Textile Prototyping Lab: A Platform and Open Laboratory for the Promotion of Open Innovation and Networking between Research, Design and Industry

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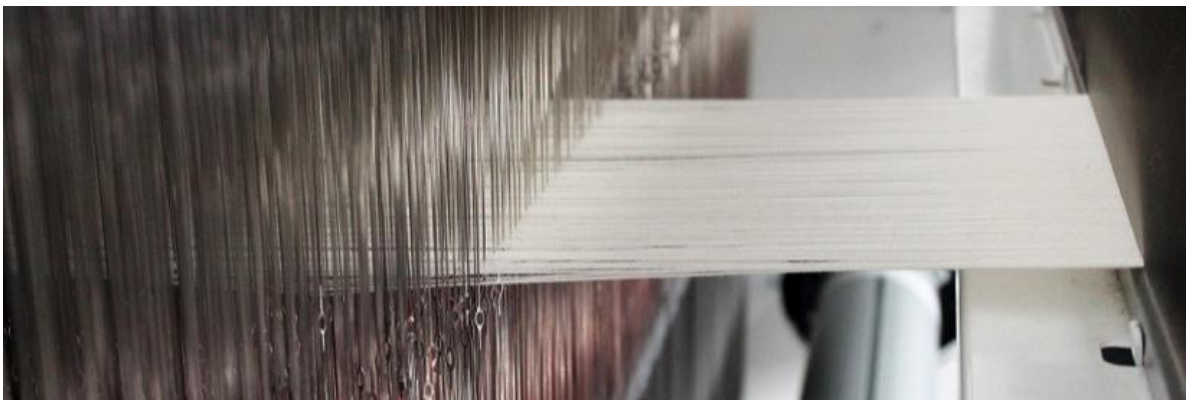

Figure 1. Detail of the weft threads of the TC2 Jacquard Loom installed at the TPL Central Lab. © TPL.

This paper introduces and discusses the Textile Prototyping Lab (hereinafter referred to as TPL), which is a joint research project in its early stages of five organisations from the fields of textiles, electronic research, design and economics. It comprises the concept, design, installation and testing of a textile prototyping laboratory that is more open, flexible and interdisciplinary than other textile-related laboratories known to date. The core topic of the project is Open Innovation, which means research and development is conducted within the new context of sharing resources and results amongst the directly involved actors and the interested community consisting of industry, individual professionals and students. Thus the research and development activities relevant to the individual parties involved in this project are conducted jointly and made available beyond their own organisational boundaries.

The concept is implemented by five partners with a sound expertise in their respective fields of action: The Saxon Textile Research Institute (STFI) and the Textile Research Institute Thuringia-Vogtland (TITV Greiz) - two leading German textile research institutes - are contributing their expertise in textile process chains, lightweight construction and smart textiles to the project. The Fraunhofer Institute for Reliability and Microintegration (IZM) supports the lab in the field of microelectronic integration into textile structures, but Fab Lab Berlin - with their expertise related to Open Innovation processes. weißensee academy of art berlin serves as the network coordinator and contributes its knowledge in textile design, design education and design research. This research project is part of futureTEX, an interdisciplinary competence network in which industry, scientific institutions and associations work together to actively shape the future of the German textile industry, fostering new interdisciplinary ideas, funded by the Federal Ministry of Education and Research in Germany.

The infrastructure of TPL consists of a digitally supported central prototyping lab located at the weißensee academy of art berlin, supplemented by highly specialised facilities and 'focus labs' located at the partner institutes. A specifically developed software connects the different facilities and supports lean development processes. Additionally an extensive material library embodies and represents the textile expertise and serves as an analogue resource of references, information and inspiration in order to communicate the competence fields and technological possibilities of TPL.
TPL connects different stakeholders from the textile sector and beyond promoting exchange among these. Diverse actors benefit from the competences of the TPL infrastructure and its network. The processes are adapted to serve different user types (e.g. industry, SMEs, start-ups, designers, engineers, developers, free-lancers, students). Thus TPL is an open and agile place where interdisciplinary practices and interests meet to foster quick and effective innovation processes within the extended field of textiles.

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Additional Key Words and Phrases: Open innovation; Interdisciplinary collaboration; Infrastructure development; Textile processes; Rapid textile prototyping; Practice-led research; Smart textiles; Textile design & technology

1 INTRODUCTION

This paper presents and discusses a new and multi-dimensional concept for the implementation of interdisciplinary textile research with an aim to establish novel product development processes through an early inclusion of design as a driving force for innovative marketable products and services. This proposed and currently tested concept aims to close the gap between cutting-edge product ideas, research and industrial production in textile product development through strategic implementation of beneficial collaborations.

