPERIENCE STRUCTURE AND OUTLINE

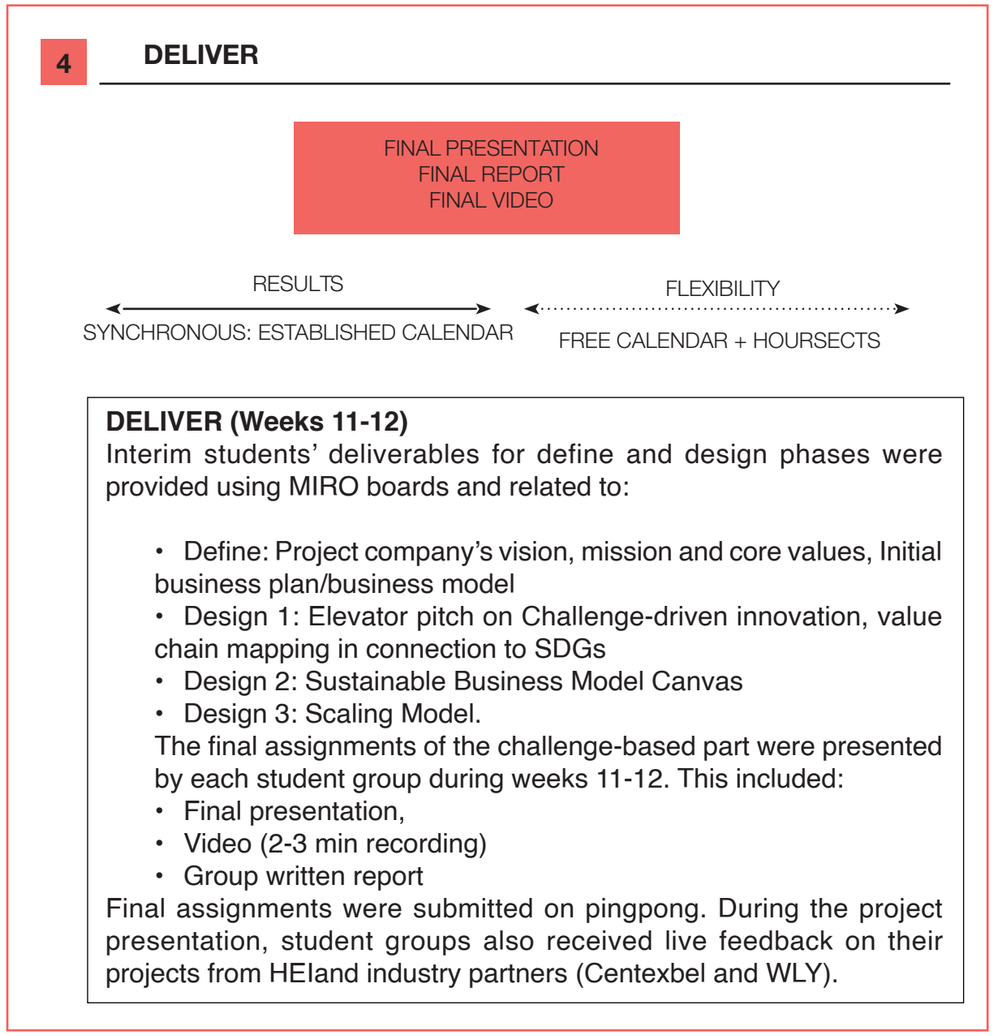


FIGURE 12 LEARNING EXPERIENCE STRUCTURE AND OUTLINE

Participants

The classroom was composed of 21 interdisciplinary and international students, 11 teaching staff, and 2 professionals from Fashion-Tech companies from the FTalliance consortium (Fig. 13).

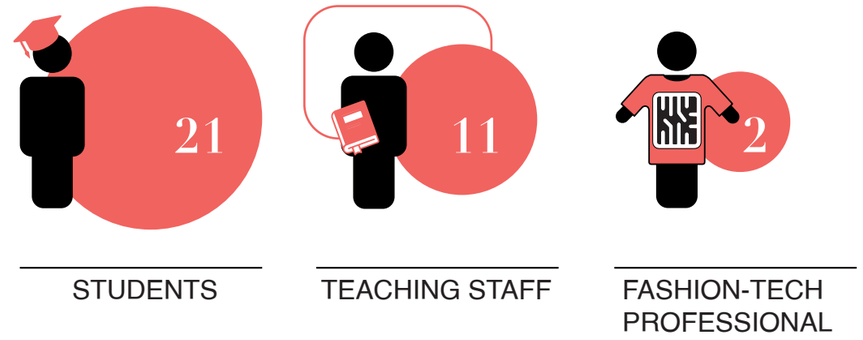


FIGURE 13 LEARNING EXPERIENCE PARTICIPANTS

Teaching Staff

Teaching staff members were involved in delivering the learning experience as follows (Fig.14):

- 5 professors from Politecnico di Milano, School of Design (Italy) focusing on Fashion and Fashion-Tech Design, Sustainability, Circular Design and Materials.
- 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;
- 1 professor from TU/Delft - Industrial Design Engineering Faculty (The Netherlands) focusing on Smart materials and textiles.
- 2 professor from Ecole supérieure des Technologies industrielles avancées (France) focusing on Robotics.

81% of teaching staf (9 professors) were involved in delivering theoretical lectures during the theoretical part and the 55% (5 professors) were involved in delivering the challenge-based part of the learning experience. They were available during the project design through a series of mentoring and tutoring activities covering different topics such as Fashion and Fashion-Tech Design, and Fashion-tech value chains and business models, Societal Challenges, Scalability, Circularity,

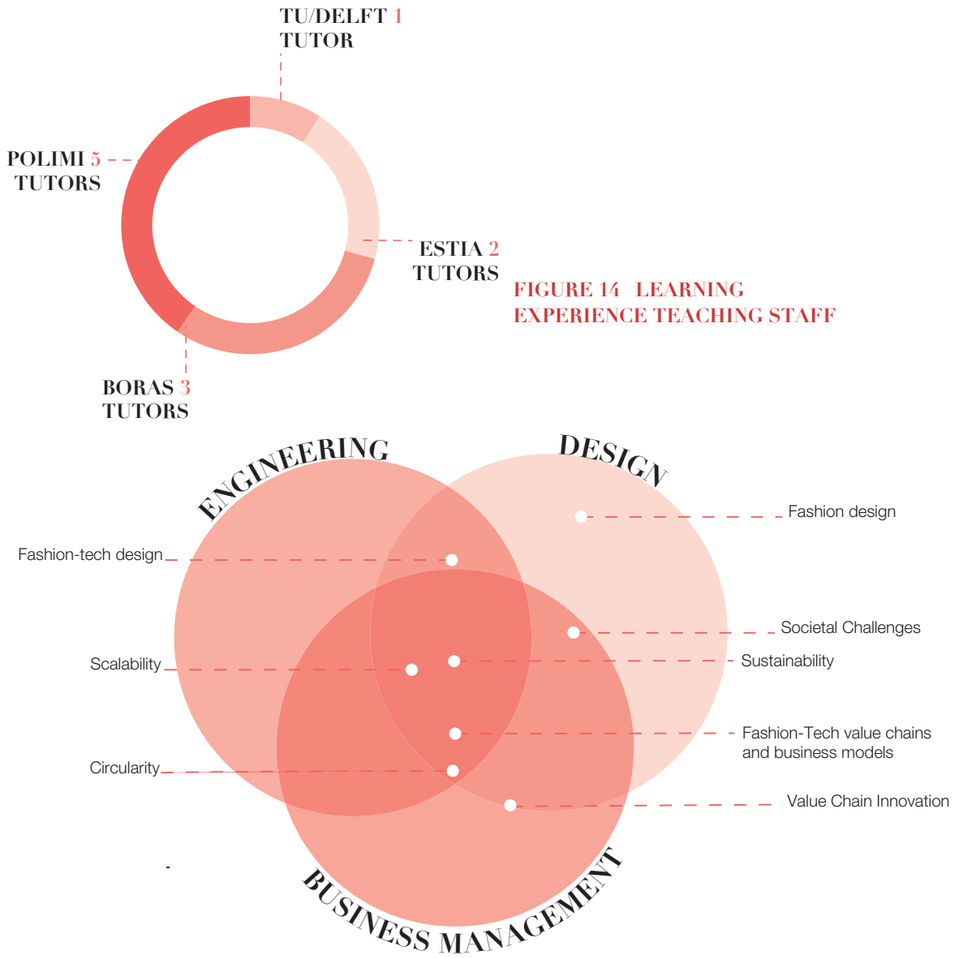


FIGURE 14 LEARNING EXPERIENCE TEACHING STAFF

Sustainability.

Students

Students have been selected and participated to the learning experiences, as follows (Fig.15):

- 9 students from Politecnico di Milano, School of Design (Italy) (second year MA in Design for the Fashion System and Integrated Product Design),
- 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 Textile Value Chain Management, Fashion Marketing and Management, Fashion and Textile Design,

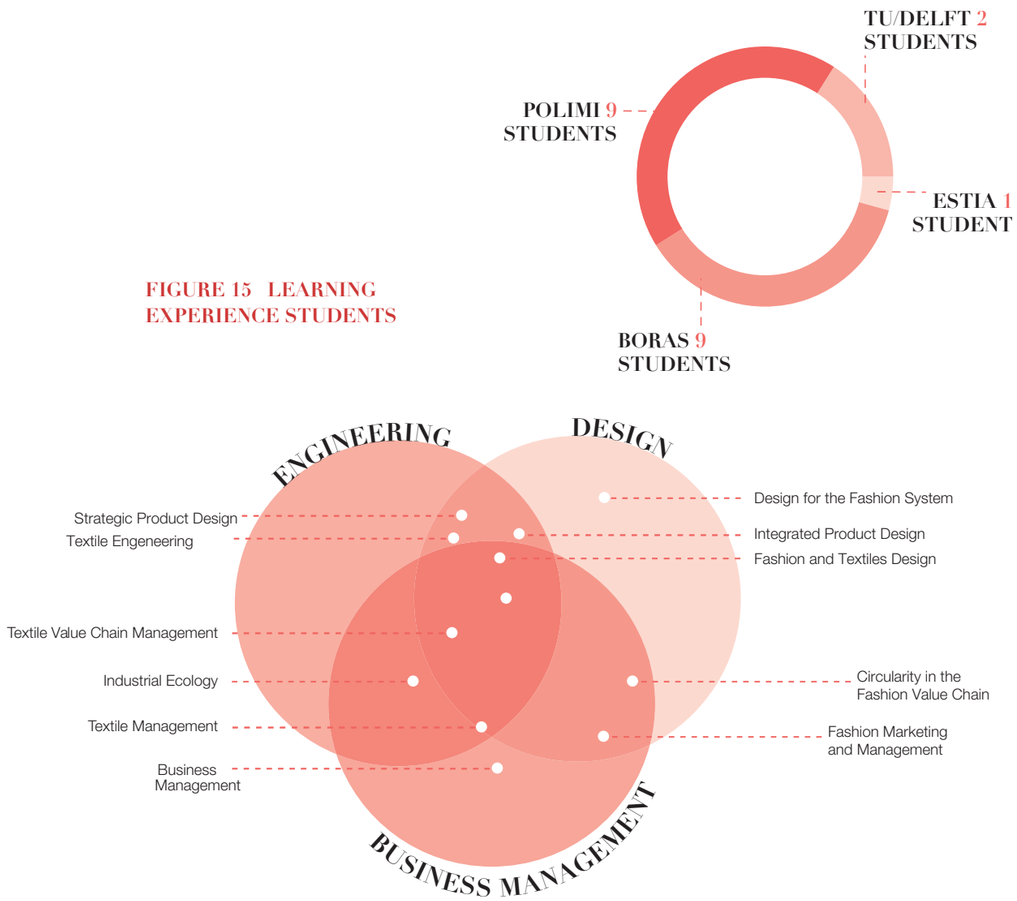


FIGURE 15 LEARNING EXPERIENCE STUDENTS

Textile Engineering, Business Management)
- 2 students from TU/Delft - Industrial Design Engineering Faculty (The Netherlands) (MA in Strategic Product Design),
- 1 student from Ecole supérieure des Technologies industrielles avancées (France) (PhD student in Circularity in the Fashion Value Chain).

Students worked in 7 teams of about 3 members each, with interdisciplinary backgrounds and varied abilities. Group selection has been defined from the teaching staff, in order to create a balanced mixture of disciplines in each group. The learning experience has been partnered with two European companies leading the sector of Fashion-Tech: Centexbel (CTX) and We Love You (WLY).

3.4 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, and business management related to new technologies applied in the fashion sector with a clear aim to advance sustainable development. The course has also focused on skills related to scalability from a social innovation perspective in terms of scaling-out, scaling-deep and scaling-up dimensions (Fig.16).

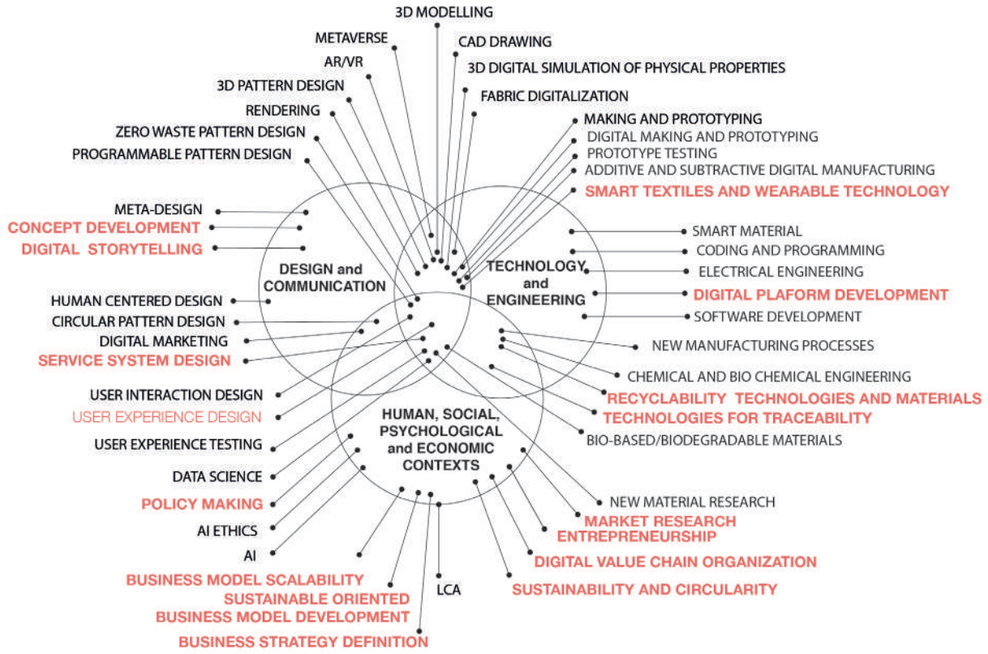


FIGURE 16 SUBJECT SPECIFIC SKILLS IMPLEMENTED IN THE LEARNING EXPERIENCE

Lesson learned from integrating design and business management education

The examination of the didactic experience identifies opportunities and challenges when integrating learning activities between two main different disciplinary domain such as design and business management, in the field of Fashion-Tech focusing on sustainable and societal challenges. The results of this study come from a thematic analysis of the project documentation delivered by students during and after the didactic experience, as well as from a comparison of these projects with the Intended Learning Outcomes initially presented. The findings have been clustered according to the projects' topics/contents (sustainability-oriented challenges, multi-dimensional value creation and SDGs, architecture of delivered solutions, technology, revenue streams and scaling opportunities) and to elements influencing the process development/ implementation (tools and phases of the didactic experience). The intention is to highlight lesson learned and recommendations for future implementations of similar learning experiences in the Fashion-Tech field within interdisciplinary and international students and teaching staff.

Reflections on the project topics/contents

Sustainability-oriented challenges

The developed portfolio of 7 projects in total addresses the topic of the diversity of sustainability challenges, offering product and service-oriented solutions for both business and customers. These include:

- B2B services that directly target reduction of pre-consumer and post-consumer textile wastes by enabling upcycling (UP:CO) and recycling (KleerTech);
- B2B2C product service systems tackling fashion overconsumption and deadstock/excess inventory by offering on-demand personalized locally produced fashion from sustainable (Clod3) or biomass/living materials (Enokitake);
- B2B and C2C services driven by social mission of preserving local craftmanship traditions (Coordinates, B2B) and re-investing income from re-commerce of second-hand/vintage clothing into local communities by funding education and social initiatives that promote standards of conscious consumption (R-Indumento, C2C);
- B2B services that help bring supplies of innovative sustainable materials (e.g. orange fibers) to market by matching scientific knowledge of materials innovation with the needs of textile industry actors for eco-friendly fabrics. These services also provide financial resources in the form of venture capital investments (I Turn Around).

Multi-dimensional value creation and SDGs

The solutions developed aim for systemic changes in the textile industry

and target multidimensional value creation for different stakeholders (e.g., economic, environmental, social, information etc.) as reflected in a range of addressed SDGs:

- SDG 12 (Responsible production and consumption) by all 7 projects;
- SDG 17 (Partnering for goals) by 5 projects (e.g., KleerTech, Clod3, UP:CO, R-Indumento, Enokitake);
- SDG 8 (Decent work and economic growth) by 4 projects (e.g., KleerTech, Clod3, I Turn Around, Coordinates);
- SDG 13 (Climate action) by 4 projects (e.g., UP:CO, I Turn Around, R-Indumento, Enokitake);
- SDG 9 (Industry, innovation and infrastructure) by 2 projects (e.g., Clod3, UP:CO);
- SDG 4 (Quality Education) by 2 projects (e.g., R-Indumento and Coordinates);
- SDG 6 (Clean water and sanitation) by 1 project (e.g., I Turn Around);
- SDG 14 (Life below water) by 1 project (e.g., I Turn Around).

Collaborative and platform-based architecture of Fashion-Tech solutions

Reflecting on the architecture of the delivered solutions in the student projects, it is evident that establishing a business ecosystem/network is essential for their existence: this means that intended multidimensional values are created in collaboration with different stakeholders. This collaboration is characterized by not mere exchange of tangible resources (e.g., products and financial capital). Instead, the focus of collaboration is on exchange of intangible assets, such as information, knowledge, competences and/or traditions, indicating the strong presence of service-dominant logic in all proposed solutions. The pursuit of multidimensional value creation via exchange of intangible assets among different stakeholders explains why all projects suggest an idea of establishing digital platform as fashion-tech solution for tackling sustainability challenges.

Technologies

The technologies suggested in students projects (as part of proposed platform solution) are big data analytics (KleerTech, I Turn Around) for facilitating design of sustainable/circular products and materials, 3D virtual digital technologies (Clod3, Enokitake) and Artificial Intelligence (Clod3, R-Indumento) for avatar creation, personalization, digital pattern generation in design phase and efficient inventory management,

convolutional neural networks (CNN) and modelling software (UP:CO) for creating upcycled fabrics and garments, NFC tags (R-Indumento) to unlock the personal story behind the garment shared by previous owner, circular product id/tag for collecting and sharing of traceable product information (KleerTech), and biomass materials (Enokitake, I Turn Around) merged with 3D scanning and printing technologies (Enokitake) to create sustainable garments with enhanced technical qualities.

Revenue streams

Ideating revenue streams for sustainability-oriented fashion-tech solutions allowed students to reflect on possible commercialization opportunities for future innovative products and/or services. These extend beyond the traditional approach of selling physical garments (Clod3, R-Indumento, Enokitake) and include membership/subscription, consultancy or royalty fees (KleerTech, UP:CO, Coordinates), as well as selling/licensing patented technologies I Turn Around, Enokitake). Capital flows are also foreseen from local/national governmental funds and investors in the form of venture capital (KleerTech, I Turn Around, Coordinates).

Scaling opportunities

As part of commercialization, scaling opportunities for Fashion-Tech solutions were devised by students. Majority of these opportunities arise from collaborations/partnerships that form the foundation of proposed digital platforms, and are viewed as imperative for scaling targeted sustainability improvements. All student projects suggest a complementary set of scaling policies, including scaling up (e.g., impacting institutions at the policy level), scaling out (e.g., replicating and disseminating business practices) and scaling deep (e.g., impacting cultural values and beliefs), that highlights a systemic approach to scaling innovation.

In particular, scaling up strategies in all projects include alliance building and advocacy to promote changes in the policy framework that supports the circular economy, e.g. adoption of regulation on data collection and management, and Extended Producer Responsibility (EPR) policy. Few projects, e.g. KleerTech, I Turn Around, UP:CO, argued for the need of establishing partnerships with governments (in the form of governmental support and/or funding) to promote industry-wide collaboration for the adoption of these regulations and policies. Scaling out strategies are pursued via diversifying the product portfolio (e.g., I Turn Around), by licensing/selling the developed solutions to other firms (e.g., Clod3), by replicating business units in other regions/countries (e.g. R-Indumento). Among the often suggested scaling deep strategies are practices of

offering online events, workshops and courses to educate customers about sustainable and circular fashion, support technological upskilling and highlight advantages of developed solution both from individual and environmental/social perspectives. Few projects, e.g. R-Indumento and Clod3, suggest re-investing parts of revenues in research and local communities development by funding sustainable education and social innovation projects.

Results on tools and phases of the didactic experience

Discover Phase

The discover phase consisted of three theoretical modules (sustainable design, Fashion-Tech interventions and Fashion-Tech business and impacts) delivered via HB's educational digital platform Pingpong. To demonstrate the completion of the theoretical part and to be admitted to the project-based activities, students were required to pass the quizzes following the lectures. Although the participants found the theoretical part of the course (discover phase) to be comprehensive and aligned with activities in the challenge based part of the course (define and design phases), there are a number of improvements can be recommended:

- Inclusion of more 'real life' cases of companies and specific sectors of the industry so that students can discover, analyse (using presented theory in lectures) and critically reflect on before engaging in the consequent project tasks (in define and design phases). This can be done using peer review methods that will also stimulate more collaboration and interdisciplinary skills exchange in the early stage of the learning experience;
- More lectures covering different topics on the engineering perspective (expanding theoretical module on 'Fashion-Tech interventions') to create better understanding among learners on the application opportunities and role of technology;
- Better explanation of theories, tools and templates (including practicing its application, e.g., in analysis of aforementioned 'real life' cases) to be used in the design phase.

Define Phase

The define stage as mentioned earlier was designed to facilitate interaction between students' peers and students-tutors. It included the following activities:

- Presentation of tutors, team building and intro of challenge brief;
- Group tutoring in smaller groups (30 minutes per group) with no formal deliverable and provided as opportunity to ask questions to clarify the tasks of the design phase;
- Asynchronous student-led activity (drafting project company vision, mission, core values and initial business plan using MIRO boards with provided templates) to support problem formulation in the consequent design phase. The review of this activity was included in design 1 phase of the learning experience.

Reflecting on activities of the define phase, it can be suggested to provide more precise categories of sustainability and societal challenges to better guide students in the early process of developing their initial business ideas. This in turn would contribute to a more focused problem formulation and concrete solution developments in the consequent design phase.

Design Phase

Design phase consisted of three design sub-phases.

Design 1 phase focused on the following tasks:

- Identifying a critical societal/sustainability challenge that your company pivots on;
- Elaborating on how your company is guided by this challenge and associated SDGs in its vision, mission and business plan.

The following activities were carried out to complete the tasks of design 1 phase:

- Industry expert talks from WLY & Centexbel followed by Q&A;
- Asynchronous student-led activity to deliver the above mentioned tasks (using MIRO boards with provided templates/tools);
- Group tutoring in smaller groups to help ideation process (10 minutes per group)
- Plenary review session with tutors where each group delivered 10-15 min elevator pitch on critical challenge, related SDGs targeted by their company and how it is reflected in company's vision, mission and business plan (using MIRO board as presentation space)

The problem/challenge in design 1 phase was primarily informed by students desktop research of the scientific and 'grey' literature. By engaging in dialogue with potential users of the solution (e.g. companies and consumers) during the early design phase of the project, allowed a more specific/in-depth problem identification by students. It will also enable development of more specific and applied fashion-tech solutions/ offers. For instance, corporate tutors can engage in presenting and discussing cases, needs and challenges from their experience of working in the industry.

Design 2 phase focused on the following tasks:

- Locating the Fashion-Tech solution rendered by your company;
- Mapping the value profile (proposition, means to create, deliver and capture these);
- Detailing sustainable business model blueprint;
- Preparing additional material, e.g. Images, sketches, to explain how your solutions works (detail technology, design, processes, materials etc. based on what is relevant and possible based on your group expertise).

Design 3 phase focused on the following tasks:

- Identifying the current scalability challenges and opportunities in the solution provided by project company;
- Identifying approaches/strategies for scaling impacts based on systemic innovation perspective;
- Reflect on scaling outcomes on SDGs and providing recommendations for the adjustment of scaling strategy/approaches (if relevant).

The following activities in design 2 and design 2 phases to complete the associated tasks:

- Industry expert talks from WLY & Centexbel followed by Q&A;
- Asynchronous student-led activity to deliver the above-mentioned tasks (using MIRO boards with provided templates/tools);
- Plenary review session with tutors (15-20 minutes per group) where developed ideas were presented and discussed (using MIRO board as presentation space).

The dominance of the platform-based solutions and broadness of delivered students' concepts often lack in-depth elaboration of product/service/experience design aspects, pointing towards the need to provide more focused project brief and more concrete design-driven tasks, guidelines and methodologies, so that students better understand the selected problems, develop and present more specific solution related ideas in the design phases. There is also a need for providing a room for more elaborated discussion on interaction between design, technology and business perspectives in the design phases so as to facilitate understanding of how complementarities and tensions of multifaceted considerations affect the final solution, and its real-life application and commercialization potential. This discussion should be implemented more proactively within and between student groups (for instance via using peer review approach), as well as between students and tutors from companies and academia. Whereas more time and commitment would be required on behalf of tutors from different organizations, such discussion will help establishing a shared understanding of what is a sustainable design from a plurality of perspectives, as well as enabling more tangible/concrete concepts design in interim and final project deliverables.

Deliver phase

As mentioned above, final deliverable included project presentations in the format of the pitch (15 min), video communicating the project outputs (2-3 minutes) and group written report (max 6000 words excluding references). For all deliverables accompanied templates were provided both on pingpong and on MIRO boards. Although the overall quality of student's presentation, reports and video making skills was generally perceived as good, it was obvious that substantial differences existed between the different group presentations. Reflecting on final project outputs, more in-depth presentation of developed solutions was expected to enhance its quality and relevance, especially in terms of referring to customers and competitors research, detailing design and technology choices. In addition, more critical reflection with regards to sustainability implications of developed solutions was expected.

Digital learning environment and tools

The digital environment and tools facilitated the learning experience and knowledge sharing well. MIRO, PINGPONG and ZOOM were of rather high usability and functionality, although several challenges related to the use of the MIRO collaborative boards were encountered, e.g., contents moving or disappearing, slow performing interface. Also, pre-structured boards based on use of templates were found by some students as constraining.

Opportunities and limitations of the case study

Business-driven and design-driven Fashion-Tech innovation

The developed portfolios of student's projects and experiences shared at the end of the course reflect the multidisciplinary nature of proposed Fashion-Tech innovative solutions, combining business, design and technology perspectives. Within the frames of the course run by HB and dominated by presence of HB enrolled students, the stress nevertheless was on business-driven (vs. design- driven) Fashion-Tech innovation. We envisioned business opportunities driven by multidimensional value creation (aligned with triple bottom line approach and SDGs) and by new revenue streams. This was the major pathway for ideating innovative Fashion-Tech products and services. This pathway was then enriched with design and technology-oriented perspectives when possible, in line

with envisioned sustainability-oriented business innovations. However, based on received project results and lessons learned, it should be acknowledged that design and technology perspectives should become more prominent/integrated in students delivered portfolios (e.g., in terms of more detailed explanation of product/service design and technology use/application), so as to deliver more concrete Fashion-Tech solutions and improve its innovation/exploitation potential for the industry. In particular, there is a need: 1) to provide more room for design activities in order to perform in-depth research and mock-up some concepts, 2) to include more contents covering technology perspective, 3) to formulate more focused industry brief to guide more concrete project definition and implementation, and finally 4) to facilitate better discussion on interaction between plurality of perspectives (design, engineering and business) on sustainable design of innovative Fashion-Tech solution.

Sustainability skills development/critical reflections on sustainability implications of developed solutions

Sustainability considerations were at the forefront of the student's projects, guiding the development of the Fashion-Tech solutions throughout the define and design phases. The delivered projects were specific in terms of targeted societal challenges, SDG goals and associated targets (2-3 goals were selected per project). Moreover, it was complemented by a mapping of the multidimensional sustainable value creation opportunities for different stakeholders when ideating business model architecture and scaling. At the final stage of the challenge-based part, students also reflected on how the ideated Fashion-Tech solution might affect directly and indirectly other SDGs not inherent to the initial project ideas, so as to be aware of the possible negative sustainability impacts of the developed concepts. Nevertheless, this was accomplished at a superficial level, as the implications of developed Fashion-Tech solutions for the use phase and possible rebound effects that can lead to more unsustainable consumption patterns and levels that were not highlighted in the final students' reports and presentations. By default, digitalization and digital platforms were perceived by majority of students as advantageous for sustainability, dismissing debate on the 'dark side' of digitalisation and platform economy. Therefore, in the future courses it is recommended to include learning contents and activities that help students in developing more critical perspective on sustainability implications of technologies, e,g., how it affects use phase behaviour and users motivations, equality issues etc.

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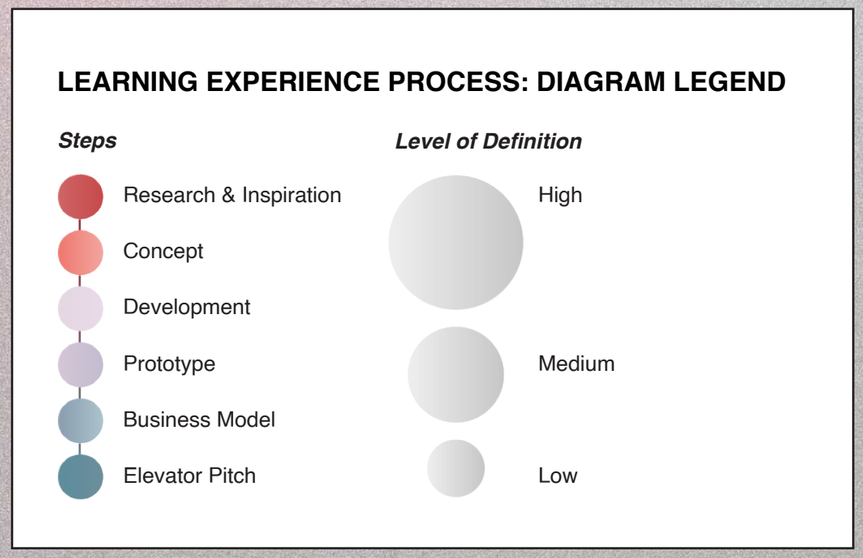
FIELD EXPERIENCES
The portfolio of innovative fashion-tech concepts of product and services

KLEERTECH
CLOD3
UP:CO
I TURN AROUND
R-INDUMENTO
ENOKITAKE
COORDINATES



KLEERTECH

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Diego Bellesini, Integrated Product Design (POLIMI)
Kevin Mac Donald, Strategic Product Design (TUD)

#RECYCLING NETWORK **#CONNECTEDNESS** **#CIRCULARITY**

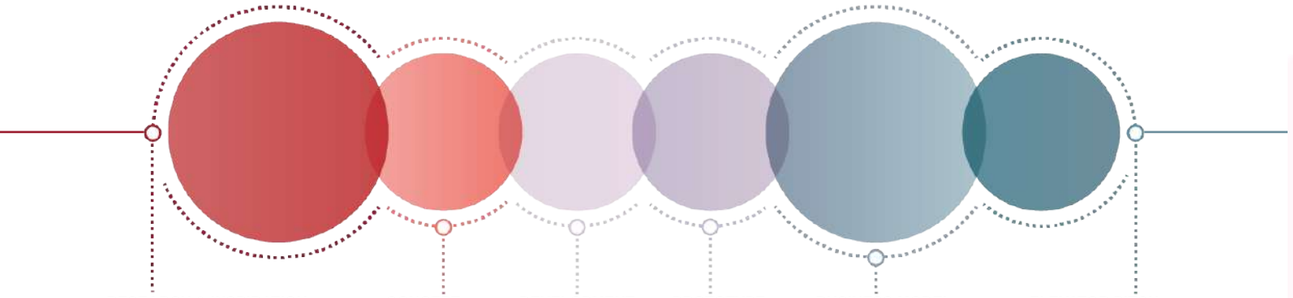
ABSTRACT
KleerTech is an online platform that aims to create efficient collaboration among brands and recycling companies, establishing a dialogue on the materials choices for the next generation of garments. Brands can in fact browse a wide digital material library constantly updated by recycling companies. Moreover, as all new fashion and textile collections become digitized, brands are given the opportunity to create a digital passport for their products embedded in the labels to communicate production data about the brand, price, care of the product, and production processes.

LEARNING OUTCOMES

Soft Skills
Multidisciplinary collaboration
Team development
Communication skills

Subject Specific Skills
Sustainable business management
F-tech research and state of art
Corporate strategy development

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Corporate strategic statement & sustainability challenge: lack of transparency

CONCEPT
Collaboration network among brands and recycling companies

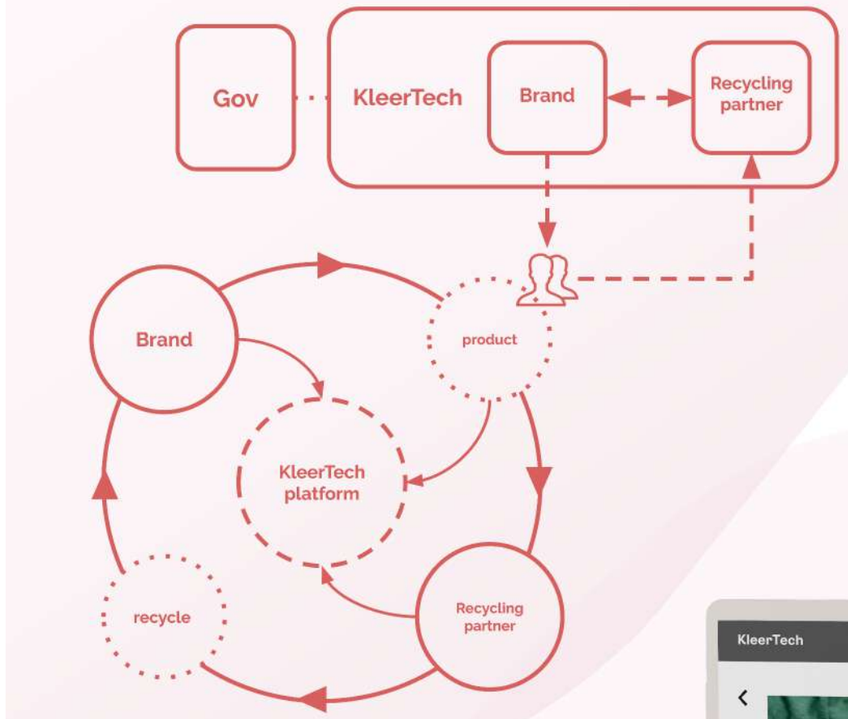
DEVELOPMENT
Digital passport for products & materials, platform design

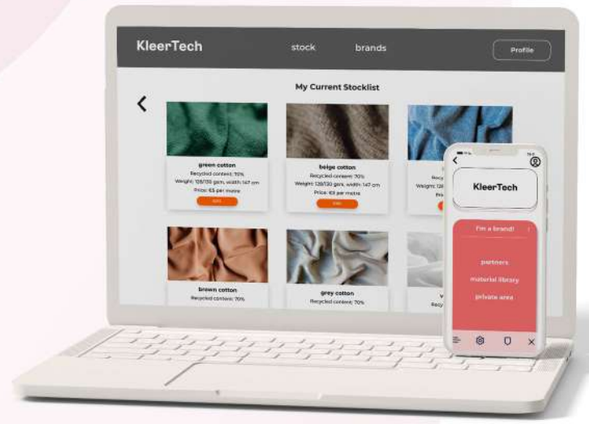
PROTOTYPE
Website prototype

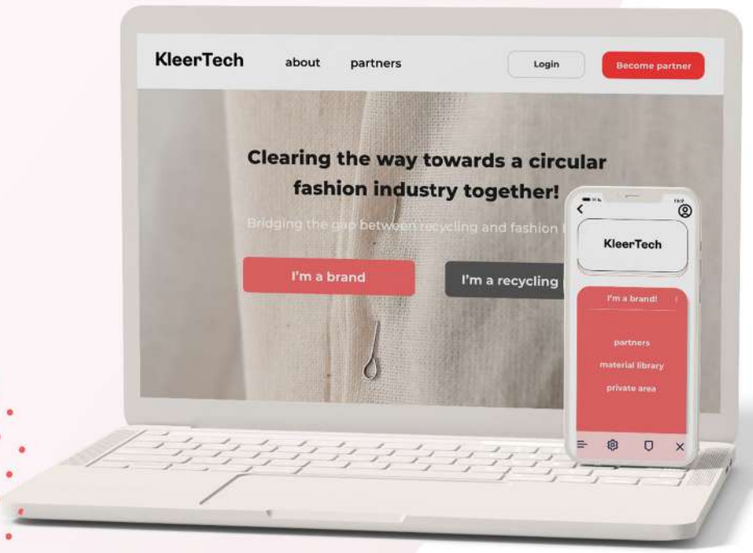
BUSINESS MODEL
BM canvas, scaling strategies & sustainability considerations

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS







CLOD3

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#DIGITAL FASHION #PERSONALIZATION #AI FORECASTING

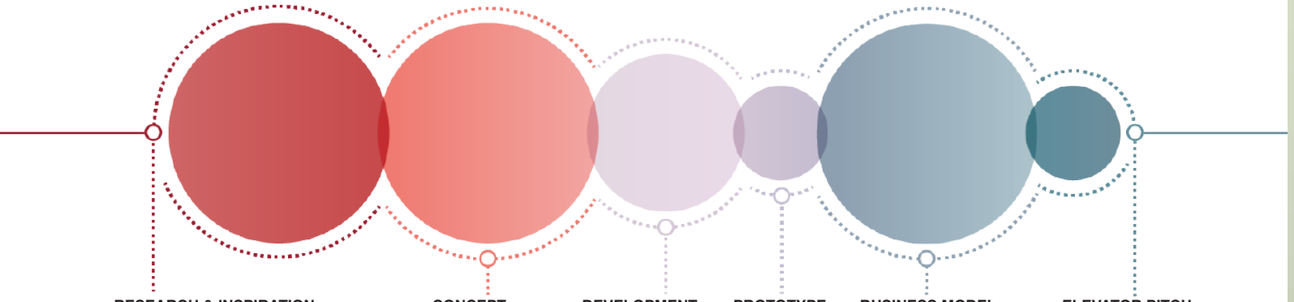
ABSTRACT
CLOD3 addresses overconsumption by using Artificial Intelligence and 3D-based solutions to create fashion collections. It is conceived as a worldwide digital business that combines AI-generated avatars based on customers' measurements and on-demand produced garments. CLOD3 also tackles inclusivity and a niche market, including consumers that have trouble finding the right size clothes due to their body types, and cannot relate to standardized body shapes and measurements.

LEARNING OUTCOMES

Soft Skills
Multidisciplinary collaboration
Overcoming technical difficulties
Lateral thinking

Subject Specific Skills
Concept development
Fashion business management
Iterative design process

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Corporate strategic statement & sustainability challenge: overconsumption

CONCEPT
Made-on-demand garments on AI and 3D-based platform

DEVELOPMENT
Avatar-based try-on technology definition, social impact of AI

PROTOTYPE
Website architecture

BUSINESS MODEL
BM canvas, scaling strategies & sustainability considerations

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS

UP:CO

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#COLLABORATION #REPURPOSING #CNN

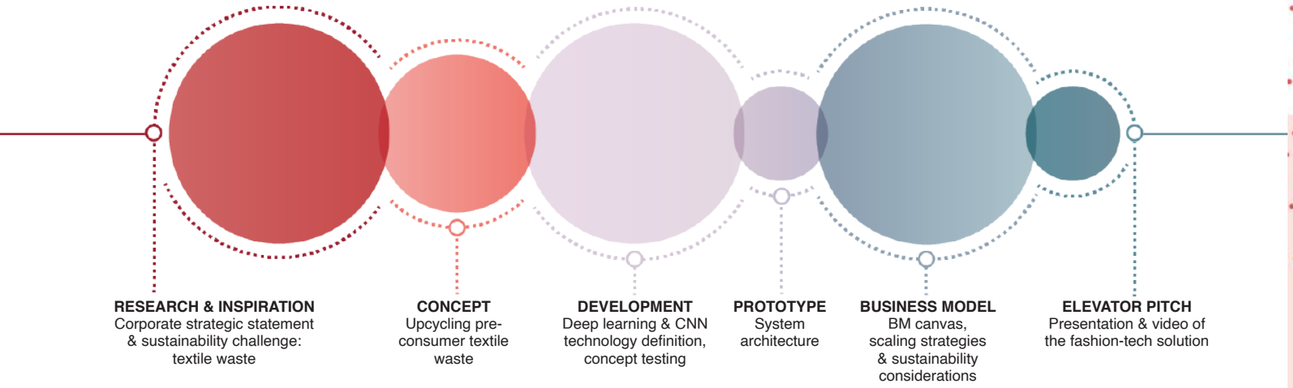
ABSTRACT
UP:CO is an online platform aiming to repurpose pre-consumer textile waste to transform it into high-value fabrics and garments. It connects upcyclers, manufacturers and the general public to help them exchange the unused fabric cut-offs. Using convolutional neural networks (CNN) and modelling softwares, it is able to maximize the use of textile waste in innovative ways, creating upcycled fabrics and garments. It also promotes collaboration with designers and fashion design students through an online shop that sells the upcycled materials.

LEARNING OUTCOMES

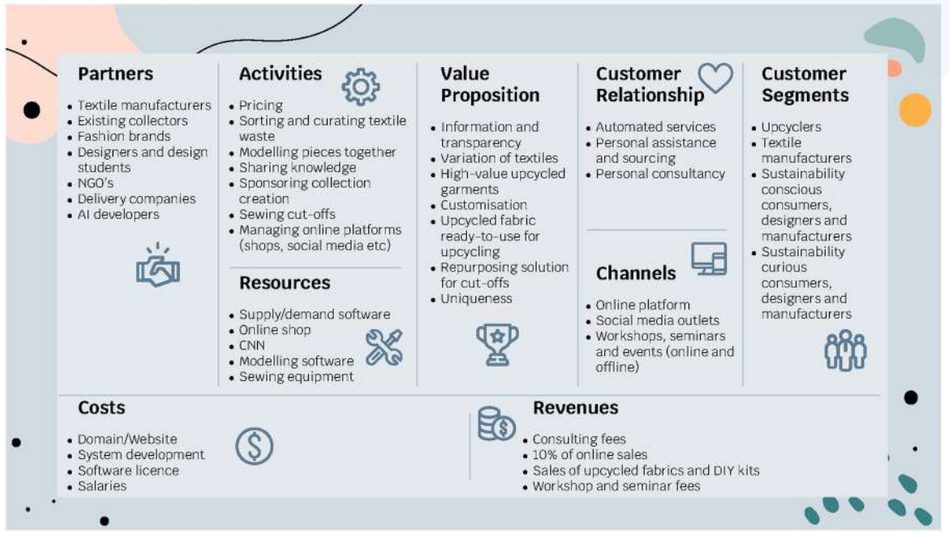
Soft Skills
Multidisciplinary collaboration
Team development

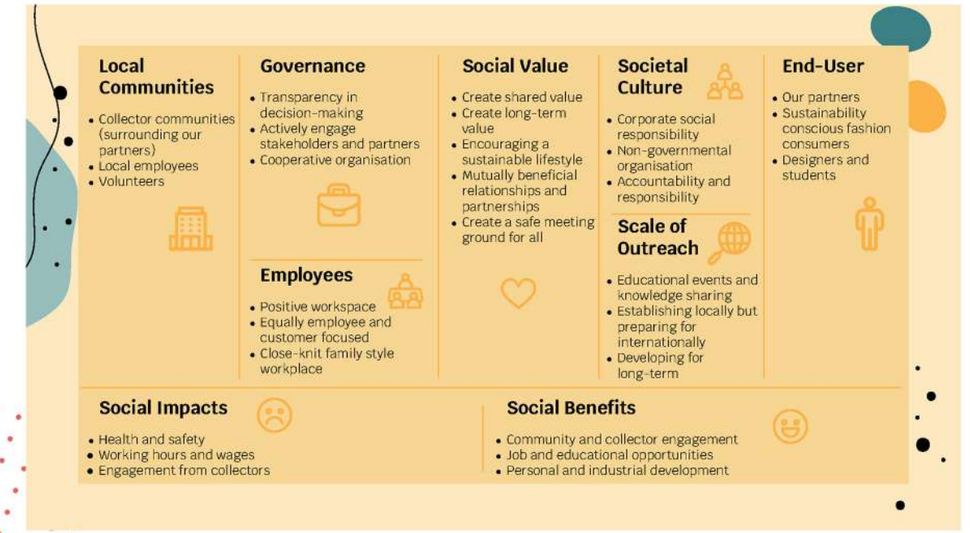
Subject Specific Skills
Sustainable business management
Consumer profiling

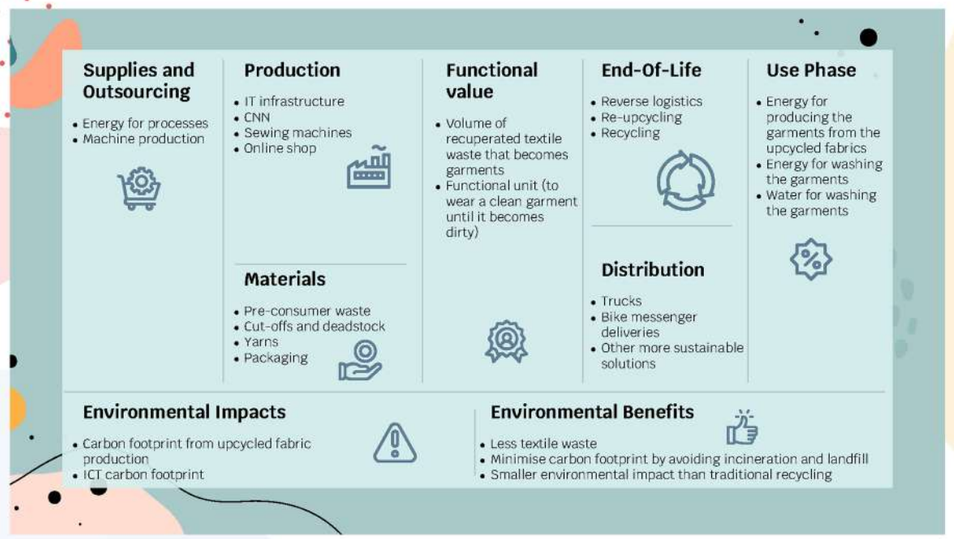
LEARNING EXPERIENCE PROCESS



IDENTIFIED SUSTAINABILITY IMPLICATIONS







I TURN AROUND

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Elena Ilicheva, Fashion Marketing and Management (HB)

#ALTERNATIVE FIBERS **#SUPPLY CHAIN MANAGEMENT**

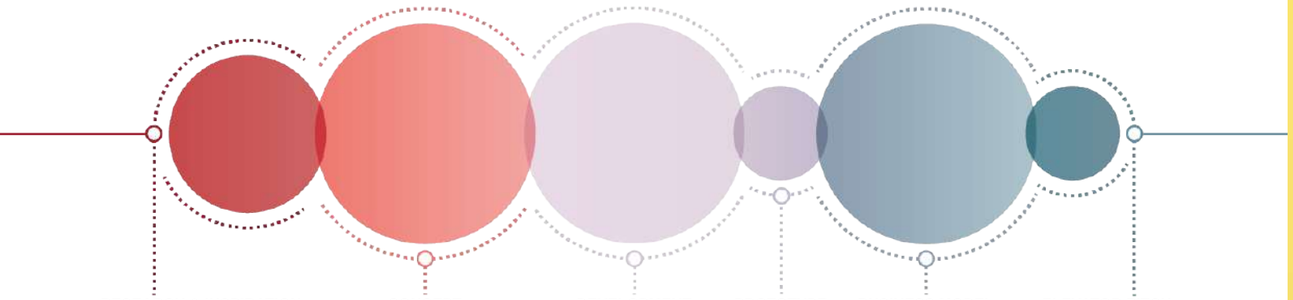
ABSTRACT
I Turn Around is a venture investment fund focused in buying rights and producing alternative textile fibers. It creates a network between brands and developers targeting the B2B market. The final aim is to create a sustainable hi-tech value chain and stimulate the scientific society to innovate. To ensure transparency, the intellectual property of the inventor is protected, and the entire production and supply chain, along with calculation of materials cost and value chain processes are monitored through online tracking and blockchain technologies.