The concept implies the conceptualisation, building up and testing of a textile prototyping facility in Berlin called Textile Prototyping Lab (TPL) as a physical space for transdisciplinary and interdisciplinary textile research and development. This is complemented by an external shared infrastructure network comprising diverse specialist expertise relevant to the project. Additionally, a platform for textile-related technology trends and research is being established along with other formats as discussed later in the paper. All levels of the infrastructure are aiming to accommodate different user types to enable flexible top-down and bottom-up innovation processes functioning at the same time or as relevant.

This paper also aims to outline the four strategic pillars serving as a base for the implementation of the project: Interdisciplinarity, Open Innovation, Design Thinking and Resource Sharing. Furthermore it will introduce different methods and tools for implementing the concept, such as a Textile Material Library, a Process Management Software and a specifically developed E-textiles Toolkit. Along with the results of the first use cases, which tested the entire TPL's infrastructure and process chain with different stakeholders and participants, the paper discusses the initiation and execution of these use cases, the so called TPL Development Projects.

TPL is both a research project as well as a physically implemented and actively used textile prototyping facility for Open Innovation processes. Since the project is in its early stages, the methods and models are still being developed through trial-and-error testing, based on and informed by the following:
- an initial overall survey of European textile labs in order to identify their operational models and their target group(s);
- an in-depth analysis of selected European textile labs (site visits and interviews with lab teams)[1];
- the extensive applied expertise in Open Innovation processes and operational models of Fab Lab Berlin
- an integral project partner of TPL.

2 TEXTILE PROTOTYPING LAB

2.1 Research Context

The overall context to which the TPL research project reacts is the current situation of the European textile industry, in particularly addressing that in Germany, which is characterised by high expertise in the field of technical and smart textiles. The textile and clothing industry is the second largest consumer goods sector in Germany and employs more than 130,000 people in Germany today[2]. Within this context, SMEs from the former East Germany regions play a specific role: they look back on a long tradition, secure jobs and structurally weak regions (during and after the GDR[3] era) thus now undergoing a complex transition period suffering in particularly from global competitive pressure. Let us highlight a few aspects below:

[1] The lab visits and interviews were conducted at the following textile-related laboratories within the EU: A:Space/Textiles Interaction Lab, Aalto University Helsinki, Finland (Oct. 2017), Smart Textiles Initiative, Swedish School of Textiles, Borås, Sweden (Oct. 2017), TextielLab, Tilburg, Netherlands (Oct. 2017), Wearable Senses Lab, TU Eindhoven, Netherlands (Oct. 2017), TextileLab, Fab Lab Amsterdam/Waag Society, Netherlands (Oct. 2017).

[2] The Confederation of the German Textile and Fashion Industry website. Textil-mode.de. (2019). *Daten/ Zahlen - textil+mode*. [online] Available from: https://www.textil-mode.de/branche/daten-zahlen [Accessed 12 Jun. 2019].

[3] The abbreviation GDR stands for the former East Germany, officially the German Democratic Republic.

- German Textile Industry. The (East) German textile industry has been facing great challenges for decades due to socio-economic, political and global developments. Textile innovation in companies is associated with considerable costs, long development periods and subsequently great economic risk. Producers often do not have access to an innovative pool of ideas for future-oriented products and applications. Thus, the German traditional textile industry has been experiencing a shift to a highly technology-driven industry with great potential. So far, according to an Ernst & Young study conducted in 2016, the innovation strategy within this industry has been based on close cooperations between 17 national textile research institutes and companies to fill R&D capacities within their own structures[4]. This leads to a technology market leader position within the technical textiles segment [7]. Nevertheless, innovative technologies alone do not necessarily lead to new applications and end-user acceptance or open up new market possibilities.

- Technical Textiles. The strongest growth in the industry is attributed to the technical textiles, which are used in a large number of high-tech products and generate about 60 percent of the sector's sales[5]. The exceptionally high export quota of more than 40 percent[6] reflects the appreciation of German textile and apparel products on the international markets and underlines the competitiveness with the world's top companies.