LEARNING OUTCOMES

Soft Skills
Real life challenge
Communication skills

Subject Specific Skills
Business model development
Sustainable textiles management

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Corporate strategic statement & sustainability challenge: encouraging textile innovation

CONCEPT
Venture investments in textile technology

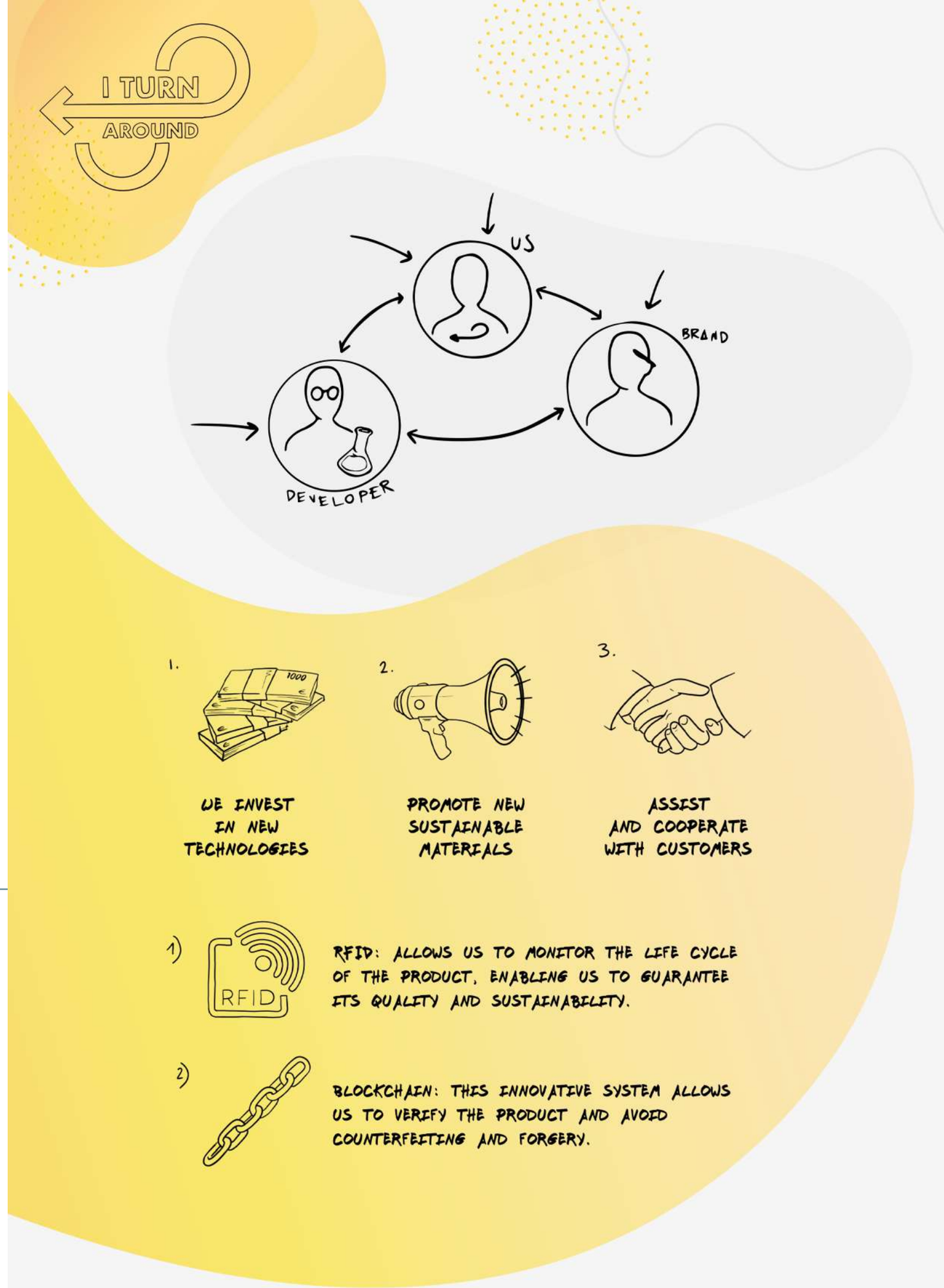
DEVELOPMENT
RFID and blockchain technologies definition

PROTOTYPE
System architecture

BUSINESS MODEL
BM canvas, scaling strategies & sustainability considerations

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS



R-INDUMENTO

Ana Filipa da Silva, Design for the Fashion System (POLIMI)
Magdalena Kaczmarek, Fashion Marketing and Management (HB)
Zhixiang Tao, Integrated Product Design (POLIMI)

#SECOND HAND **#COLLABORATIVE CONSUMPTION**

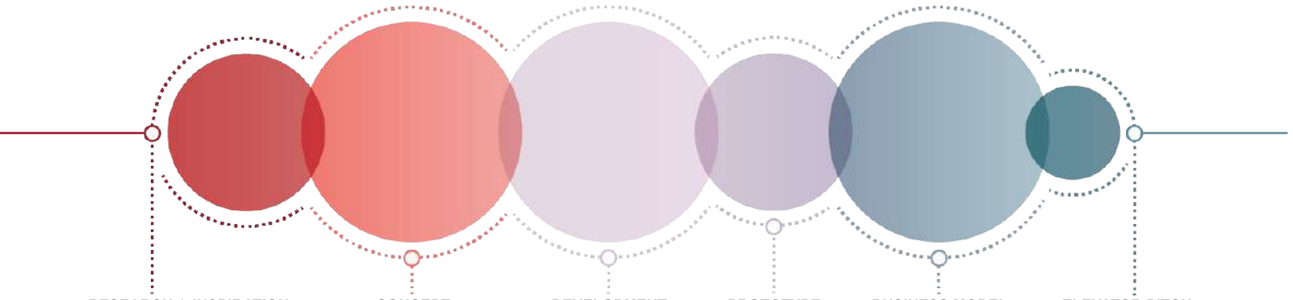
ABSTRACT
R-Indumento is a social enterprise launching B2C re-commerce tech-powered digital platform for vintage and second-hand garments and accessories. The system is composed by the digital platform via website/app is coupled with offline spaces via pop up events, where the consumer can donate, style, reuse and recycle their items. It partners with brands to sell unsold stocks to customers and with a recycling enterprise to tackle waste responsibly. Ozone & UV cleaning technology are used to sanitize the garments, and AI and innovative NFC labels that tell the story behind the re-used garment.

LEARNING OUTCOMES

Soft Skills
Multicultural teamwork
Tasks distribution
Decision-making

Subject Specific Skills
Commercial product roadmap
Corporate strategy development
Sustainable business

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Corporate strategic statement & sustainability challenge: reducing material footprint

CONCEPT
Digital platform to promote second-hand & repurposed clothing

DEVELOPMENT
NFC and AI technologies definition, garment storytelling via digital notes

PROTOTYPE
App prototype

BUSINESS MODEL
BM canvas, scaling strategies & sustainability considerations

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS

ENOKITAKE

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Shan Lu, Design for the Fashion System (POLIMI)
Carolina De Lara, Fashion and Textile Design (HB)

#BIOMATERIALS #3D PRINTING #3D SCANNING

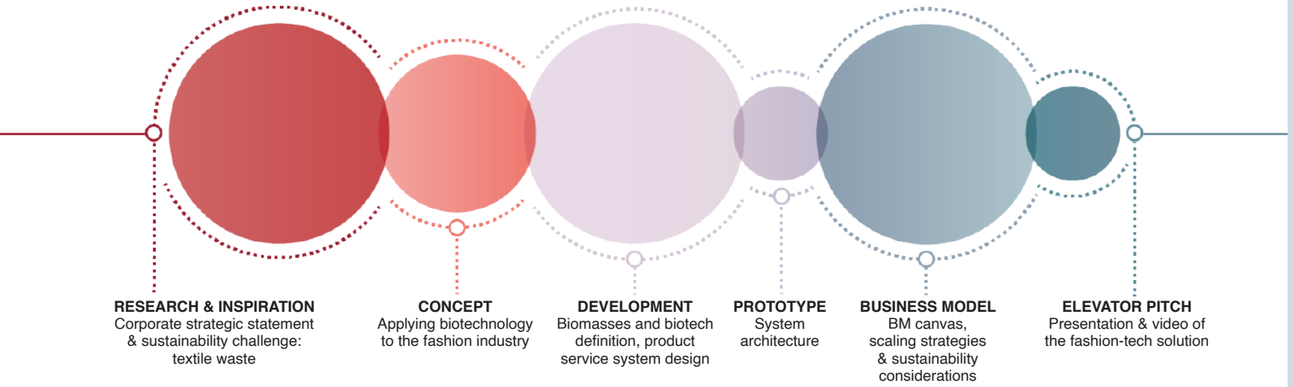
ABSTRACT
Enokitake strives to reduce waste production through the combined use of 3D scanning and printing technologies coupled with the emerging field of biomasses and living materials. The concept is to produce a small collection made out of biomaterials, that the consumer could personalize and fit to themselves through an app. The customer's 3D file would be translated into a pattern and a garment to be 3D printed or sewn as locally as possible, and finally, delivered to their doorstep. Being organic and biodegradable, the final product is easy to recycle.

LEARNING OUTCOMES

Soft Skills
Real life challenges
Tackling specific issues

Subject Specific Skills
Market research
Sustainable business management

LEARNING EXPERIENCE PROCESS



IDENTIFIED SUSTAINABILITY IMPLICATIONS

USE 3D SCANNING TO OBTAIN THE EXACT REPLICA OF YOUR BODY

"We make what we need, no more and no less.
We make sure it looks flawless."

COORDINATES

Riccardo Guiducci, Design for the Fashion System (POLIMI)
Alva Hjelm, Textile Engineering (HB)
Ulrika Hoonk, Business Management (HB)

#CRAFTSMANSHIP #LOCALNESS #SLOW FASHION

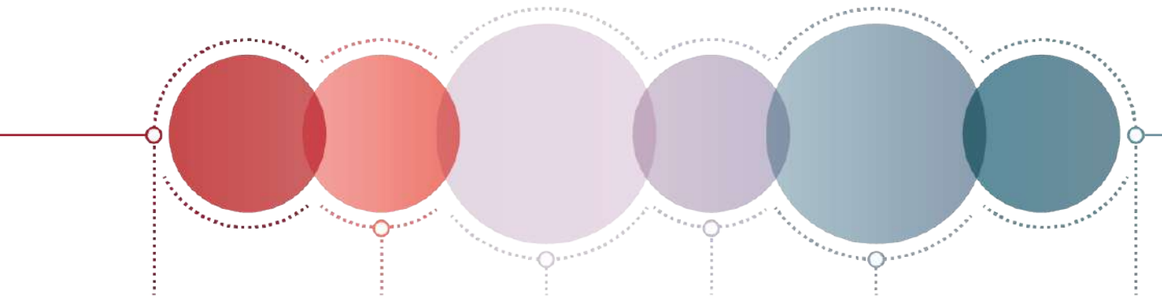
ABSTRACT
Coordinates is a digital display window for designers, producers and the general public, aspiring to educate designers about circularity and to teach the general public how to consume responsibly. They offer a catalog of producers to support customers in finding locally produced materials and use a sustainability index to monitor producers. Coordinates aims towards slow fashion while at the same time promoting small, local and traditional craftsmanship.

LEARNING OUTCOMES

Soft Skills
Tackling specific issues
Multidisciplinary collaboration

Subject Specific Skills
Consumption patterns identification
Sustainable business management

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Corporate strategic statement & sustainability challenge: encouraging slow fashion

CONCEPT
Digital display window for local craftsmanship

DEVELOPMENT
User journey mapping, platform structure and delivery model

PROTOTYPE
Website prototype

BUSINESS MODEL
BM canvas, scaling strategies & sustainability considerations

ELEVATOR PITCH
Presentation & video of the fashion-tech solution

IDENTIFIED SUSTAINABILITY IMPLICATIONS

4. CASE STUDY THE SECRET LIFE OF CLOTHING

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4.1 EXPLORING GARMENT INTERACTIONS

As a society we are becoming increasingly aware of the need to understand product lifecycles, so that we can use, repair and re-use the material things we consume more sustainably. We are also increasingly aware of the issues relating to the usage of our data in product linked services. At the centre of these concerns sits the field of wearable technology (WT). By combining the cycles of obsolescence and novelty for which consumer technologies and fashion are notorious, WT is generally created with a limited period of utility. It often combines materials such as textiles with traditional electronics incorporating rare earth elements, making disassembly and recycling incredibly complex *(Saunders, 2021).* Plus, WT must capture data from the wearer's body, their digital presence and their surroundings to provide services to the waerer. To begin to address these issues it is vital to design interactions with WT which are useful in the long term, so that the lifecycle of a WT product is extended. Yet while a focus on interactivity is a key skill required by designers of WT, current pedagogic models evolving from traditional fashion, jewellery and accessories courses generally maintain a focus on aesthetics. Thereby limiting student designers' ability to fully engage with technology design. In addition, the interactions we have on a daily basis with the items we wear and in turn their interactions with our environment (including other technologies) are rarely understood or investigated.

This section situates the course 'The Secret Life of Clothing: Exploring Garment Interactions' in relation to existing literature on learning and pedagogy for WT, along with relevant design research methods. The design and implementation of the course are further described in the following sections, concluding with a discussion of student outcomes and our insights as educators having delivered the course.

The majority of literature exploring pedagogy for WT focuses on developing coding or physical computing skills through in-situ making activities, primarily in the form of hackathons *(e.g. Byrne, O'Sullivan, & Sullivan, 2017)*, or makerspace and maker community projects with particular social aims *(e.g. Okerlund, Dunaway, Latulipe, Wilson, & Paulos, 2018; Pasquini et al., 2020)*. In addition, UX pedagogy is increasingly situated in studio practice models *(e.g. Mitchell et al., 2019)*. While collaboration is often proposed to be a key competence in developing a WT design, the traditions of hackathons, community projects and studio pedagogy are challenged by remote, online learning in which student groups may be situated in different cities, countries and time-zones (the context of the FTalliance project).

As the foundational skills of coding and technology prototyping have taken precedence in prior pedagogic models, they often fail to develop students' understandings of the use and functionality of WT. While community projects sometimes attempt to solve problems through critical making *(Pasquini et al., 2020)* thereby engaging with the reasoning behind creating a garment or accessory augmented by technology, consideration of its day-to-day usage is rare. Instead, teaching primarily supports the creation of prototypes which often use technology to provide a novel *(Okerlund et al., 2018),* rather than a genuinely useful interactive experience. This reflects the majority of fashion WT projects which receive significant media attention, as they are created to generate publicity or to showcase emerging technical developments. These contexts are a major informant of designers sociotechnical imaginaries *(Jasanoff & Kim, 2015)* in relation to the purposes and applications of WT. As novelty WT has such a strong influence on designers' imaginations, it can be difficult for them to conceive what a truly useful and beneficial interactive technology, which maintains its relevance and utility in the long term might be.

For this reason, novel research methods were investigated to prioritise the exploration of the daily use of a designed product or service, and speculation on the application of emergent technologies in a product or service which cannot yet be realised as a functional prototype. These are discussed further in the following sections.

Thing Ethnography and Thing Centered Design

Thing ethnography' *(Giaccardi, Cila, et al., 2016; Giaccardi, Speed, et al., 2016)* refers to the use of sensor augmented objects (usually mundane, everyday items) to capture data which is used to produce an ethnographic account of the lifeworld of a non-human thing. It is derived from design ethnography and anthropology but places a specific emphasis on de-centring from human perspectives in order to gain new insight into human relationships with things, and their related use practices. This background informs the methodological aims of thing ethnography as a means to identify and solve problems (create actionable insights) for humans. Yet Giaccardi et al. *(2016)* dispute the ontological framing of humans as the only entities capable of generating such insights and solutions. Instead, they propose that things be treated as 'co-ethnographers', similarly to Pink's *(2015)* human research participants. The 'ontological symmetry' *(Giaccardi, Speed, et al., 2016: P237)* between humans and things, when exploring human processes is particularly suitable for emphasising the true usage of a fashion item and the associated habits, we develop around it. Crucially, thing ethnography attempts to de-centre from some of the cognitive biases we hold as humans but maintains a recognition of the role of the human within a

vitalist (Bennett, 2016) New Materialism.
The primary methods reported in thing ethnography are visual. Using lifelogging cameras to automatically capture data depicting things as emplaced within their environments, from which adjacencies and relationalities to other things, along with temporalities are noted *(Chang, Giaccardi, Chen, & Liang, 2017; Giaccardi, Cila, et al., 2016; Giaccardi, Speed, et al., 2016).* In the studies reported, this visual data was organisedinto timelines, seemingly concurring with the importance of temporality in understanding material practices observed by *(Gowlland, 2015)*. Moving beyond visual data and methods Chang et al., *(2017)* propose the use of both time lapse cameras and smartphones for GPS tracking.
Finally, and importantly Giaccardi, Speed, et al. argue that 'as objects connected to the Internet become more common and able to collect massive amounts of data, they may begin to reveal patterns that were previously invisible to humans, and contest what we usually take for granted' *(2016: P236).* This suggests that the focus on data collected by connected WT can also be foregrounded through thing ethnography. Productively re-framing our perceptions of usage habits and passive data capture by connected WT.
Thing ethnography is conceived as a key informant of 'thing centred design'. A design process which leverages insights into the life of a thing through methods such as 'Interviews with Things' *(e.g., Chang et al., 2017)* and the creation of 'Object Personas'. Both can be informed by ethnographic data captured through lower tech methods than a true thing ethnography, even by the designer themselves capturing contextual data, although this is more limited in understanding the temporality of use of the studied thing. Arguably these methods are a creative and somewhat speculative response to the ethnographic data. Speculation is also a key method in exploring emerging technologies.

Speculative Methods

Speculative methods enable students to consider the use and functionality of a proposed technology, without recourse to what is currently possible to build, or to their perhaps limited knowledge of technology prototyping. For example, speculative prototyping was employed by Jewitt and colleagues *(Jewitt, Leder Mackley, & Price, 2021; Jewitt, Price, Leder Mackley, Yiannoustou, & Atkinson, 2020)* to explore participants' sociotechnical imaginaries (Jasanoff & Kim, 2015; Mager & Katzenbach, 2021) – hopes, fears, ethical concerns and collective predictions – for digital touch technologies. An area of technology which is currently emergent, largely lab-based and un-domesticated. Jewitt and colleagues' *(Jewitt et al., 2021, 2020)* methodology also incorporated storytelling and

bodystorming with the speculative technology prototypes, an approach discussed later in this chapter.
The creation of speculative prototypes may be considered a form of design fiction, though the exact nature of what design fictions are is still contested. In some views, design fictions involve the creation of physical artefacts as a means to engage their audience with a speculative scenario, which questions current social norms and invites critical thinking *(Dunne & Raby, 2013).* These artefacts are known as 'diegetic prototypes' and are generally considered as props to help situate the viewer within a design fiction and to suspend their disbelief in a fictional world. The term diegesis refers to the world of the story and as such a diegetic prototype is a prototype which exists within and is consistent with the fictional world that has been created. Lindley et al. *(2014: P5)* observe that 'By prototyping, in the traditional sense, we can touch, feel, and interact with possible futures. In many ways prototypes allow designers to have 'situated' interactions with concepts.' Lindley et al. *(2014)* further argue the situating aspects of design fictions and diegetic prototypes can help to immerse an ethnographer in an imagined emplaced encounter. As Pink *(2015: P192)* observes: 'Uncertainty, anticipation and expectation are often considered to be feelings, as much as verbal articulations of what has not yet happened. We imagine not only with our minds, but also with our bodies.'

Bodystorming and Designing with the body

The critical role of the body in designing interactions, movements and engagements with a wearer is highlighted by research into WT development. Indeed, Tomico & Wilde *(2016)* propose a shift from Human Computer Interaction (HCI) to Human Garment Interaction (HGI). The body is a critical informant to 'Experience Prototyping' in UX *(Mitchell et al., 2019)* during which an experience is acted out, so it can be more fully understood, particularly through sensory experience as highlighted by Tomico and colleagues' research into 'Somatic Practices'. An emerging area in HCI derived from dance research (Dean, 2011). Such studies can be considered autoethnographic in that they contain first person accounts of otherwise inaccessible bodily (somatic) experience, particularly relating to movement and sensation *(Höök, Jonsson, Ståhl, & Mercurio, 2016; Loke & Schiphorst, 2018; Núñez-Pacheco, 2018; Núñez-Pacheco & Loke, 2017; Wilde, Schiphorst, & Klooster, 2011)*. Many of these studies use experiential activities to help the researchers become more attuned to their somatic experience, including body scanning and Feldenkrais exercises *(Höök et al., 2016).* Further methods include the creation of estrangement or destabilising established practices in relation to movement and bodily experience

(Wilde, Vallgårda, & Tomico, 2017). This is discussed as performing established tasks in new ways, using on-body props, or interacting with a material in a non-traditional context. This creation of familiarity and estrangement is similar to that proposed by speculative design *(Dunne & Raby, 2013).*

The learning experience proposed in the following section attempts to address the identified gaps in current WT pedagogy research and the collaboration and contextual issues posed by online learning and multi-sited remote teamwork. Additionally, it employs the methods of Thing Centred Design, Anticipatory Ethnography and Bodystorming to engage participating students in exploring the use of worn objects as design informants.

unctionality of WT. While community projects sometimes attempt to solve problems through critical making *(Pasquini et al., 2020)* thereby engaging with the reasoning behind creating a garment or accessory augmented by technology, consideration of its day-to-day usage is rare. Instead, teaching primarily supports the creation of prototypes which often use technology to provide a novel *(Okerlund et al., 2018),* rather than a genuinely useful interactive experience. This reflects the majority of fashion WT projects which receive significant media attention, as they are created to generate publicity or to showcase emerging technical developments. These contexts are a major informant of designers sociotechnical imaginaries *(Jasanoff & Kim, 2015)* in relation to the purposes and applications of WT. As novelty WT has such a strong influence on designers' imaginations, it can be difficult for them to conceive what a truly useful and beneficial interactive technology, which maintains its relevance and utility in the long term might be.

For this reason, novel research methods were investigated to prioritise the exploration of the daily use of a designed product or service, and speculation on the application of emergent technologies in a product or service which cannot yet be realised as a functional prototype. These are discussed further in the following sections.

4.2 FOCUSING ON THE LEARNING EXPERIENCE

The Secret Life of clothing learning experience focussed on aspects of interaction design research which could be conducted independently in diverse locations. The creation of a functional WT prototype was deemed to be impossible for a group to achieve through remote collaboration without placing an unfair burden on more technically skilled students. Though this may lessen the material competencies proposed as central to hackathon and maker pedagogies, different forms of material engagement were foregrounded through the focus on bodystorming and the development of soft skills *(Byrne et al., 2017; Kafai, Fields, & Searle, 2014)*. Through the development of soft skills, increased understandings of technology, collaboration and project development remain a part of the pedagogic experience.

The learning experience was delivered entirely online via Microsoft Teams for lectures and file hosting, Miro for collaborative workboards and a custom course site on the Moodle platform for course information and content.

Teaching took place over ten weeks and was divided into synchronous and asynchronous components, with asynchronous lecture content ('Theoretical Pillars'), quizzes and preparatory activities delivered during an initial two-week period of self-directed learning. The practical 'Challenge Based' component of the course began in the third week, at which point students were formed into teams and the collaborative aspect of the learning experience began.

Learning experience contents description

The course structure and focus were introduced to students at a kick-off event prior to the two-week period of asynchronous, independent study and included in the syllabus of the course *(2022).*

Brief indicative contents

Discover: The Theoretical Pillar lectures are intended to help students develop a comprehensive background knowledge of Fashion-Tech in their own time to inform students' responses to the challenge-based part of the course. Students were encouraged to manage their own learning, selecting the most interesting lectures before the challenge-based part of the course. During this time, they were invited to create a 500-word Blog post about a lecture of their choice and discuss it with their peers'. All students were required to engage with at least eight of the Theoretical Pillar lectures, demonstrating their engagement by answering the related quiz questions.

Design: Students were asked to create a low-tech prototype of an

interaction with an object worn on the body, which will be used in the long-term, makes considerate, ethical use of the wearer's data and may promote more sustainable behaviour. The challenge-based part of the course introduced low-tech interaction design methods to simulate the data generated by a connected wearable device, to inform an interactive experience that reflects long-lasting interaction and ethical data treatments. Students were guided through a process of research informed design ideation for an interactive wearable technology concept.
Deliver: Teams showcased their design concept and low-tech interaction prototype in a short video and accompanying project pitch.

Learning Experience Objectives

The general purpose of the course was to train future professionals in transferable interaction design research skills, applicable to a wide range of user centred technology and experience design contexts. Additionally, it aimed to support them in developing critical responses to current issues in the fashion WT sector, particularly in relation to sustainability and ethics.
To do this, the course aimed to provide students with tools to critically address contemporary social challenges in their development of interactive WT concepts and low-tech prototypes. In response to the increasing public awareness of data privacy issues and the negative environmental impacts of the fast fashion and consumer electronics industries, students were asked to explore sustainability and ethics holistically including the following:

- the identification of preferable futures as design contexts;
- the creation of genuinely useful interactive designs which offer repeated use by remaining in circulation longer;
- ethical sourcing, supply chains and social responsibility;
- use of less harmful materials;
- design for disassembly and end of life;
- economic sustainability; data capture and usage by interactive Fashion-Tech products.

Through an innovative combination of contextual asynchronous learning in 'Theoretical Pillars', and a challenge-based 8 week taught programme, students gained understandings of a range of interaction design research methods which they used to gather and analyse primary data. This enabled them to develop research skills while exploring the design context and use of a WT item.
The programme delivered a range of collaborative activities to diverse, international and interdisciplinary groups, allowing the students to develop teamworking skills that would prepare them for employment in the interdisciplinary field of Fashion-Tech.

The student teams were asked to develop a design concept and prototype for an interactive experience based on their primary research into the everyday lives of worn items. This would include a WT fashion item, considering sustainable principles, data ethics and long-term utility as well as aesthetics. Students were coached in pitching their design concepts in an appropriate manner for industry and investors, and asked to produce a video and accompanying project presentation. The videos needed to demonstrate the concept, the interaction design and low-tech interaction prototype. Students were also asked to contribute to online Miro development boards to share and reflect on their personal development.
To conclude, the challenge-based phase aimed to train professionals to collaboratively deliver a high level project in the field of Fashion-Tech (specifically WT), or in other sectors that also require the combination of a creative attitude, research informed proposals and sensitivity to economic, social, ethical and environmental impacts.
Learning Experience Outcomes
Upon successful completion of the course students will be able to:

- Select appropriate interaction and UX methods to conduct rigorous primary research into everyday behaviours and interactions;
- Critically analyse primary research data and apply findings to design development for interactive wearable technology;
- Apply an in-depth understandings of social, environmental and economic sustainability to the development of systems and product design for interactive wearable technology;
- Recognise key issues related to data ethics and propose solutions to manage and mitigate then when designing digital systems and products;
- Present design outcomes orally and visually in a professional manner appropriate to a wearable technology product pitch.

4.3 METHODOLOGY

Learning Experience Structure and Outline

The course was delivered over 10 weeks (September to December 2021), beginning with a welcome and 'kick-off' event that introduced the course syllabus, brief, and the asynchronous 'Theoretical Pillar' lectures and tests. During the initial two-week period of asynchronous learning, students were tasked to self-select and view 8 lectures which were of personal interest. There were(27 lectures to choose from grouped into 'Design', 'Methods', 'Technology' and 'Business' themes. Then they were asked to write a 500 word blog post about one selected lecture and discuss other students' posts.

Following this, the learning experience was structured in regular weekly online sessions that incorporated workshop activities and feedback on work in progress. The sessions were recorded and tasks were listed online so that students who were unable to attend had the option to catch up. Weekly asynchronous tasks were set to help students develop their projects, and were often related to a particular Theoretical Pillar lectures as a means to integrate synchronous and asynchronous teaching. The asynchronous tasks were documented by student teams on a shared Miro board.
To help students navigate the course, each week's topic, tasks and associated theoretical pillar lectures were organised into weekly tiles on the course Moodle site. Each tile outlined the class content and included an 'After the Session' section describing the tasks students were expected to complete before the next weekly class (see Fig. 17 to 19).

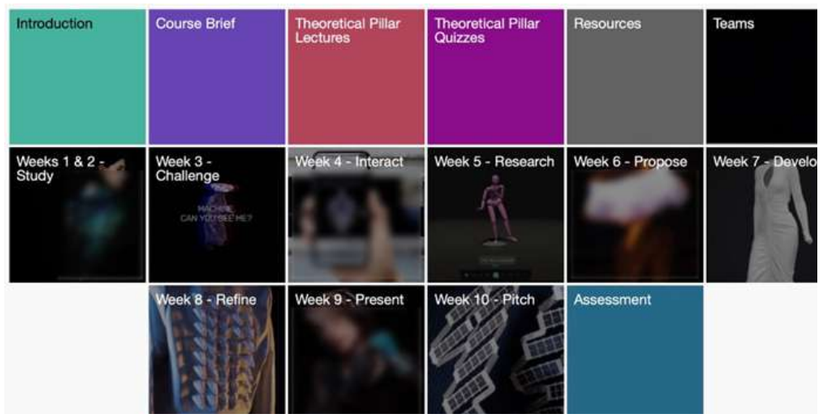


FIG.17 - WEEKLY COURSE STRUCTURE AND RESOURCES ON THE UAL MOODLE PLATFORM

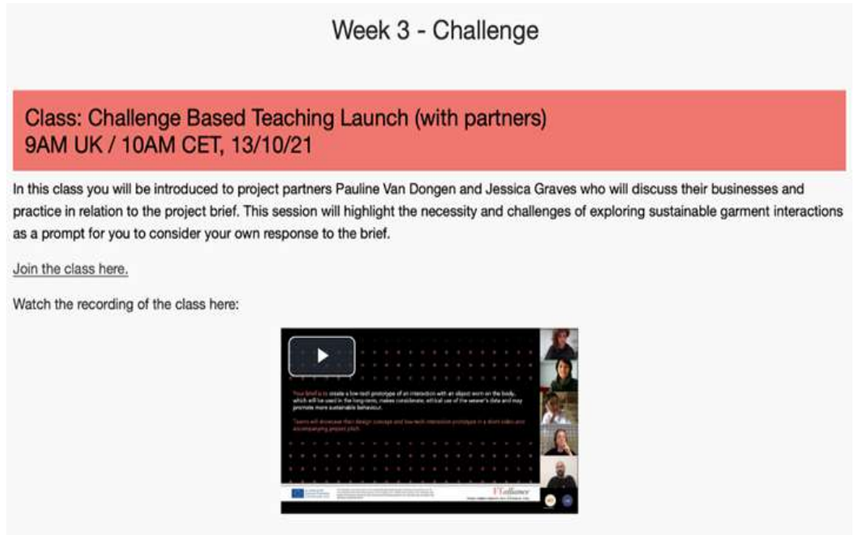


FIGURE 18 - EXAMPLE WEEKLY TASKS AND LEARNING ACTIVITIES

THEORETICAL PART

0 WELCOME + INTRODUCTION + SYLLABUS

WELCOME (Weeks 1)
The first weekly session introduced the representatives of the European partner companies: Pauline Van Dongen and Jessica Graves (see Participants section, below),and invited them to discuss their interest in the project brief and how it related to their practice. There was an opportunity for Q&A from participating students. At later stages,, the representatives of the European partner companies returned to discuss the student projects and give feedback, both at the initial project proposal stage (week 6) and then (week 10) final project pitches. This structure allowed students to maintain a longitudinal relationship with industry partners and to understand the perceived relevance of their proposed interactive designs..

1 DISCOVER (WEEK 1-3)

THEORETICAL PILLARS

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

2 DEFINE

EXAMPLES COLLECTION
PILLARS LECTURES
KEY INTERACTIONS INTRO

CONTENT SPECIFIC

SYNCHRONOUS: ESTABLISHED CALENDAR

DEFINE (Week 3)
Following the course kick off in Week 3, students were asked to collect examples of interactive wearable technologies and watch the theoretical Pillar lectures “Designing experiences and interactions”, and “Low-tech prototyping for high-tech designs”. This was to introduce key interaction and experience design concepts and prototyping methods

3 DESIGN

INTERACTION WITH WORN OBJECTS | IOT AND THING CENTRED DESIGN | THINGS ETHNOGRAPHIES | CAPTURING BODY DATA | INTEGRATING SUSTAINABILITY STRATEGIES

TUTORING COACHING AND REVIEWING ACTIVITIES

SYNCHRONOUS: ESTABLISHED CALENDAR

DESIGN (Week 4 – 9)
Weekly tasks were designed to guide students through a process of design research that explored everyday interactions with worn objects. This was to inform the development of a prototypical interaction represented in a short video. The weekly tasks were as follows:

Week 4 – Initial discussion about the examples of interactive WT identified by students, and bodystorming workshop to guide students to focus on everyday interactions. Students were asked to document the body, garment/accessories and environment interactions and to watch theoretical Pillar lecture: “IoT and thing centred design”.

Week 5 – Brief lecture presenting methods to capture and document the everyday life of a ‘fashion thing’, followed by group tutorials to discuss students’ choice of items to research and plan methods of data collection. Students were asked to conduct individual ‘thing ethnographies’ of the chosen wearable items and prepare a presentation about it.

Week 6 – Students presented initial ideas for their interactive design to peers and industry partners for feedback. A short lecture on data ethics for fashion brands was given by Jessica Graves from Sefleuria (to prepare students to consider data capture and usage of their device. Students were asked to propose a new iteration of their interactive design, based on received feedback and to watch Theoretical Pillar lecture “Capturing body data”.

Week 7 – Lecture discussing different additional approaches to sustainability in fashion items and WT, and sustainable adaptations to a business model canvas. This was followed by a workshop on design iteration and prototyping, guiding students through a rapid process of

FIGURE 19 - LEARNING EXPERIENCE STRUCTURE AND OUTLINE

sketching, making and digitising. Students were asked to integrate sustainability strategies into their final interaction design concept.

Week 8 – Group reviews to discuss the development and plans for presentation for the final delivery of interactive designs. Students were asked to watch the Theoretical Pillar Lecture: "The Pitch", giving tips for engaging presentations of interactive projects.

Week 9 – This was the final taught class prior to student's presentations of their design concepts which involved a mentoring session focused on developing and refining a professional standard project pitch.

4 DELIVER

FINAL PRESENTATION
FINAL REPORT
FINAL VIDEO

RESULTS ← → FLEXIBILITY

SYNCHRONOUS: ESTABLISHED CALENDAR

FREE CALENDAR + HOURSECTS

DELIVER (Week 10)
The final outcomes of the student groups were presented through video and presentation pitch.

FIGURE 19 - LEARNING EXPERIENCE STRUCTURE AND OUTLINE

Participants

The classroom was composed of 29 interdisciplinary and international students, 17 teaching staff, as well as 2 professionals from Fashion-Tech companies FTalliance consortium (internal and external) (Fig. 20).

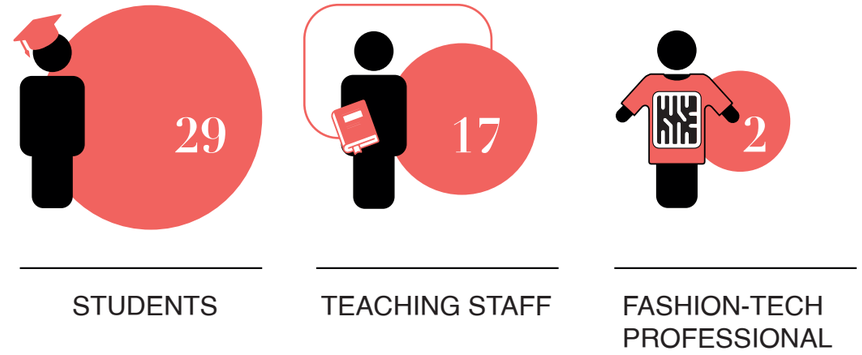


FIG.20 - LEARNING EXPERIENCE PARTICIPANTS

Teaching staff

Teaching staff members involved in delivering the learning experience are as follows (Fig.21):

- 5 professors from Politecnico di Milano, School of Design (Italy) focusing on Fashion and Fashion-Tech Design, Human-centered qualitative research methodologies, Sustainability, Circular Design and Materials;
- 3 professors from University of the Arts London – London College of Fashion (UK) focusing on Trend, Fashion and Speculative Design, pitch methods, low-tech prototyping, interaction and user experience;
- 4 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, textile sensors, sustainability in smart textiles;
- 2 professors from Ecole supérieure des Technologies industrielles avancées (France) focusing on Robotics.

94% of teaching staff (16 professors) were involved in delivering theoretical lectures during the theoretical part and 23% (4 professors)

were involved in delivering the challenge-based part of the learning experience, being available during the project design through a series of mentoring and tutoring activities covering different topics such as user experience, interaction design, qualitative research methodologies, bodystorming, low fidelity prototyping, pitching.

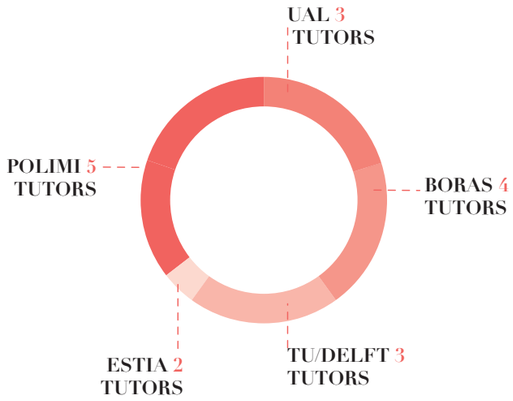
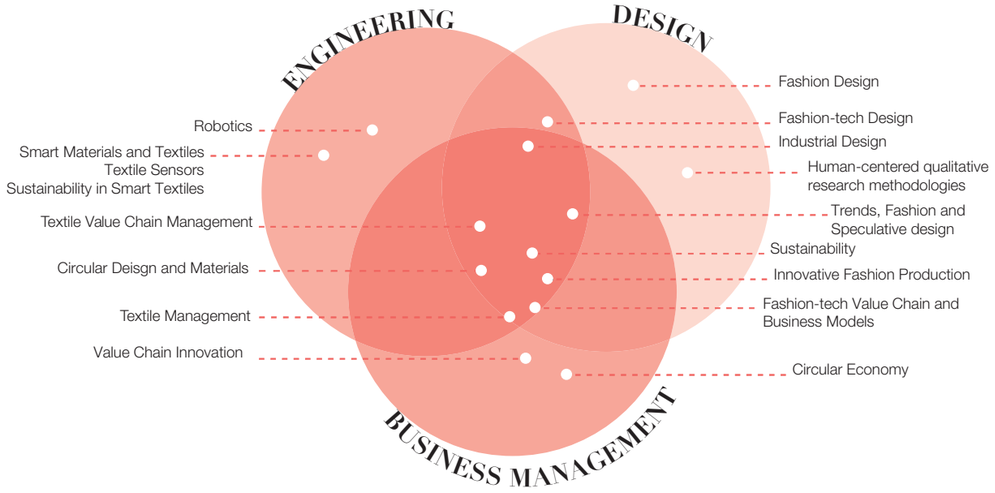


FIG. 21: LEARNING EXPERIENCE TEACHING STAFF



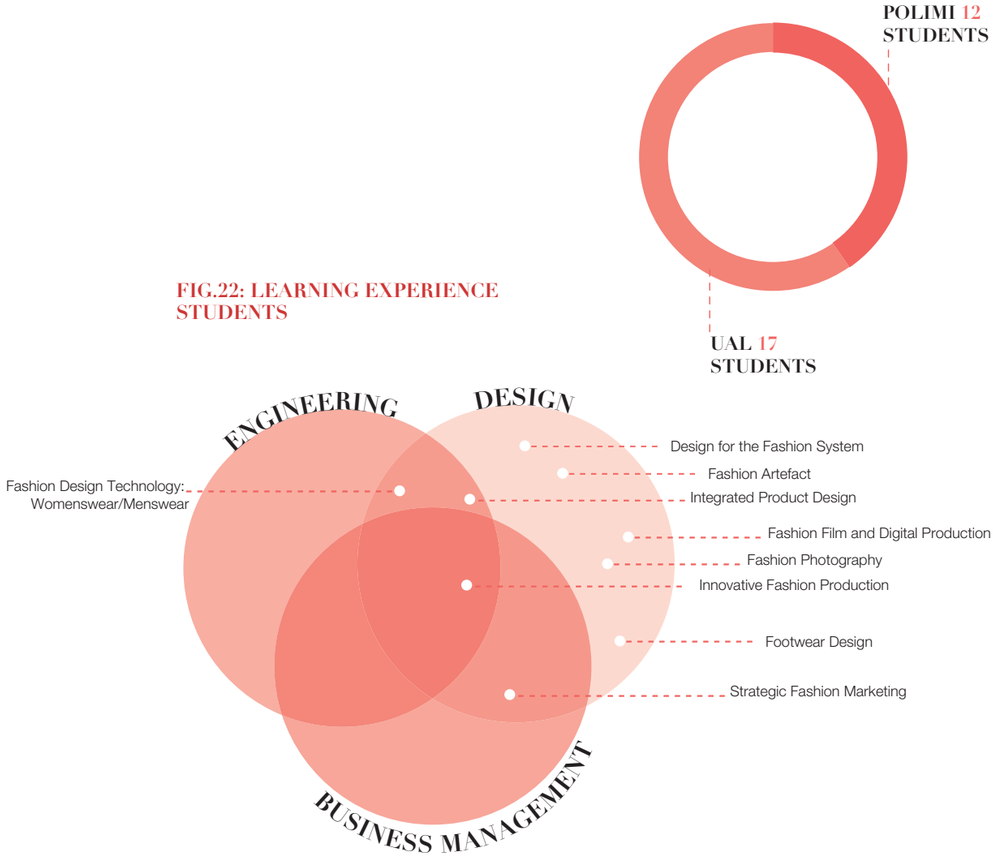
Students

Students who participated in the learning experience were selected from the following Universities and courses (Fig. 22):

- 12 students from Politecnico di Milano, School of Design (Italy) (second year MA in Design for the Fashion System and Integrated Product Design),
- 17 students from University of the Arts London – London College of Fashion (UK) (first and second year MA in Fashion Film and

Digital Production, Innovative Fashion Production, Fashion Design Technology: Womenswear/Menswear, Fashion Photography, Strategic Fashion Marketing, Fashion Artefact, Footwear Design).

FIG.22: LEARNING EXPERIENCE STUDENTS



Students worked in 10 teams of about 3 members per group, all with interdisciplinary backgrounds and vareid abilities. Participating students were allocated a group on the basis of their degree specialism, to ensure groups contained a range of skillsets. This was intended to promote skills sharing and to allow students to take ownership of different aspects of the project work.

The learning experience has been partnered with two European companies leading the sector of Fashion-Tech, Pauline Van Dongen (PVD) from the Consortium of FTalliance and Jessica Graves of Sefleuria (2022). They mentored students through the process of developing their interaction prototype. They were chosen as mentors due to their respective practical expertise in data ethics for the fashion industry and WT design.

4.4 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 a design-driven approach to technology, aiming to design new ways of applying smart wearables to increase sustainable products, processes, systems and users' behaviours (Fig. 23).

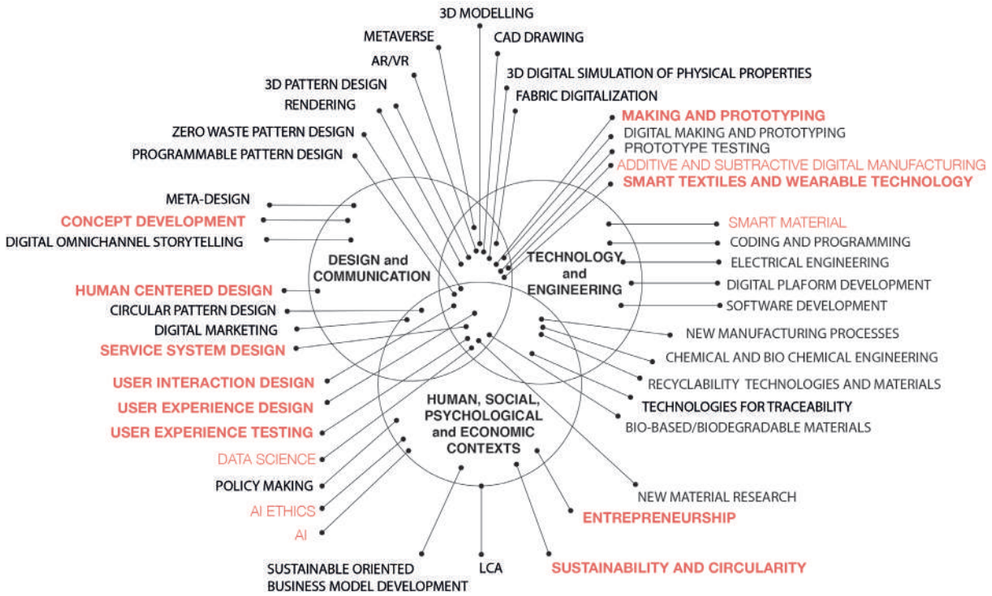


FIGURE 23 SUBJECT SPECIFIC SKILLS IMPLEMENTED IN THE LEARNING EXPERIENCE

Lessons learned from integrating novel methods in WT education for fashion

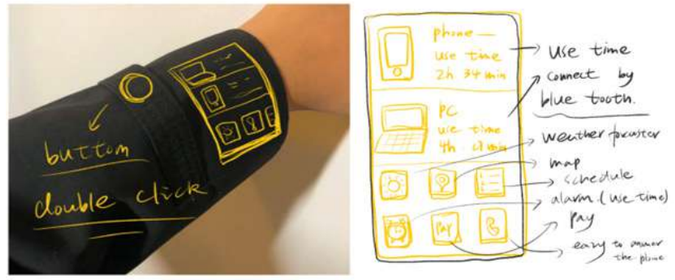
In this section, reflections on the course are captured from the teaching team, and student feedback is discussed in relation to strengths, weaknesses and areas for future development. Finally, the emergent themes represented in student projects are discussed in relation to the project aims of developing interactions with WT which would be sustainable, both in terms of durational use and environmental impact.

Reflections on emerging topics for research and education

Technology Archetypes

As previously discussed, WT has developed many recurrent themes and forms. These often feature in student's' proposed interactive designs, demonstrating the power of social understandings of technology development *(Jasanoff & Kim, 2015; Mager & Katzenbach, 2021).* This is sometimes problematic as it prevents students from following interesting themes in their research because they do not relate to existing WT, or students sociotechnical imaginaries. An example of this is seen in the development of the 'Bubble Life' project. For one member of the group, their thing centred research and bodystorming highlighted the significance of the sleeve as a multi-purpose form of protection and cushioning for the hand during day-to-day activities. In their initial designs, the focus on the sleeve resulted in sketches of a smartwatch like device integrated into a garment sleeve, rather than exploring the function of protection which the research revealed.

FIG.24 - BUBBLE LIFE INITIAL SKETCHES DEMONSTRATING A FOCUS ON EXISTING TECHNOLOGY ARCHETYPES



Thematic understandings of sustainable WT applications

Developing from, and referencing established WT archetypes, the following sociotechnical imaginaries of WT revealed by students' project outcomes were identified: Shape and Property Change Clothing, Anti-Technology Technology, Safety and Wellbeing. Each is discussed in further detail below, providing a snapshot of contemporary aspirations for WT and exploring what was enabled or revealed by the selected methods employed by the project. Each theme is also discussed in relation to the way it constructed sustainability and longevity of the interactive WT.

Shape and Property Change Clothing

A significant number of projects proposed garments and accessories which might change shape (e.g., 'BM Jacket', 'Bubble Life', 'Moov', 'Pillow Hat' and 'Weathair'). The primary motivations for this were to enable garments to function in multiple contexts, or weather conditions, therefore enabling the wearer to use them more often and potentially

reduce consumption by eliminating the need to purchase additional items. However, the convenience and wellbeing of the wearer also featured as motivations, for example in relation to protection from adverse weather conditions, or discomfort when too hot or cold in 'Moov' and 'Weathair'. These projects were often developed from personal insight into usage of clothing in different contexts, derived from students' thing centred design research. For example, the need to often add, or take off an item of clothing when transitioning between activities or locations. Shape change was differently conceived as a way to provide emotional support in the 'BPM Jacket' (discussed further in Safety and Wellbeing) which was designed to mimic the haptic sensation of a hug. In this case the project's bodystorming activities focussed on exploring where on the body the pressure of a hug was experienced and how to mimic this with inflating materials, thereby inspiring the location of the shape changing elements.

The speculation of technical processes by which garments and accessories might transform enabled students to envisage products and related services which they could not easily prototype. These were extrapolated from research into emerging textile technologies such as soft sensors and actuating fibres. By proposing speculative solutions, students were able to move beyond troubleshooting technical limitations of a prototype and explore the ecosystem in which a shape changing garment or accessory would be sold, used and re-used. This often happens when considering modularity and recycling services which exist beyond the temporal and functional focus of a physical prototype.

Anti-Technology Technology

A contradiction is often evident in contemporary sociotechnical imaginaries of technology, proposing that we use technology too much and need to reduce our screen time or tech addiction, but also that additional technologies can help us to 'digitally detox'. The 'Bubble Life' project exemplified this in its final outcome, inflating cuffs which monitor the wearer's screen time and inflate to prevent them using a keyboard or touchscreen until they take a break. This final iteration returned to the protective role of the sleeve identified through bodystorming.

The 'Everyday Hacking Hoodie' presented a humorous and DIY approach to protecting the wearers' identity and data. Using a kit of sound dampening materials and white noise generators to protect against the concern (or sociotechnical imaginary) of the voice assistant services on our devices listening in on conversations without our awareness. Both projects can be seen as social comments whose outcomes are more akin to diegetic prototypes *(Dunne & Raby, 2013)* which push current concerns to extremes, rather than commercial products. Though the 'Everyday Hacking Hoodie' presented a well-developed business model and marketing campaign, along with nuanced consideration of the potential to sell DIY kit form of WT to digitally skilled programmers and gamers. Similarly 'usPockets' devised as a service to customise existing garments with a smart pocket lining. In this way the WT did not require the wearer to buy more clothing or accessories and could be removed for re-use and disposal. 'Bubble Life' had a similar, though a less explicit focus on one element of a garment (the cuff), demonstrating an understanding of modularity as a key means to reduce consumption, waste and enable repair in WT.

Safety and Wellbeing

While WT for safety is a relatively well-established use context. For example, the use of safety lights for cycling, which were incorporated in a shape changing jacket proposed by the 'Moov' project. This was developed to encourage the use of a more sustainable form of transport (cycling) by protecting the wearer from road hazards as well as climate protection. Many of the student projects explored wellbeing in relation to experiences of isolation during the Covid-19 pandemic. The 'Scentiment', 'Blue: focus' and 'BPM Jacket' projects all utilised forms of sensory feedback to promote wellbeing, including the less commonly explored senses of scent and touch. Thing centred research revealed habits of fidgeting with jewellery when stressed, or the need to cocoon and hug oneself when feeling lonely. Both of these actions formed the trigger for interactions designed to reduce negative emotions. In these projects the key to inspiring repeated daily use of the proposed WT products was their role as day-to-day support for stress the wearer might experience. The themes of wellbeing and safety overlapped in 'usPockets', a project which proposed a subtle form of private communication and connection among a closed group of users. Tactile messages could be sent and received through the wearers' pockets, limiting the need to visibly use a mobile phone. This was a particular concern in public contexts when wearers might feel unsafe and wish to signal this to friends and family. However, the creation of a personal tactile language for communication in a chosen group was also considered to be a way to develop and maintain personal connections.

Reflections on tools and phases of the didactic experience

In addition to an analysis of student outcomes, the following reflections are linked to student experience during the phases of the learning experience and the learning methods particular phases employed:

Discover

Connecting critical discussion with critical design and making

During the Discover phase learning was exclusively asynchronous and student-led, with no live peer to peer interaction. While this opportunity for self-directed learning was welcomed by the majority of students, it presented certain challenges which suggests that synchronising theoretical lectures with the design phase would work better.. In this phase the Moodle platform was the primary resource, hosting the Theoretical Pillar lectures, quizzes and a blog for discussion of the lectures. The blog posts on the Moodle platform are not widely accessible, requiring the student to visit and post on a sub-section of the Discover phase Moodle page. A more accessible, or public platform may have encouraged greater engagement and gained more peer feedback on blog posts. However, careful consideration of creating a safe space for students to share should be balanced with fears around exposure when discussing an unfamiliar topic. Though students chose a favourite Theoretical Pillar lecture to discuss in their blog posts, these were not taken into account when allocating student groups, as the diversity and interdisciplinarity of student groups was prioritised. In future projects if students are allowed to self-select their groups, the discussion of blog posts could be used to aggregate groups with shared interests. This would overcome some of the negotiations necessary when forming groups with very different imaginaries and expectations of WT and fashion more broadly. It would also help the students to reach a consensus on their design aims more quickly and therefore have a longer period to refine their proposed interaction design.

The Theoretical Pillar lectures were intended to prime participating students with additional theoretical and technical understandings (beyond the scope of the core learning experience). The impact of this on their projects was not assessed, instead, multiple choice quizzes were used as a metric for measuring student comprehension and engagement with lectures which could be undertaken while watching, or immediately after a lecture. This format failed to capture students' nuanced understandings of complex topics such as sustainability and ethics, and the longitudinal impact of the Theoretical Pillar lectures was not captured. Therefore, it potentially reduced their perceived relevance and connection to the main learning experience.

Define

Understanding the nature of interactions

The initial student research for the course highlighted that prior to the synchronous teaching some students found it difficult to differentiate between interactive and non-interactive WT. For example, there were many references to light up garments and accessories which focussed on the visual change in the garment, rather than whether this was caused by a trigger and response mechanism sensing an input. This may in part be due to the influence of Miro as a visual platform in which eye-catching images will be prioritised, creating an effect similar to a mood board.

Understanding the nature of an interaction may also be a beneficial aspect of hands-on prototyping with physical computing systems, as such activities that allow students to immediately observe inputs and outputs *(Byrne et al., 2017),* triggers and responses, or complex interactions between multiple sensors and actuators. They promote learning through 'tinkering' and from making and troubleshooting mistakes *(Pasquini et al., 2020).* Therefore, when working remotely, it could be beneficial for students to undertake the initial inductions in person on physical computing systems. These could be organised in local groups (e.g., per participating University), as this may help their comprehension of the topics and interactions. Some participating students continued to apply terms such as sensor and actuator inaccurately throughout the project, possibly because they had no physical examples of the separate hardware and stages involved in a process of sensing and responding.

Design

As well as producing novel designs, the methods introduced during the Design phase created challenges for students due to their unfamiliarity, and due to the the limitations of applying these methods in an online and distanced context.

Thing Centred Design & Ethnography

The challenge of changed perspectives

A thing centred design perspective foregrounds new perspectives on fashion items. Many students found this to be valuable in thinking differently about their relationships to everyday items, making comments such as:

"Thing ethnographies were the area I was most interested in and it allowed me to observe how my jackets/outwear changed along with my lifestyle changes. For the first time I was able to take a third perspective on these clothes and it was an amazing experience that reconnected me with what clothes mean to me."

However, it was not always easy for students to change perspectives from documenting their lives with a fashion item, to imagining and documenting from the perspective of a fashion item. The 'Interviews with Things' method was helpful for students to make this cognitive shift. Additionally, a more subtle shift in perspective was impacted by the online context of the learning experience: the ability to observe others

from a third person perspective. While conducting digital and online ethnographies is not a new phenomenon *(Kozinets, 2010)*, the recent constraints of the Covid-19 pandemic have highlighted that many of the traditional, embodied aspects of ethnographic study, particularly the role of the ethnographer's body as a research tool (which despite being less foregrounded in thing ethnographies, is still present in the analysis of the interaction between humans and things), and the observation of activities in a broader situated context, are restricted by the visual capabilities of digital platforms. Students were restricted from observing one another, or a peer's daily engagement with fashion things and so their reflections were primarily autoethnographic and sensory *(Pink, 2015).* This may have informed the focus on highly personal emotional and sensory experience in many of the project outcomes, yet these themes were also foregrounded in social consciousness by collective experiences of reduced sensory stimuli and isolation during Covid lockdowns.
The limitations in sharing full body experience and occlusion of participant perspectives, also proved problematic for bodystorming activities, as discussed in the following section.

Bodystorming
Understanding the relevance of 'acting' and audience
Similarly, a key consideration of bodystorming is its live, situated character. Although carried out to reflexively gain insight into the designer's own bodily experience, bodystorming is often carried out in group contexts *(Mitchell et al., 2019).* The external observation of a bodystorming process can often highlight observations which the wearer may overlook, or afford different value, and is particularly useful in understanding the social acceptance of a worn item (e.g., publicly visualising emotion), action (e.g., sleeping in public spaces), or interaction. Though restricted when conducted over video call, some of these aspects can still be observed and understood when watching a designer bodystorm. However, a significant collaborative issue was the contrast in timetables between participating students, meaning that prototyping activities were often carried out asynchronously and independently, only being shared afterwards in still images or video. Asynchronous bodystorming no longer provides the same opportunities for social feedback, as it does not offer the opportunity for comments and questions which can alter the way a designer considers the experience they act out, or the way they may move and behave in response. In addition, asynchronously shared documentation can be edited and curated, removing vital original context.
Asynchronous and individual bodystorming offered a way to circumvent students' insecurity around performing and being the focus of attention, which was also demonstrated in an initial reluctance to act out interactions. Yet in this instance it is precisely this social critique and duality of perspective which is desirable.
A further consideration in relation to perspective and bodystorming, is whether the creation of familiarity and estrangement when performing everyday tasks differently *(Wilde et al., 2017)* is impacted when the mediation of a video calling platform such as Teams already serves to make the familiar strange and differently experienced?

Deliver
Interdisciplinarity: Perceptions of skillsets and ability to contribute
Students confirmed that the team-working and business focussed aspects of the course helped them to develop soft skills *(Byrne et al., 2017; Kafai et al., 2014)*, particularly relating to collaboration across disciplines, and increased their confidence in presenting project work. However due to the interdisciplinary nature of the student groups, perceptions of students' ability to contribute to it were varied. Though the project was designed to be accessible to all, and requiring no particular design skills, the derivation of the course methods from design research led to an epistemic and linguistic framing of the course tasks which seemingly prioritised design. Indeed, the term 'interaction design' itself may mislead students from business, marketing and engineering backgrounds to feel excluded. While interactions and interactivity can be understood from many perspectives, the weekly activities were often based on visual documentation, such as photographing, filming etc. Some students observed that they had not had tuition in drawing skills, or film making and felt the need to produce visually refined outcomes, rather than focus on the research exploring interactions. The introduction of business planning tools earlier in the project may have helped balance students' perceived ability to contribute. Groups with well-developed business model canvases and value propositions undoubtedly created more nuanced and believable proposals for their interactive WT products.

Opportunities and limitations of the study
The study highlights several opportunities for the design of future learning experiences and topics which they might address.
In organisational terms, it is suggested to further connect the asynchronous and synchronous parts of the course, giving the students incentives to engage in discussion and peer feedback, by linking early stage conversations around theoretical interests to the development of group projects. Include assessment of students' recall and application of theory to support their project development longitudinally throughout the learning experience. Providing live feedback is crucial to their physical and psychological engagement and also to the results of the projects but

also in the learning outcomes and skills.Some insights emerged from students' feedback in regards to the topics of interest:

- **Histories of WT archetypes**. As students often designed familiar WT applications, a contextual lecture, or lectures, highlighting the common themes in many past WT projects may help students to think outside the box and challenge their sociotechnical imaginaries.
- **Introductions to wearable actuators**. While the focus of the project was on sensing to trigger an interaction and ethical handling of the sensed data, many projects proposed shape change in a fashion item. Inflation and deflation were the most commonly proposed method of actuation, demonstrating limited awareness of other options such as servo motors, Nitinol shape memory wires, or recently developed shape change yarns. Further learning experience should focus on organising inductions to physical computing hardware early in the learning experience, emphasising input and outputs, trigger and response, so that an understanding of cause and effect is developed at an early stage.
- **Designing non-digital experiences and interactions with clothing**. In relation to the projects which highlighted a perception that technology was not always necessary, or a positive force, teaching could consider how interaction and experience design might be used to create novel experiences with conventional clothing. Thereby demonstrating the transferrable skills developed through exploring WT. During early stages of student research, it may be beneficial to provide students with templates highlighting the temporal nature of an interaction, e.g. a blank storyboard with multiple frames which they must populate, encouraging them to consider and document the interactivity of WT they discover during research.
- **Psychological principles for WT design**. Given the focus on wellbeing in the majority of the projects of the students, the inclusion of psychological theories of wellbeing in supporting lectures could help students in exploring how emotional experience could be supported through mechanisms validated by psychological studies. Lectures could also incorporate methods and metrics accepted in psychology studies which students could apply when assessing the impact of an interaction design on wellbeing.

Analysis of the use of thing ethnographies and bodystorming in the learning experience have highlighted that embodied pedagogic activities still benefit from third person observation and feedback. As this is problematic in online and asynchronous learning designs, a key pedagogic challenge will be to explore how future learning experiences can create collaborative spaces online, in which the full body is visible, and not subject to restrictive framing. Teaching staff should ensure that when conducted remotely, bodystorming activities are always carried out live, with at least one observer and one performer. Small groups of up to three may be ideal and reduce anxiety around performance. The observer should be instructed that they may direct the performer, the camera angle and frame (where possible) and question the performer about their experience as they move/act. Invite students to swap roles and reflect on the differences between observing and acting. Group learning in virtual, or augmented reality (VR or AR) may offer a solution to this issue when used in conjunction with motion capture systems. The significance of seeing aspects of the full body such as posture and gaze in collaborative garment design environments has already been highlighted *(Yang and Lee, 2021).* Yet, while this is an interesting pedagogic application of Fashion-Tech, there is currently a lack of fashion or interaction design specific VR collaboration environments *(Ibid.)*. This possible future is also currently limited by the cost of VR equipment, possibly leading to concerns over digital exclusion of students not able to afford the technology.

In relation to the study's aim to explore sustainable interactions, while student projects made significant attempts to define useful day to day contexts in which WT would be used over long periods of time, they highlight the problem of finding genuinely useful interactions which are not already supported by other technologies, or low-tech solutions which do not present the same ethical or sustainability concerns as current WT. It may be advisable when teaching WT projects to maintain a balance between allowing students to follow their enthusiasm for experimentation with new technology and ensuring they consider the utility, relevance and sustainability of their design outcomes. Although it is desirable for final product/service designs to show a nuanced understanding of their end usage, social and environmental impact, it is suggested that students be allowed to ideate initial WT proposals following their own technology interests and later refine, or adapt their proposals to be more practical, ethical and sustainable. Considering all these aspects when first designing with a new technology may be overwhelming and stifle experimentation.

All these elements considered, the field still requires further research and experimentation to discover a truly essential day to day application for WT, or to define a sustainable interaction. However, the inclusion of strategies for modularity, repair, or rental and shared ownership in the student outcomes demonstrate that while a 'killer app' for WT may be elusive, consideration of the secret life of clothing can help to foreground more sustainable ways to own and use WT.

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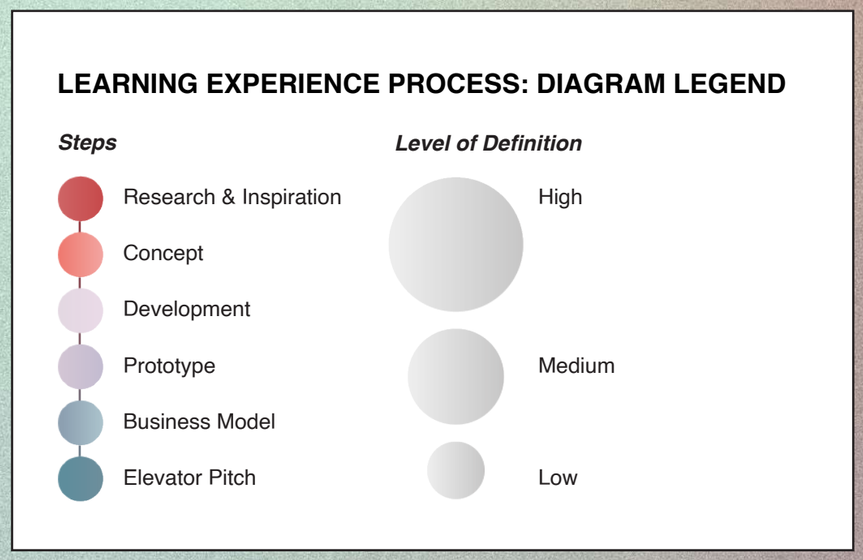
FIELD EXPERIENCES
The portfolio of innovative fashion-tech concepts of product and services

MOOV
SCENTIMENT
USPOCKETS
BLUE
BUBBLE LIFE
WEATHAIR
EVERYDAY HACKING HOODIE
SPI-C
PILLOW HAT
BPM



MOOV

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Chris Vooren, Integrated Product Design (TU/D)

#PHYSICAL FEELINGS **#MOOD** **#ENVIRONMENT**

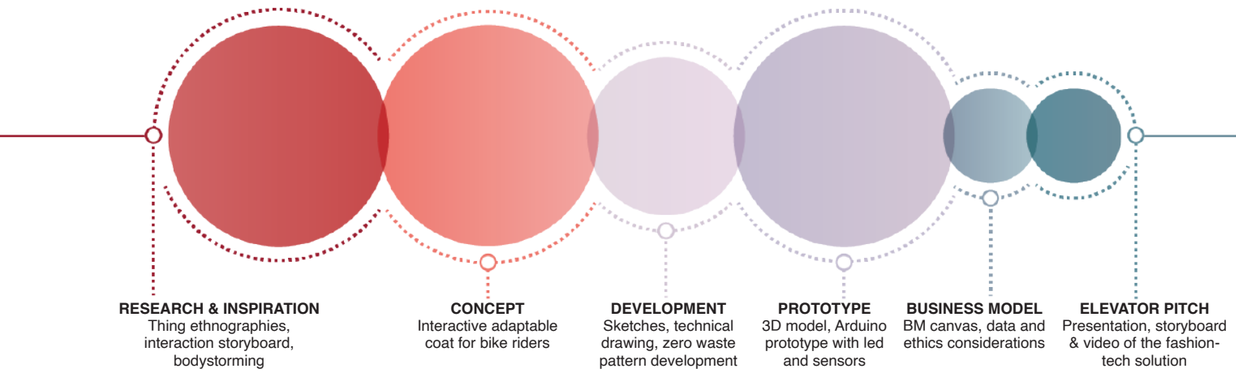
ABSTRACT
MooV is an interactive coat that aims to promote healthy behaviours, like cycling, being more sustainable and conscious about the environment. Body temperature defines the interaction: in colder situations, sections of the waist and cuffs will be tight and close to the body to trap heat and keep the body warm; in warm conditions, the coat will open and be looser to allow air to enter, cooling down the body. In addition, a light sensor turns the jacket's integrated LEDs when biking at night.

LEARNING OUTCOMES

Soft Skills
Multidisciplinary collaboration
Collaboration with professionals

Subject Specific Skills
Wearable technologies prototyping
Interaction design process

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Thing ethnographies, interaction storyboard, bodystorming

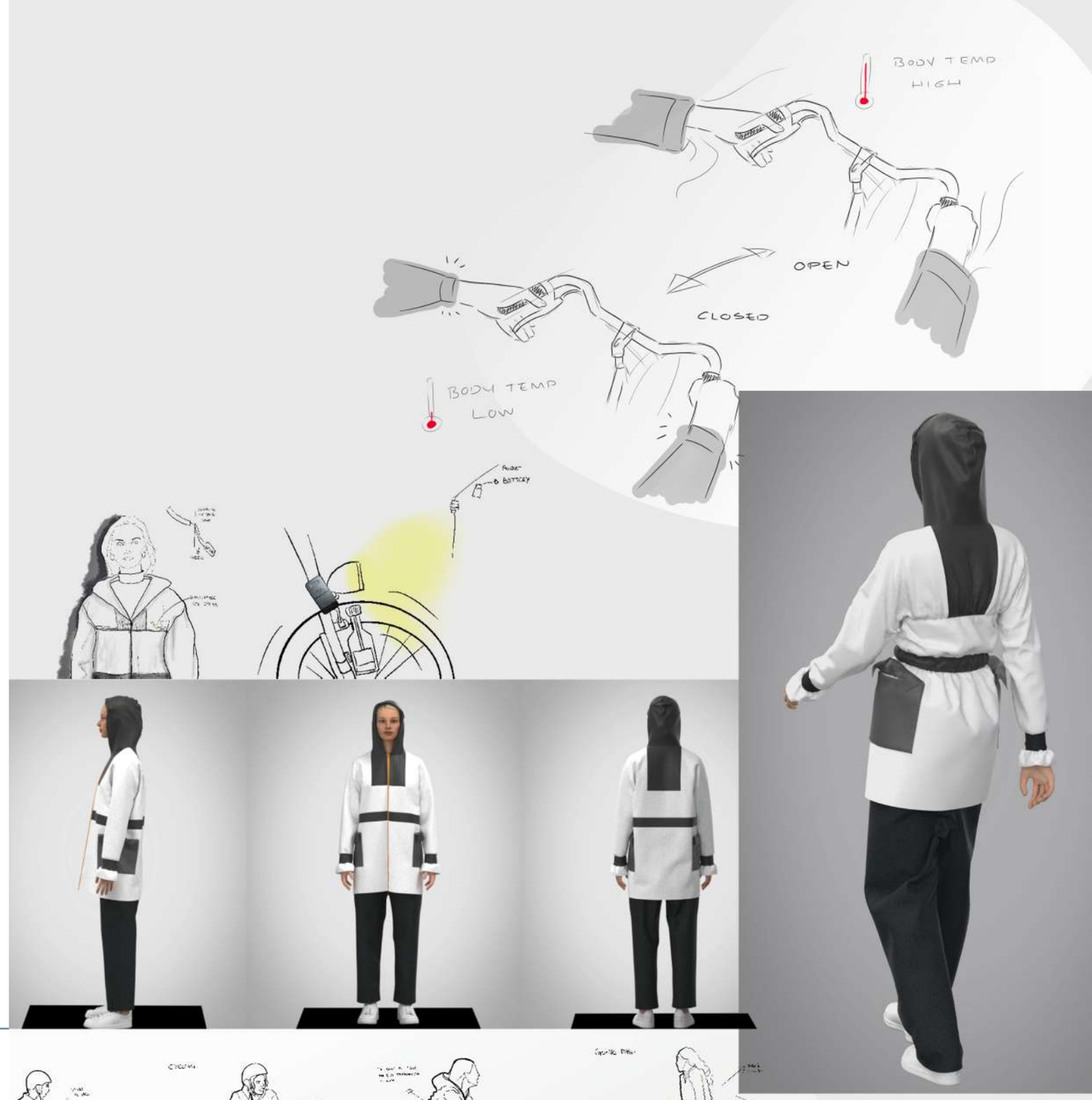
CONCEPT
Interactive adaptable coat for bike riders

DEVELOPMENT
Sketches, technical drawing, zero waste pattern development

PROTOTYPE
3D model, Arduino prototype with led and sensors

BUSINESS MODEL
BM canvas, data and ethics considerations

ELEVATOR PITCH
Presentation, storyboard & video of the fashion-tech solution



SCENTIMENT

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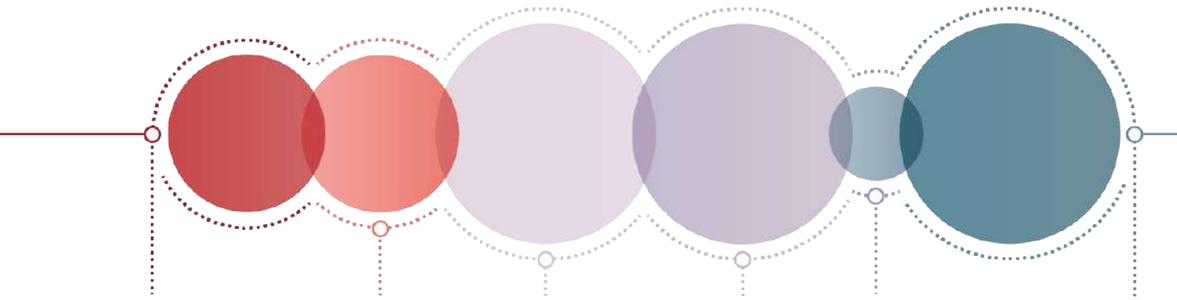
#ANXIETY **#STRESS** **#FIDGETING**

ABSTRACT
Scentiment aims to relieve peoples' anxiety and stress through an interactive necklace that uses aromatherapy. When the user is feeling stressed or overwhelmed, they can grab the bead of the necklace, fidgeting with it or shaking it. The movement will activate a heating element, which will pass heat through a copper tank that will quickly warm up and melt a bit of the scented wax encased within it. The perfume is released, calming the wearer.

LEARNING OUTCOMES

Soft Skills	***Subject Specific Skills***
F-Tech research and state of art	Sensors application
Real life challenges	Sustainable design process

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Thing ethnographies, interaction storyboard, design scenario: stress and anxiety

CONCEPT
Interactive necklace to relieve anxiety through aromatherapy

DEVELOPMENT
Sketches, technical drawings & gas sensor implementation

PROTOTYPE
3D model & 3D-printed prototype

BUSINESS MODEL
BM canvas, data and ethics considerations

ELEVATOR PITCH
Presentation, storyboard & video of the fashion-tech solution

USPOCKETS

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#CONNECTION #PRIVACY #FEELING

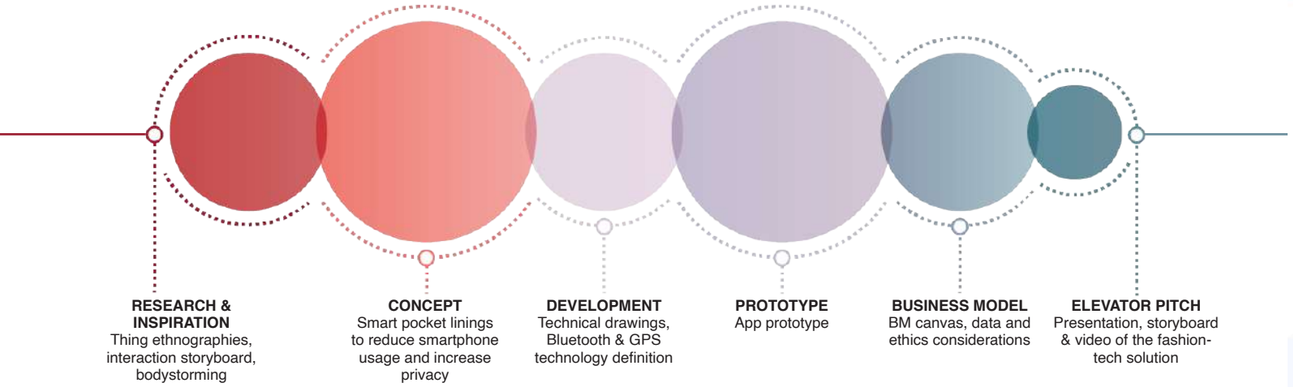
ABSTRACT
usPOCKETS are smart inner pocket linings that can be applied to existing jackets as a product-service system. Left pockets are supplied with a pressure sensor, used to send a tactile message, and GPS for tracking, while right pockets have a speaker to receive the vibration or audio message. The aim is to create a safe way to communicate with friends without other people noticing. usPOCKETS are a way of communicating with peers to make users feel safe, in dark streets, crowded areas, play games, create an intimate moment, or connect people far away.

LEARNING OUTCOMES

Soft Skills
Task distribution
Time management

Subject Specific Skills
Interaction design process
Product service system design

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Thing ethnographies, interaction storyboard, bodystorming

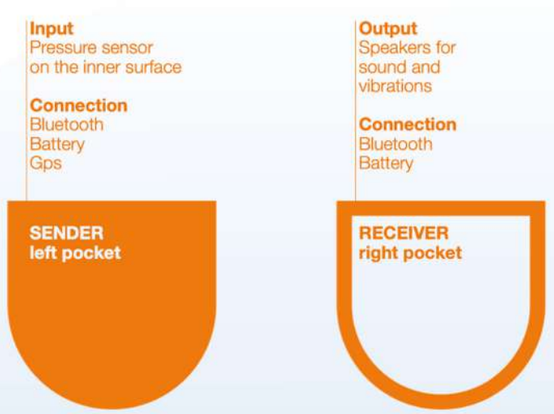
CONCEPT
Smart pocket linings to reduce smartphone usage and increase privacy

DEVELOPMENT
Technical drawings, Bluetooth & GPS technology definition

PROTOTYPE
App prototype

BUSINESS MODEL
BM canvas, data and ethics considerations

ELEVATOR PITCH
Presentation, storyboard & video of the fashion-tech solution



BLUE

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#MENTAL HEALTH **#HUGS** **#ANXIETY**

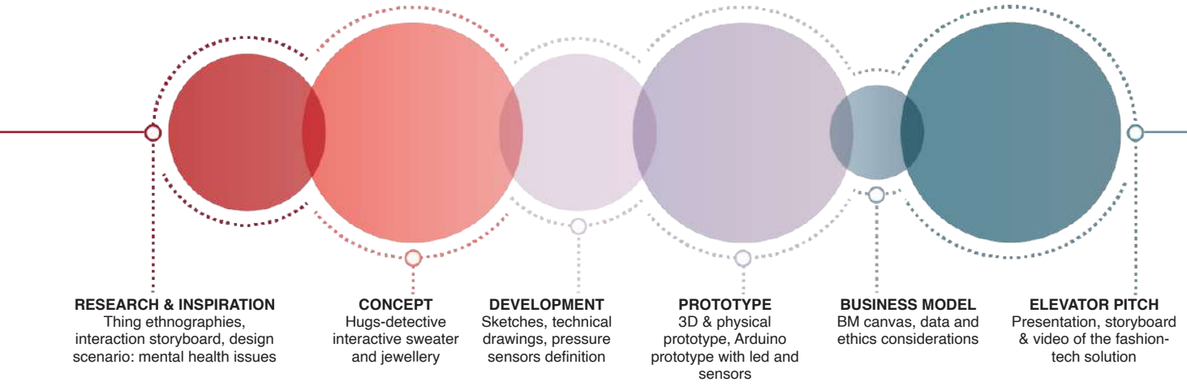
ABSTRACT
Blue promotes physical contact in the form of hugs to alleviate stress and anxiety through two components: a ring and a sweater. The ring tracks the user's stress level, while the sweater soothes tensed body parts via a vibrating mechanism. Further, when a pressure sensor perceives physical contact, LEDs light up, conveying the changes in stress and anxiety level. These real-time data can be used by medical professionals in clinical treatments of their patients and to provide immediate relief in case of an anxiety attack.

LEARNING OUTCOMES

Soft Skills
Overcoming technical difficulties
Multidisciplinary collaboration
Time management

Subject Specific Skills
Design ethnography methodology
Product service system design
Interaction design process

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Thing ethnographies, interaction storyboard, design scenario: mental health issues

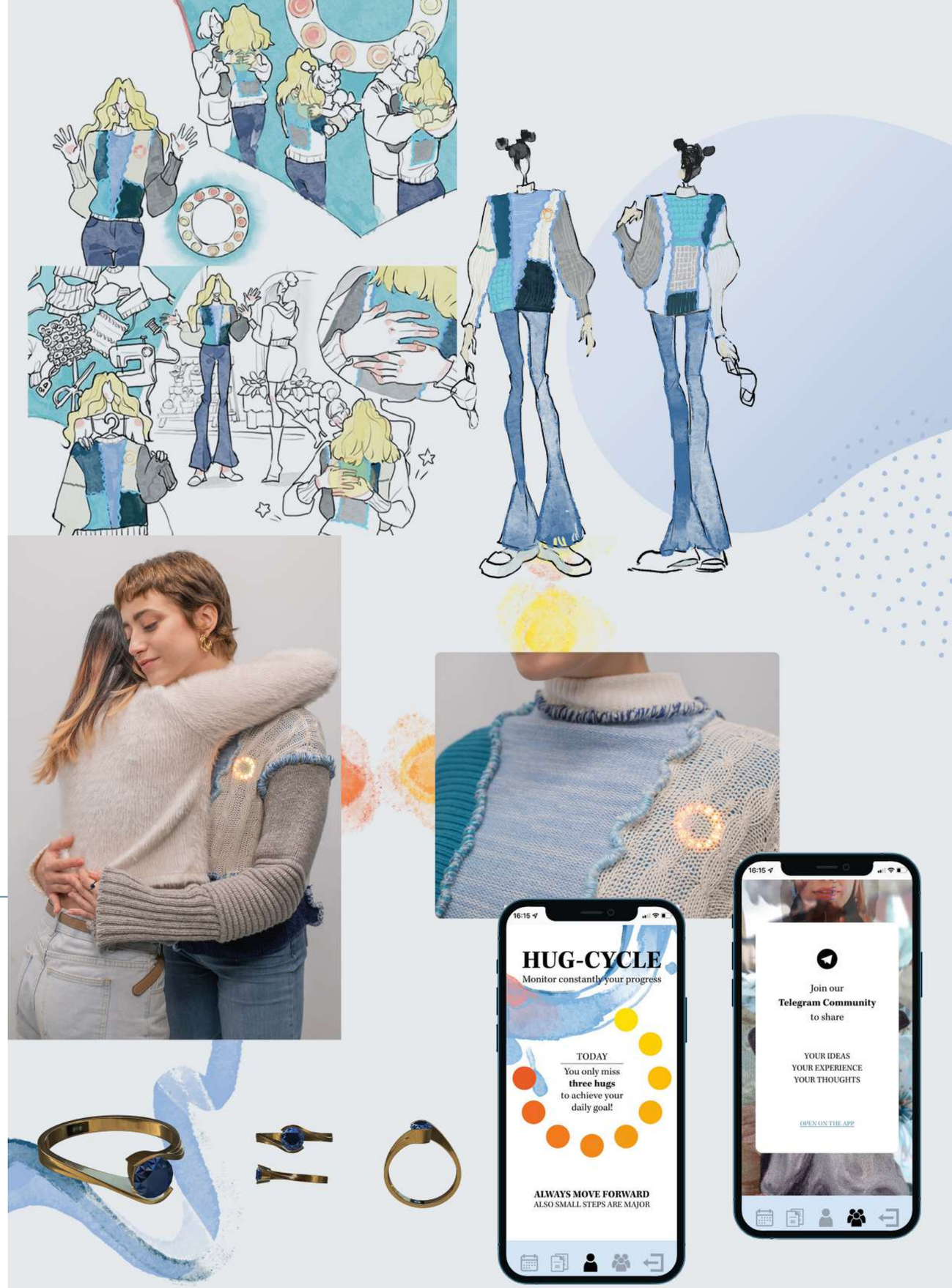
CONCEPT
Hugs-detective interactive sweater and jewellery

DEVELOPMENT
Sketches, technical drawings, pressure sensors definition

PROTOTYPE
3D & physical prototype, Arduino prototype with led and sensors

BUSINESS MODEL
BM canvas, data and ethics considerations

ELEVATOR PITCH
Presentation, storyboard & video of the fashion-tech solution



BUBBLE LIFE

Ye Tian, Fashion Artefact (UAL-LCF)
Shitong Fu, Design for the Fashion System (POLIMI)
Haizhu Dong, Fashion Film and Digital Production (UAL-LCF)

#TECHNOLOGY ADDICTION **#SOCIAL DISTANCING**

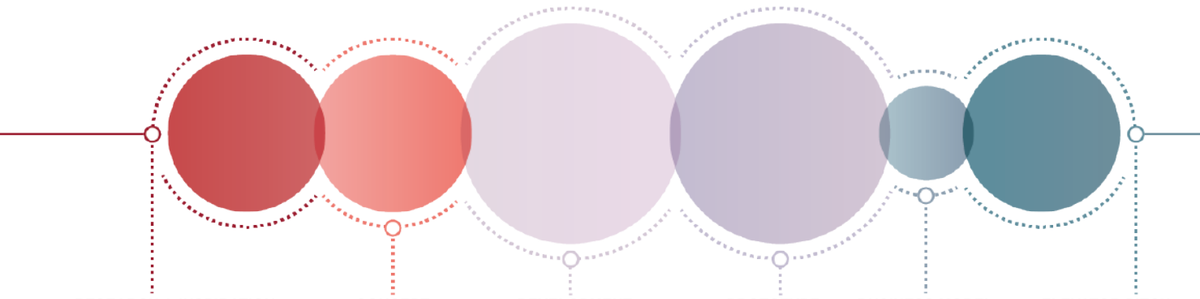
ABSTRACT
Bubble Life is a garment with interactive sleeves that remind people to limit their use time of smartphones, thus reducing the addiction to electronic devices. The user puts on the garment, first setting their expected maximum use time on their mobile phone, and connecting to the inflatable sleeves via Bluetooth. When the usage time is longer than the time set, the sleeves inflate, sending a visual message and creating a physical barrier to stop using the electronic device. The sleeves will slowly return to their original shape during the rest period.

LEARNING OUTCOMES

Soft Skills
Real life challenges
Design thinking
Research and critical thinking

Subject Specific Skills
Business strategy tools
Research methodology
Wearable technologies prototyping

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Thing ethnographies, interaction storyboard, design scenario: technology addiction

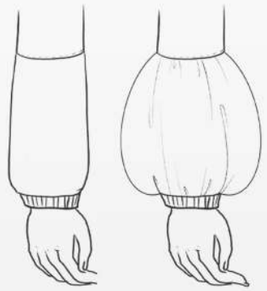
CONCEPT
Garment with inflating sleeves to reduce smartphone usage

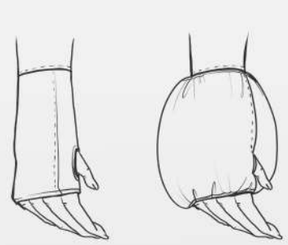
DEVELOPMENT
Sketches, technical drawing, sensors implementation

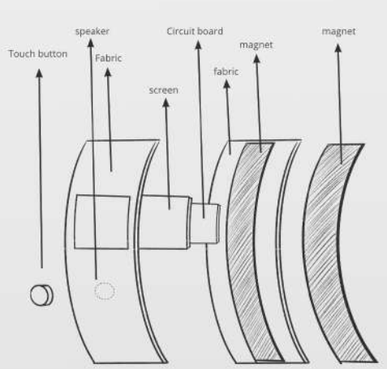
PROTOTYPE
Product low-tech prototype

BUSINESS MODEL
BM canvas, data and ethics considerations

ELEVATOR PITCH
Presentation, storyboard & video of the fashion-tech solution







WEATHAIR

Dejin Chen, Design for the Fashion System (POLIMI)
Ruoyan Dong, Footwear Design (UAL-LCF)
Lucia Galiotto, Integrated Product Design (POLIMI)

#COMFORT **#ADAPTING** **#DATA COLLECTION AND SHARING**

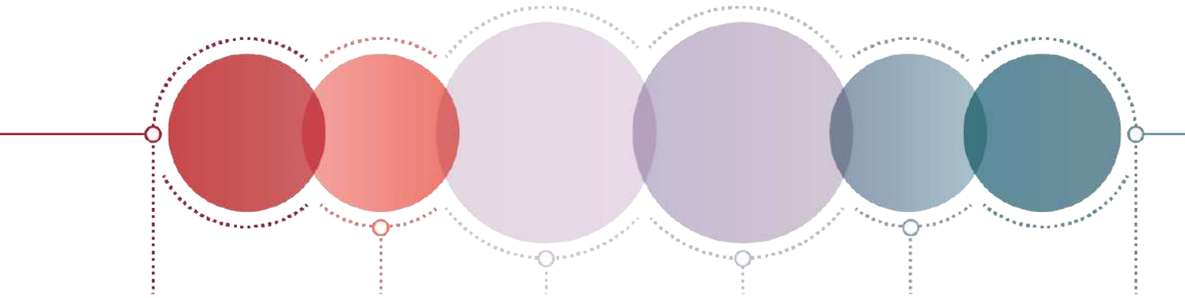
ABSTRACT
Weathair is a jacket designed to face climate change conditions and allow data sharing for the community's benefit. The jacket automatically inflates or deflates in response to external temperature changes perceived by a sensor or via direct user control of the inflation mode. Collected sensor data are shared with smartphones and combined with location data to provide real-time weather updates in urban communities. Weathair is also a sustainable jacket thanks to its sales and repair service system: obsolescent, broken components can be collected by the company, who will substitute / dispose of / repair / resell them as refurbished items to new customers.

LEARNING OUTCOMES

Soft Skills
Multidisciplinary collaboration
Pitching
Task distribution

Subject Specific Skills
User journey mapping
Bodystorming
F-tech research and state of art

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Thing ethnographies, interaction storyboard, bodystorming

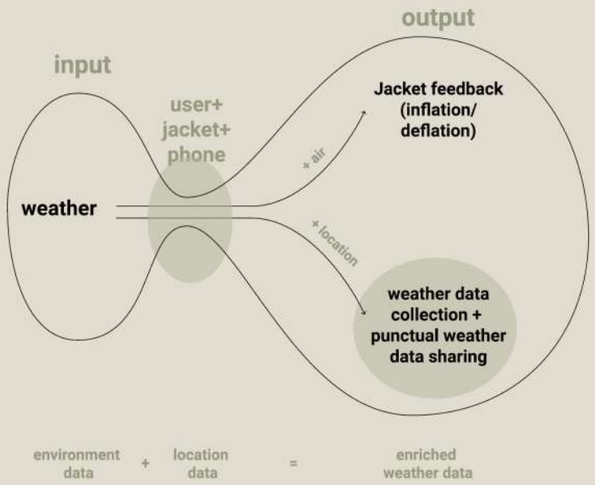
CONCEPT
Inflating jacket providing real-time weather updates

DEVELOPMENT
Materials & sensors, moodboard, sketches & technical drawings

PROTOTYPE
3D model & Arduino prototype

BUSINESS MODEL
BM canvas, data and ethics considerations

ELEVATOR PITCH
Presentation, storyboard & video of the fashion-tech solution



EVERYDAY HACKING HOODIE

Giulio Baldan, Integrated Product Design (POLIMI)
Meijun Chen, Design for the Fashion System (POLIMI)
Xinyue Ma, Strategic Fashion Marketing (UAL-LCF)

#SONIC WAVE **#PRIVACITY** **#SAFETY**

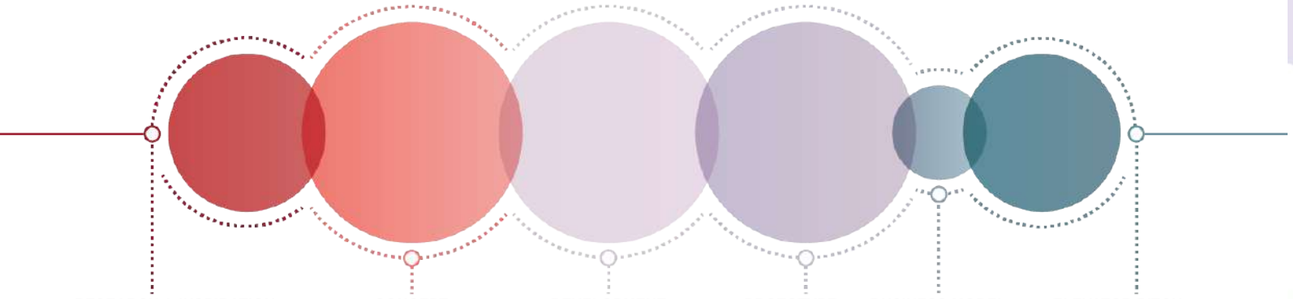
ABSTRACT
Everyday Hacking Hoodie aims to combine high-tech technology with everyday clothing to ensure data security. To tackle this issue, the hoodie incorporates electronic components located on each side of the hood that can be activated to play white noise, thus interfering keeping conversations private from digital voice assistants, or voice recognition software. Also, in the pocket of the Everyday Hacking Hoodie, RFIDsafe(TM) blocking material prevents information loss by protecting credit card NFC chips from being scanned.

LEARNING OUTCOMES

Soft Skills
Working within tight deadlines
Tasks distribution

Subject Specific Skills
Interaction design process
Wearable technologies prototyping

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Thing ethnographies, interaction storyboard, design scenario: data security

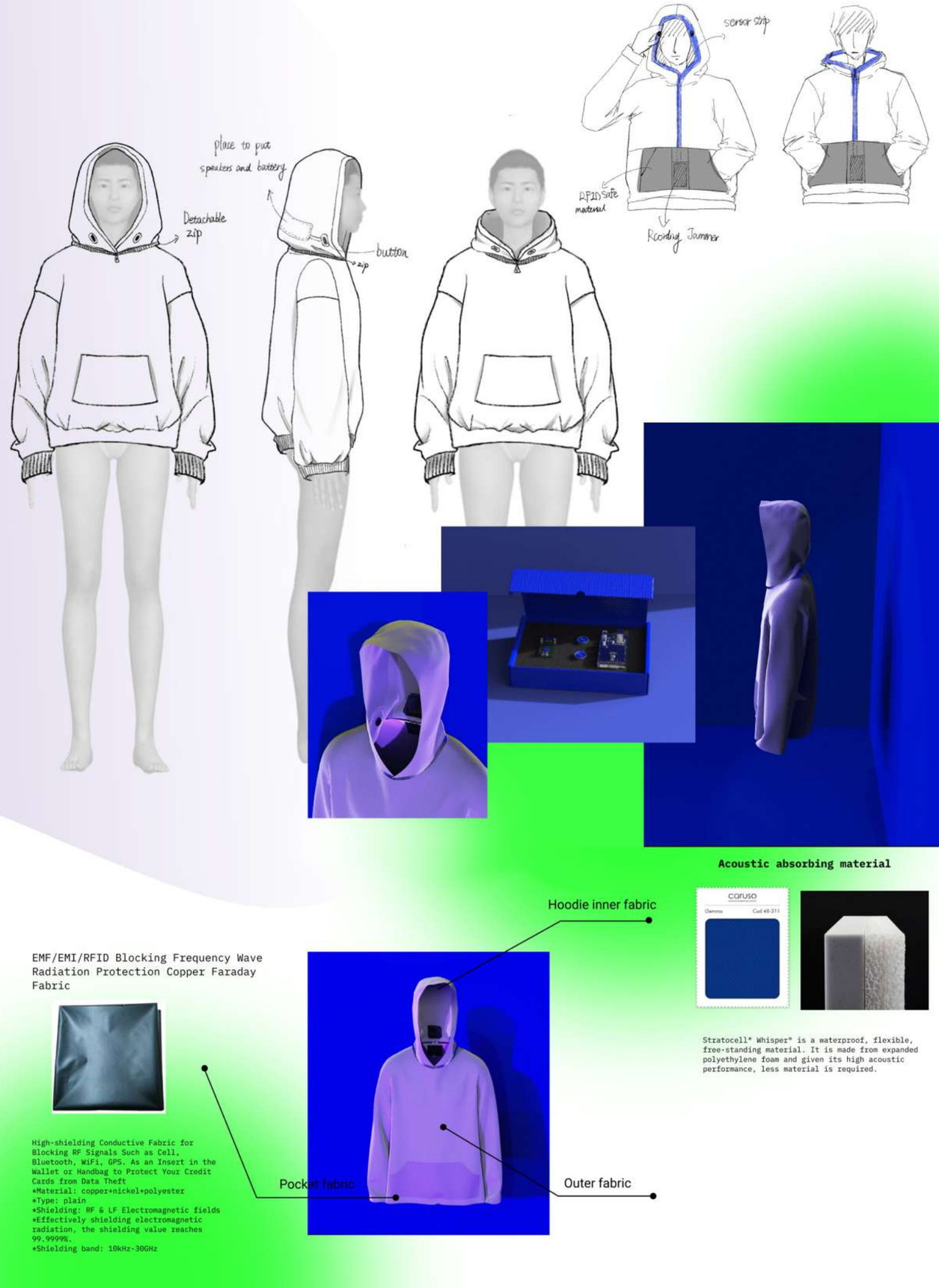
CONCEPT
Interactive hoodie to ensure privacy through white noise and innovative materials

DEVELOPMENT
RFIDsafe(TM) blocking material, sketches & technical drawings

PROTOTYPE
3D model, packaging and adv mockups

BUSINESS MODEL
BM canvas, data and ethics considerations

ELEVATOR PITCH
Presentation, storyboard & video of the fashion-tech solution



SPI-C

Shanshan Yan, Footwear Design (UAL-LCF)
Ziqian Yu, Design for the Fashion System (POLIMI)
Jiaqi Wang, Innovative Fashion Production (UAL-LCF)

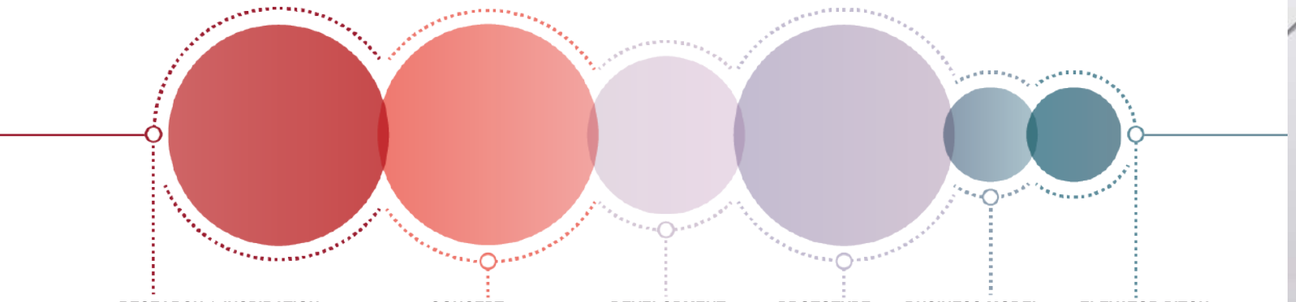
#INTELLIGENT INTERACTION **#DETECTION AND TREATMENT**

ABSTRACT
Spi-C is a light, comfortable, washable, intelligent top designed to protect the spine. By locating contact points and recording body move-ments, the top reminds users to stay in the correct posture. It also detects fatigue levels and includes a physical therapy mode that can be manually turned on and adjusted through a mobile app. The app can record the frequency and position of the users' bad posture and analyze this data to generate a treatment plan.

LEARNING OUTCOMES

Soft Skills	***Subject Specific Skills***
Research and critical thinking	User journey mapping
Time management	Market research
Working within tight deadlines	Video editing

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Thing ethnographies, interaction storyboard, design scenario: encouraging good posture

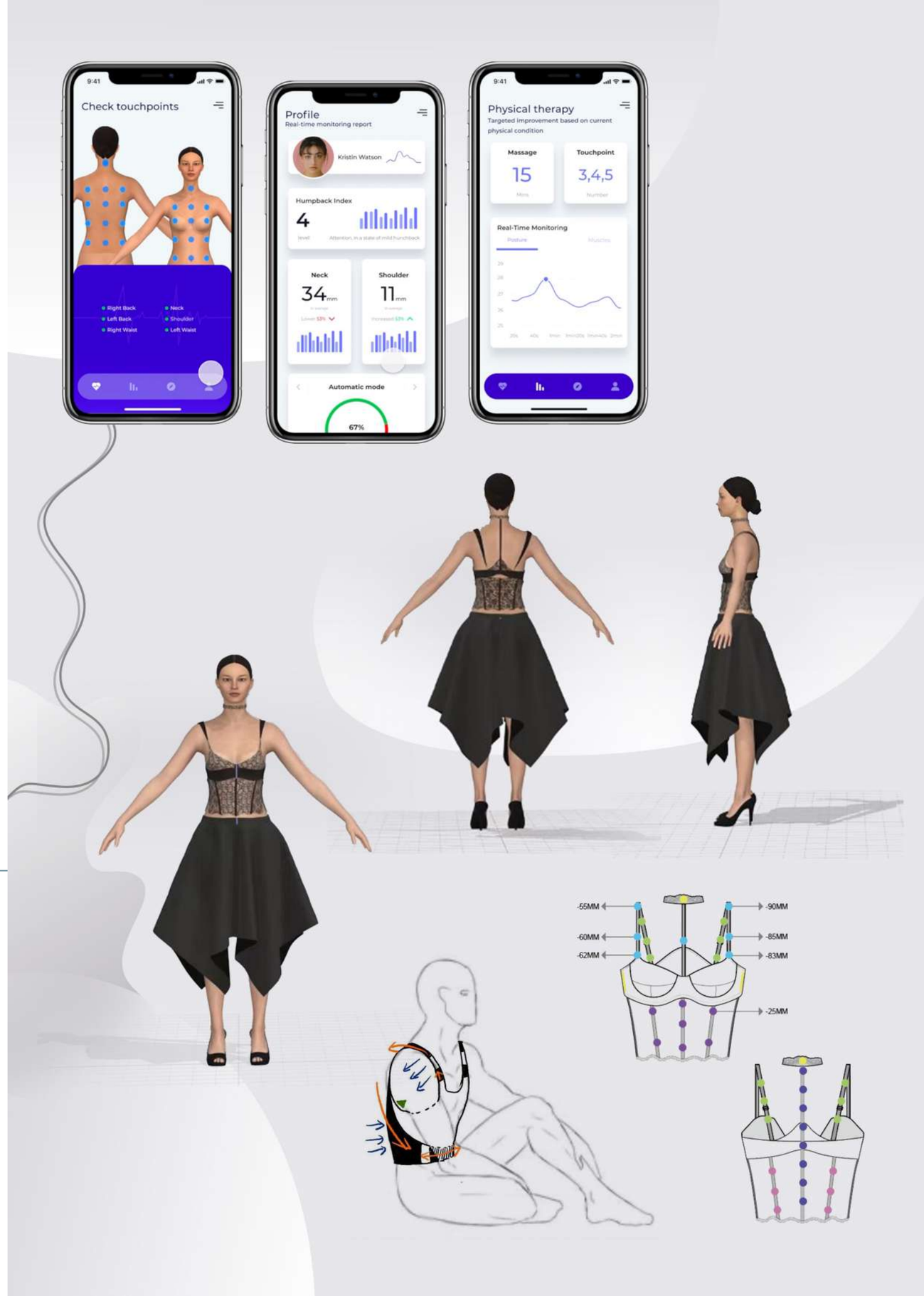
CONCEPT
Smart top to protect the spine

DEVELOPMENT
Smart textile definition, sketches & technical drawings

PROTOTYPE
3D model & app prototype

BUSINESS MODEL
BM canvas, data and ethics considerations

ELEVATOR PITCH
Presentation, storyboard & video of the fashion-tech solution



PILLOW HAT

Yuxi Sun, Footwear Design (UAL-LCF)
Shenhao Lyu, Design for the Fashion System (POLIMI)
Difei Qu, Fashion Artefact (UAL-LCF)

#COMFORT #RELAX #PORTABILITY

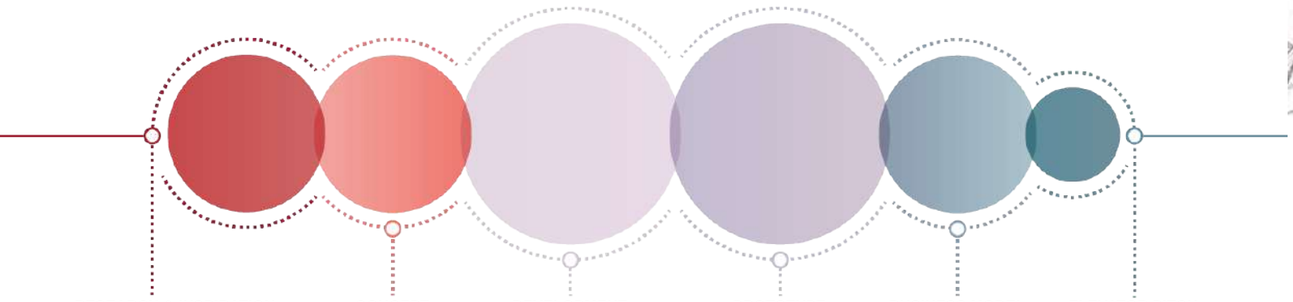
ABSTRACT
Pillow Hat is a portable accessory that aims to support busy people, such as tired workers and students, to rest comfortably in public spaces. Once inflated, the hat is worn on the user's head and provides support to relax and rest without neck pain. Pillow Hat is designed to be rented in spaces like Libraries, or public transport systems and returned after the user has taken a nap. To reduce storage space requirements, when not in use the hat can be deflated and folded using origami principles.

LEARNING OUTCOMES

Soft Skills
Multidisciplinary collaboration
Communication skills
Tasks distribution
Team development

Subject Specific Skills
Understanding societal need
F-tech research and state of art
Sustainable design process
Ergonomic design

LEARNING EXPERIENCE PROCESS



RESEARCH & INSPIRATION
Thing ethnographies, interaction storyboard, target audience

CONCEPT
Portable smart accessory to offer support when resting

DEVELOPMENT
Inflating technology and fabrics definition, sketches & technical drawings

PROTOTYPE
3D model, social media & adv mockups

BUSINESS MODEL
BM canvas, data and ethics considerations

ELEVATOR PITCH
Presentation, storyboard & video of the fashion-tech solution

BPM

Ying Ou, Footwear Design (UAL-LCF)
Miriam Kristen Perez Escudero, Fashion Photography (UAL-LCF)
Francesca Zeccara, Integrated Product Design (POLIMI)

#SAFE PLACE **#ANXIETY** **#CONTACT**

ABSTRACT

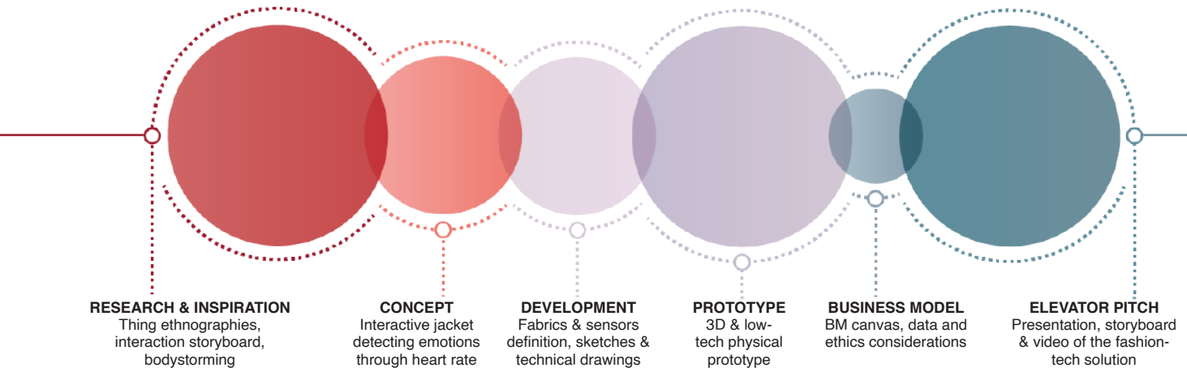
Beats Per Minute (BPM) is an interactive emotional jacket, conceived as a safe place where users pay attention to their emotions. This jacket reacts to heart rate data by inflating when beats per minute accelerate. The inflatable sections are located so that as they inflate the increasing pressure mimics a gentle hug, creating a calming effect for the wearer.

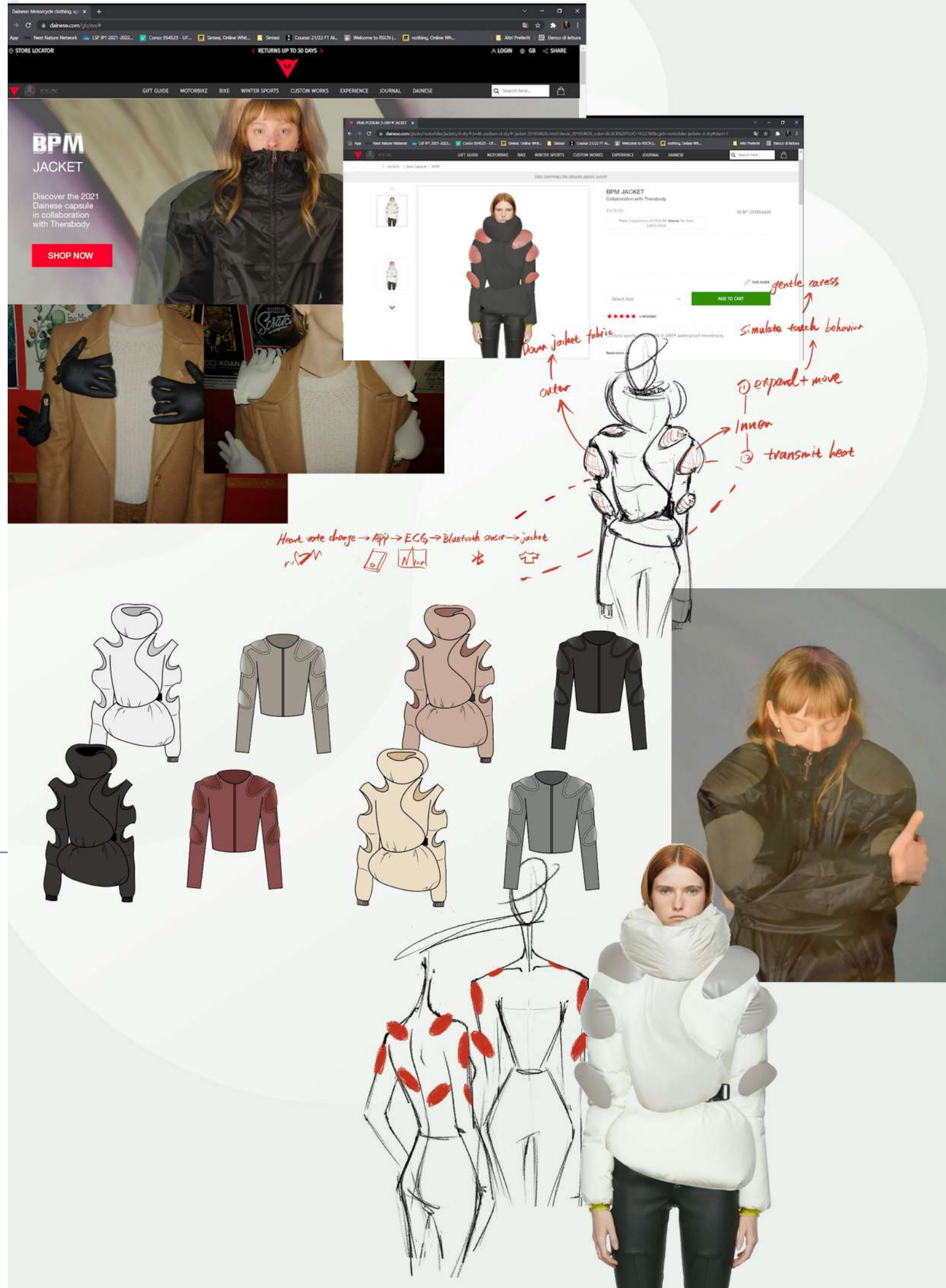
LEARNING OUTCOMES

Soft Skills
Multidisciplinary collaboration
Research and critical thinking
Remote teamwork

Subject Specific Skills
Concept development
Prototyping and user testing
Storyboarding

LEARNING EXPERIENCE PROCESS





5. FASHION-TECH FAST FORWARD FUTURES

DARIA CASCIANI
(POLITECNICO DI MILANO, DESIGN DEPT. DEPARTMENT - ITALY)

CHIARA COLOMBI
(POLITECNICO DI MILANO, DESIGN DEPARTMENT - ITALY)

This publication gives an overview on the importance of evolving the educational models in the Fashion-Tech field. These are proposed in order to nurture and prepare future fashion-tech professionals with the necessary strategic and systemic open-minded attitudes, along with soft and subject-specific skills which can be influenced by external input and which enable them to govern the changes that the sector is undoubtedly driving. Stemming from the literature review and also benefiting from the evidence provided by the applied case studies about Fashion-Tech learning experiences, this publication describes the essential features and opportunities of Fashion-Tech educational model focusing on:

- **Multi-Inter-Transdisciplinary collaborations and connections facilitation** between Higher Educational Institutions, Companies and Research Centres in the Fashion-Tech field. Facilitating the interchange between industry professionals, technicians, scientists, researchers, students as well as educational staff from various disciplines (applied sciences such as design and engineering, social sciences and natural sciences) in research and education projects;
- **Experimentation with digital transformation and sustainability.** Knowing how to apply these two transformations with a critical, transparent, and ethical perspective to the work, giving the students the ability to position themselves in a critical and reflexive way.
- **Sharing knowledge and skills on theoretical, methodological and empirical research** as a base for providing both a clear understanding and tools to explore the Fashion-Tech context and its implications for the fashion industry at large

Being a fluid and fast evolving field, Fashion-Tech has an intrinsic need to continue the dialogue between different actors on the implementation of the future of the sector. This is indeed to allow the exchange of information that contributes to current and future Fashion-Tech education. Accordingly, Fashion-Tech education should be nurtured by research in the realm of sustainability fashion and technology/digitization, by developing research programmes that share the same essential feature of transdisciplinary collaboration through theoretical, methodological and empirical approaches.

5.1 LESSONS LEARNED FROM THE FIELD: FASHION-TECH STRATEGIC INNOVATION AND APPLIED RESEARCH FOR EDUCATION AGENDA

The Fashion-Tech Strategic Innovation and Applied Research for Education Agenda focuses on two elements inform each other: (i) future perspectives of Fashion-Tech research and Innovation topics; and (ii) future perspectives in Fashion-Tech educational models. In the paragraphs below, the skills empowering future Fashion-Tech professionals are also highlighted.

Future perspectives of Fashion-Tech research and Innovation topics

Elaborating a comprehensive Fashion-Tech ontological definition

As emerged from the literature review about the sector and from the , implementation results of the learning experiences, Fashion-Tech is a multi-perspective sector that grows rapidly pace as technologies do with a fragmented and transdisciplinary domain of knowledge. Because of the complexity of the field, a comprehensive overview of the possibilities and opportunities both in terms of research and education is missing. Therefore, it is evident that a crucial part of future research could explore a more detailed ontology of the Fashion-Tech field, deeply understanding the different terminologies that have been used and examining deeper implications and the relations among the different topics and disciplines. This critical reflection on the widest perspectives of the field in research terms is deeply important to reflect it inside the curricula, understanding where to drive the educational models and pedagogical approaches both in instructional and organisational terms.

Next innovation trajectories and unexplored pathways of research and education

The three learning experiences have generated insights that would inspire specific research topic in the main investigation areas of the Fashion-Tech. These have been developed into case studies.

In digital and virtual fashion transformation, there is a need to explore (i) the relations, between the physical and digital realm and their implications in terms of meaningfulness, logistics and technological and manufacturing challenges emerging from the development and delivery of phygital solutions; (ii) Business Models and innovation strategies related to new product/service/systems elaborated in the digital and phygital fashion dimension; (iii) the holistic perspective of the sustainability of virtual fashion products/services; (iv) the communication and servitization phenomena with its implication in technological, business and customer-

related perspectives; (v) elaboration of streamlined processes of virtual fashion defining tools and methodologies, and negotiating simplification and complexity according to the desired outcome.
As garments become more intelligent, such as communication agents and data platform and collectors, more research is required for the ethical concerns they raise in data management, transparency and legislation along with other social issues related to culture, identity and education, to ensure positive sustainable values and behaviours. Further research and experimentation is needed to discover a truly essential day to day application for wearable technologies, or to define a sustainable interaction including strategies related to circular economy (shared ownership, rental and repair, modularity). In this regard, two research and education elements are crucial: (i) a reality check and anticipation of use and meanings *(Krippendorff, 1989)*, and (ii) user involvement during the project implementation, particularly at the early stages of idea generation and concept design. In a smart wearable it is very important to drive research with a user-centered design *(Norman and Draper, 1986)*, human-centered design *(IDEO, 2015; Hanington, 2010)* and user interaction design *(NNG, 2022)* approaches to challenge established sociotechnical imaginaries, and to gather insights to exploring users' ns and unintended uses and behaviours. This allows us to evaluate solutions, even at the early stages, and to measure each solution's impacts. This is important to consider the utility, relevance and sustainability of design and research outcomes. Hence, anticipatory competency are required as the ability to understand and evaluate possible, probable and desirable futures while creating one's own visions which take into account the consequences of actions, and to deal with risks and changes.

Boosting Sustainability critical reflection

Education on sustainability should be positioned at the forefront of research and educational projects, guiding the development of all Fashion-Tech solutions. This should be done with a holistic perspective encompassing cultural, social, economic and environmental consideration. It is suggested that students, teaching staff and researchers become more aware and also more critical about the case studies they are inspired by but also from the implications of their ideated Fashion-Tech solutions. A real sustainability check should be included in research and educational activities, by providing assessment tools and dedicated exercises to boost critical thinking competencies as the ability to question norms, practices and opinions inform decisions and evaluations and take a position in the sustainability discourse. A possible platform is FashionSEEDs *(2022),* aiming to provide a series of learning materials and toolkits about what

to teach, and how to teach through the discipline of Fashion Design for Sustainability.
The goal is to boost integrated problem-solving competency, an overarching analytical and critical ability to understand and solve complex sustainability problems and implications, boosting research skills in risks, barriers, criticalities, limitations' identifications, in order to develop a viable, inclusive and equitable solution.

Future perspectives of Fashion-Tech Educational models

Critical reflection and problem definition

Fashion-Tech pedagogical approaches need to boost students' attitudes inside the Fashion-Tech context, by detailing the problems and issues they are facing and also specifying all aspects of the delivered Fashion-Tech solutions (i.e. product, services and systems). Therefore, specific tools should be delivered during their project path to guide and increase the granularity of research and idea generation processes from general to specific aspects, thus grounding solutions. At the same time, students should be guided to abstraction and scaling activities, from the particular solution they have conceived to creating links and connections with a systemic thinking approach. In both the processes, students need to achieve the ability to recognize and understand relationships, to analyse complex systems, to perceive the ways in which systems are embedded within different domains and different scales, and to deal with uncertainty.

Collaborative Digital education

The concept of online education is a key component of 21st-century education. Digitalization of learning experiences is important for the expansion of students' knowledge in a more accessible and inclusive way, facilitating virtual distance learning, mixed learning, and distribution learning *(Suhartini et al., 2020).* However, some limitations occur in terms of technology associated with socioeconomic privileges *(Barbour & Revees, 2009)* and reliability, internet access and digital divide of certain areas of the world. On the other side, digital education can help students learning-by doing the implications of digital technologies that they will use in their future profession in a more and more digitised fashion sector, both learning specific digital and virtual tools (e.g. CAD systems, on-line platforms, VR/AR/MR environments) but also aiming to elaborate critical reflections about opportunities and limitations. Collaborative digital education should boost collaborative competences by enhancing the ability to learn from others, understanding and respecting the needs, perspectives and actions of others from different backgrounds, dealing with conflicts in teamwork and facilitating collaborative and participatory problem-solving activities.

Therefore, the educational system needs to transform its courses with the use of Collaborative Virtual Prototyping (CVP) activities through the implementation and testing of e-learning platforms that can articulate digitally a collaborative project between all actors involved in the design/ prototyping phase of a new collection (product managers, designers, pattern makers, marketing personnel). CVPs processes could enable the integration of remotely located 3D CAD systems, virtual fabric libraries, 2D CAD/CAM systems for the exchange of multimedia content (2D patterns, fabric data, etc) to encompass the design, prototyping, marketing phases. A preliminary version of this structure was tested and piloted during the three learning experiences. However, a key pedagogic challenge will be to explore how these spaces will enable and enhance real collaboration in such heterogeneous groups. It is suggested to boost collaboration among students, teachers and companies toward interdisciplinary and transdisciplinary activities through the design and implementation of collaborative platforms and interfaces that frame and make more evident exchange between different stakeholders. This means unpacking activities and designing learning processes through visual boards that allow reflection on disciplinary-specific contribution, facilitate the plural discussion among design, engineering and business, and guide the process of interdisciplinary decision-making along the whole project development.
In addition to this, it is also suggested to test the possibilities of remote collaborative education in Fashion-Tech by using virtual or augmented reality (VR or AR) that is an interesting pedagogic application of Fashion-Tech. However, two current limitations are envisaged: (i) missing fashion or interaction design specific VR collaboration environments *(Yang & Lee, 2021)*, and (ii) the costs of VR/AR equipment leading to concerns over digital exclusion of students not able to afford the technology.

Crafting materials and experimentation through blended modalities of education

Apart from collaboration, digital education shows its major limitation in the loss of practical activities that require tangible tinkering, material knowledge, manipulation of crafts, hacking of technologies through hands prototyping by groups of students. To avoid the visual-only based kind of learning that is provided by digital education (based on presentation, screen sharing, video recordings), some hands-on induction lectures followed by brief practice-based assignments and exercises to be launched to students. This requires an organisation of a list of necessary materials (e.g. physical computing hardware, or biomaterials) to be shared in advance to students along with the possibility to access a network of workshops to establish their dislocated on-distance laboratory. At the same time, interdisciplinary collaboration should be enhanced assigning responsibility among students with different backgrounds through peer review activities or enabling blended learning modalities boosting the physical encounters of students being located in the same university to exploit in-presence collaborative activities.

Upskilling teaching staff from HEIs

Educational staff need to be provided with tools and teaching materials, models and previously tested learning experiences in order to upskill their teaching modalities to stay up to date and to confront the continuously mutating field of Fashion-Tech. Toolkits aimed to organise, implement, and design the digital interdisciplinary and international learning experiences were implemented and shared to support and enforce the co-designing process and exchange information among all stakeholders involved in teaching activities, from interdisciplinary educational staff from different HEIs to professionals of the Fashion-Tech industries. The toolkits are openly shared and usable from all interested parties in further implementation activities of Fashion-Tech Learning Experiences *(D2.1 Project-based Learning Modules, 2021).*

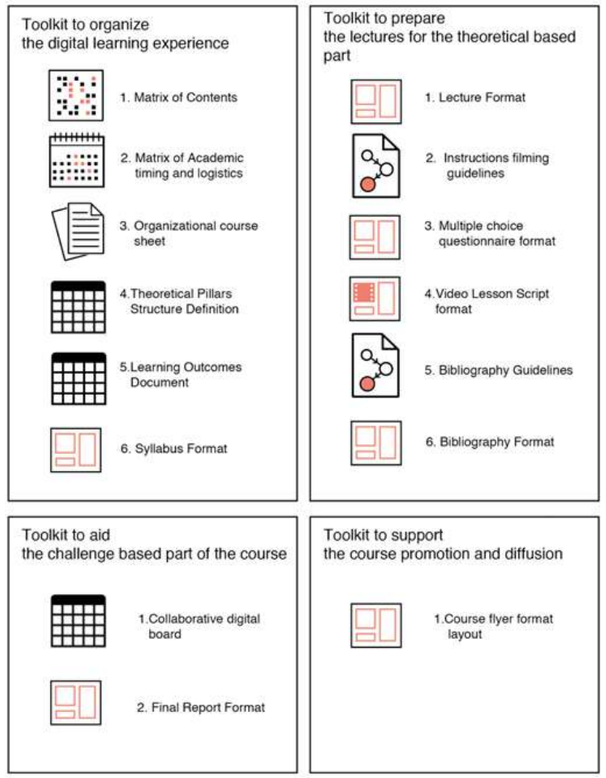


FIG. 25 - THE FASHION-TECH LEARNING EXPERIENCE TOOLKIT

Open Knowledge Production and Circulation

Knowledge accessibility is nowadays a paramount concern for education, being tools and information directly accessible out of the HEIs, and so skills could be acquired on the Internet and from open-access resources. Fashion-Tech education should also participate in making knowledge available openly to communities *(Bertola & Colombi, 2021)*. For this reason, a selection among the materials produced for the three-learning experience has been released in the shape of Open Educational Resources (OERs). The video-lectures include teaching, learning, and research materials in a digital video format focusing on presenting fashion-tech trends, methodological approaches to design next and far future scenarios, methodological approaches to assess and evaluate user experiences of fashion-tech garments/accessories, technical lectures related to digital transformation and sustainability impact, along with business oriented lectures related to new fashion-tech business and revenue streams models. OERs have been shared in the public domain under an open licence that permits no-cost access, use, adaptation, and redistribution by others with no or limited restrictions via the FTalliance OER platform *(2022)* and FTalliance Youtube channel *(2022)* to guarantee the widest reach toward interested stakeholders in the Fashion-tech sector.

The platform for FTalliance OERs has been implemented so that it allows the research of educational materials by playlists related to the implemented three learning experiences that were delivered during the FTalliance project:

(Fashion-Tech Interline, the secret life of clothing, Scalability of Multidisciplinary Fashion-Tech Solutions) but also browsing the contents via the following thematic topics:

- Fashion-Tech Business Management and Impacts
- Sustainability in the Fashion-Tech Industry
- Fashion-Tech UX, Research Methodology and Trends
- Fashion-Tech Prototyping
- Virtual & Digital Technologies in Fashion-Tech
- Sustainable, Smart & Digital Materials

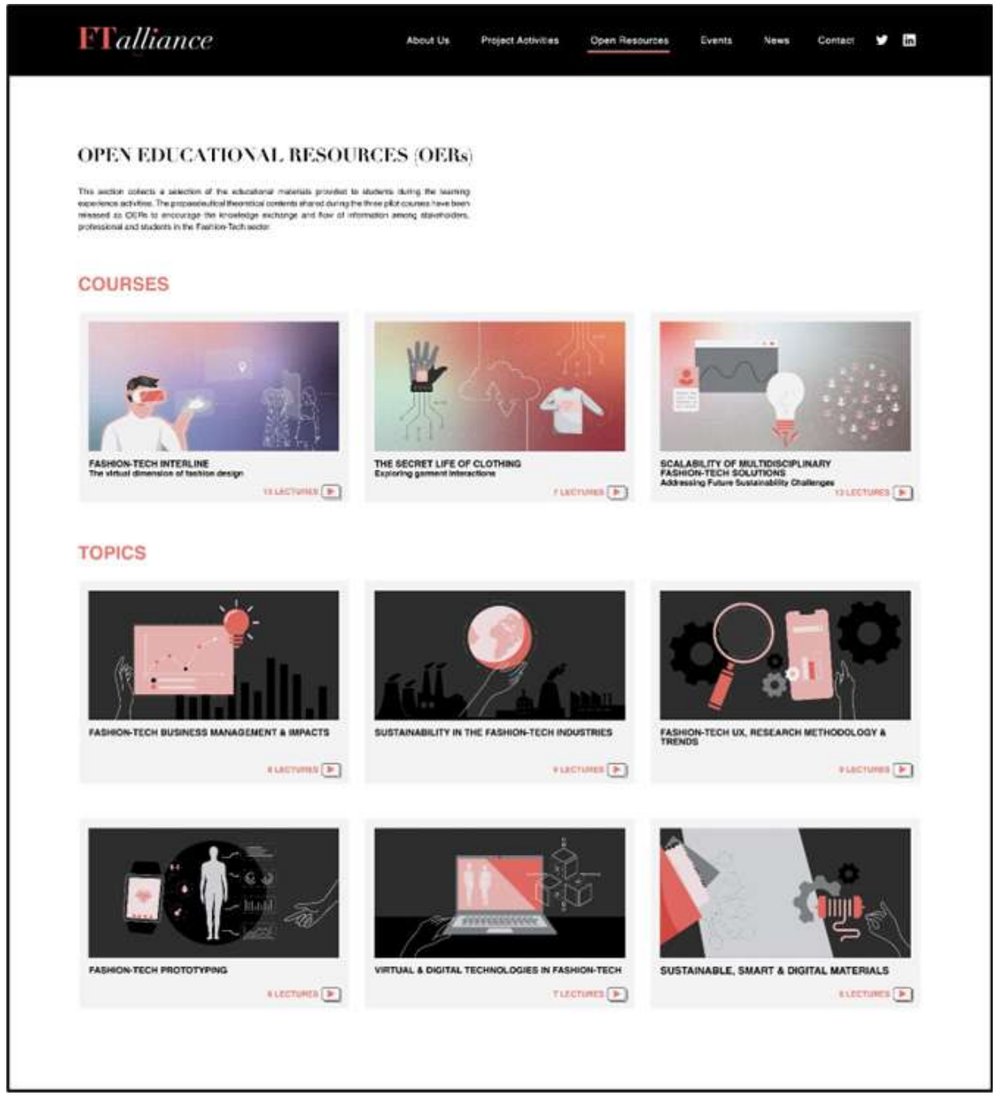


FIG. 26 - FASHION-TECH ALLIANCE OER PLATFORM

5.2 LESSONS LEARNED FROM THE FIELD: COLLABORATION AND NETWORKING

Education at the highest level in universities has a major impact on society, both developing the future executive classes and professionals and also building relationships with the external world, conceived as local eco-systems, industry and government *(Bertola & Colombi, 2021).* Thus, more than solely working on research and education, HEIs need to boost their third mission toward innovation, social, outreach and entrepreneurial scope, transferring their knowledge to the general public through societal outreach and also aiming to spread innovation through incubators and accelerators that bridge applied knowledge with the companies. In this context of HEIs expansion out of their current boundaries, sustainable collaboration among the European HEIs and companies of the Fashion-Tech field needs to be established and nurtured through a proper strategy that allows personalized educational models, and one that is willing to invest in research, continuous innovation, knowledge dissemination and establishing good practices toward entrepreneurship and societal change.

HEIs and Companies collaboration for innovation, entrepreneurship and social impact

The results of the learning experiences and the FTalliance project at its current status shows that to achieve research excellence as a key factor toward HEIs innovation impact, the importance of relational closeness, collaboration and knowledge transfer between HEIs and Industry researcher, experts and professionals are very important. In particular, strategic and long-term collaborations built around a shared research vision for a decade or beyond are the most productive for reducing non-productive tensions and conflicts that emerge from the initial cultural and communications divide happening in the Industry-Academia collaborations. In the longer term, strong collaborations increase mutual benefits between the partners, elaborating and delivering new knowledge, competence, prototypes, new methods, new technologies' application and innovative solutions. All of which are useful to improve researchers' and students' entrepreneurship which constitutes a small but crucial part of academics' innovation contribution to society and to general economic growth. In addition to this, the rise of a global knowledge economy has intensified the need for strategic partnership and alliances that go beyond the temporal and financial limitations of discrete research projects. If, on one side, policymakers need to ensure a stable environment of funding and regulation for long-term Industry-Academia strategic partnerships to thrive, HEIs need to have more agile processes to formulate and operate effectively to forms collaborations. For the first part of granting established funds at the European level, the future EU programmes on education, research and innovation through Horizon Europe will ensure that such partnerships are fostered and fully exploited.

Democratization and diffusion of knowledge

Distributed and accessible knowledge also that HEIs should become more open and offer learning activities in collaboration with a wider network of stakeholders and cooperative learning spaces *(Bertola & Colombi, 2021).* In particular, Fashion-Tech research and education should happen through the direct access to technologies in hybrid workshops (consisting of basic machinery and tools but also advanced high-tech instruments). These should be accessible both internally at the HEIs but also in the constellation of networked actors that are driving digital change (e.g. Competence Centres, Innovation and R&D Hubs, FabLabs and Maker Spaces, Research Laboratories). In this open and networked setting of spaces, comprehensive research with virtual prototyping, digital fabrication, sustainable materials and biomaterials can take place under the guidance of skilled technicians and tutors, existing within a distributed model of knowledge and educational experiences. To share knowledge and participate in thede distributed shared educational models, students should be nurtured with a basic understanding of other disciplines' languages in search of a common vocabulary.

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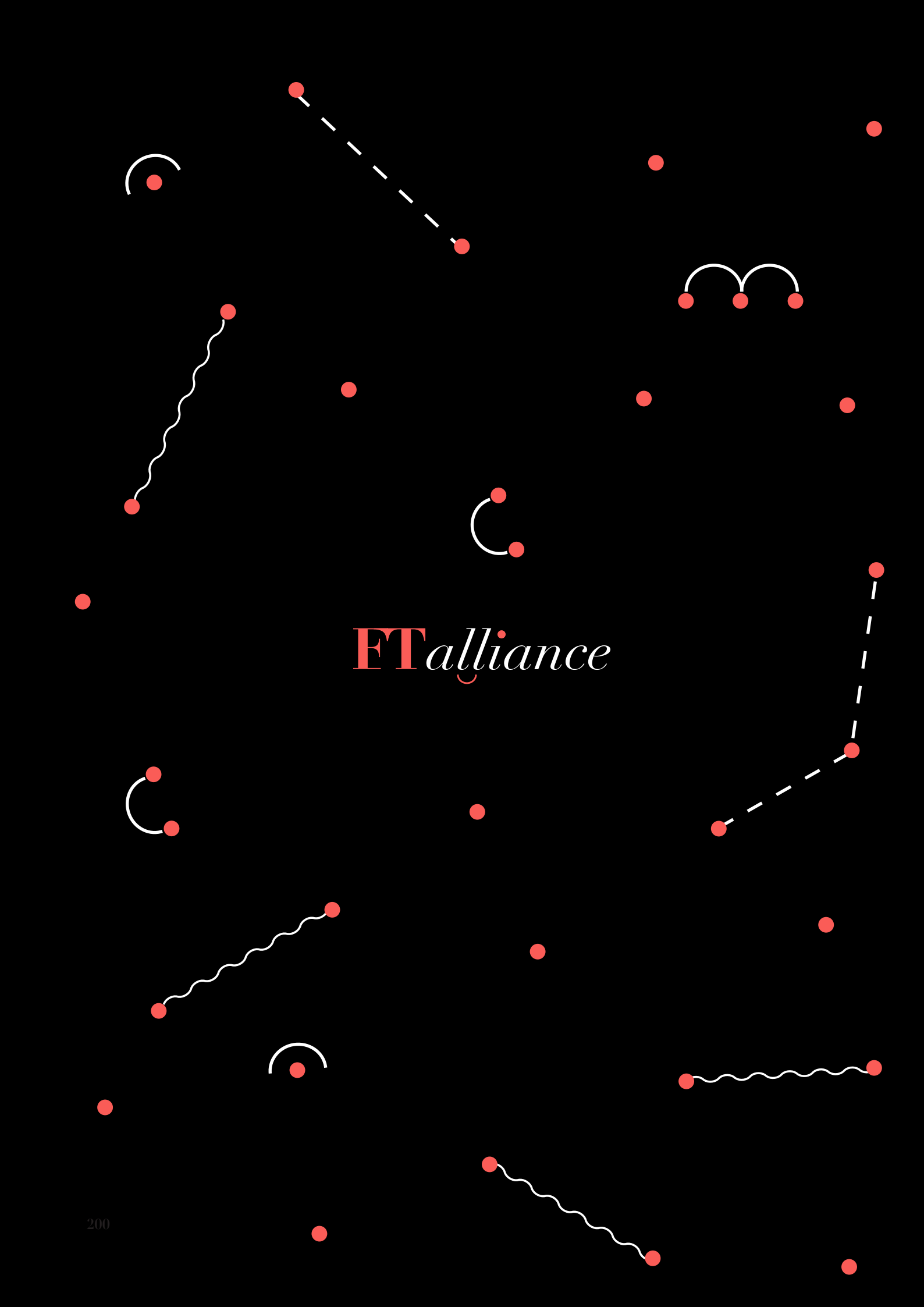
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