- Smart Textiles. For a long time textile structures and substrates have been the basis for the integration of electronic components and sensors in order to achieve added functions in our clothing and built environment. Smart textiles can be used for communication as well as in the fields of medicine and sports for monitoring bodily functions and in many other areas of our daily life. Such soft technologies[7] have been developed for more than 25 years already and still there are only a few products available on the global market [1]. Early market forecasts predicted huge smart textiles markets years ago but that did not come true. Looking more closely into the needs for the production of smart textiles, several reasons for the delay were identified. The textile industry and the electronics industry differ very much in their structure, their markets and most importantly - how they manufacture goods. However, integration of electronic components into textiles by textile companies is already possible on industrial scale, even if not on the same level of complexity (e.g. regarding density of interconnects) as in research prototypes.

The TPL concept is being developed and implemented within a governmentally funded three-years long research project[8] conducted by a consortium, which includes a variety of disciplines. It aims to develop an alternative and more effective model for the process chain based on interdisciplinary collaboration between research, design and industry within the textile and clothing sector to optimise prototype production by employing the Open Innovation approach. The project meets the challenges of the German textile industry by establishing cross-sector competence pools in the field of smart textiles, material innovation and textile construction in order to facilitate innovative forms of cooperation between businesses and R&D leading to lean development processes.

[4] Ernst & Young, STFI: TechTex, Study, 2016, p.8.
[5] Ernst & Young, STFI: TechTex, Study, 2016, p.5 - number includes composites in the calculation.
[6] Ernst & Young, STFI: TechTex, Study, 2016.
[7] In this paper the term ‚soft technologies' is used in the sense as discussed by Zane Berzina in her essay *Soft Technologies. Active Textiles, Adaptive Surfaces, and Tangible Interfaces.* (2017).
[8] Project duration: June 1st 2017 - May 31st 2020, funded by *the Federal Ministry of Education and Research (BMBF) in Germany* within the project futureTEX.

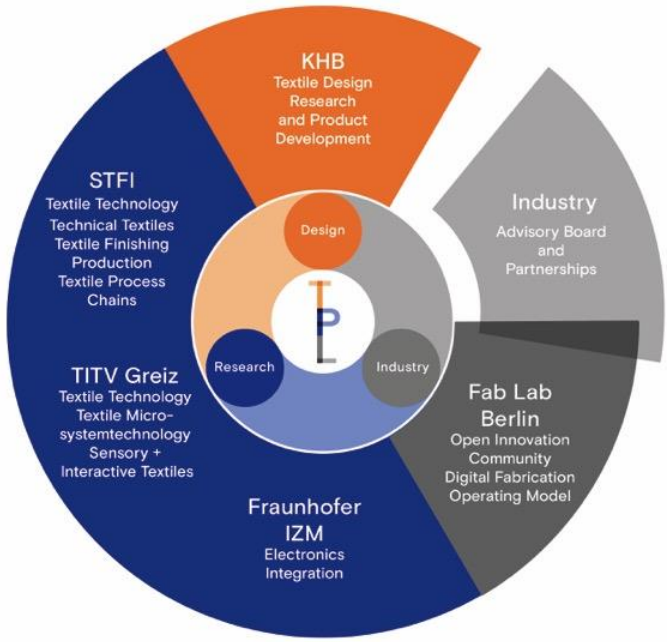


Figure 2. An overview of the TPL consortium and partnerships: KHB - the weißensee academy of art berlin, STFI - the Saxon Textile Research Institute e.V., TITV Greiz - the Textile Research Institute Thuringia-Vogtland e.V., Fraunhofer IZM - the Fraunhofer Institute for Reliability and Microelectronics, Fab Lab Berlin and the Advisory Board consisting of partners from industry. © TPL.

As illustrated in Fig. 2. the consortium partners of TPL are: the Design and Experimental Material Research unit at weißensee academy of art berlin (KHB) in the Department of Textile and Surface Design - an expert in Textile Design & Product Development, the Saxon Textile Research Institute e.V. (STFI) and the Textile Research Institute Thuringia-Vogtland e.V. (TITV Greiz). The latter two are renowned German research institutes specialised in technical textiles and lightweight constructions (STFI) as well as in the textile integration of electronics (TITV Greiz). Together with the Fraunhofer Institute for Reliability and Microelectronics (Fraunhofer IZM), the electronics and miniaturisation expert, they represent the established research organisations in the project. Fab Lab Berlin - on the other hand - contributes with their expertise to the Open Innovation structure development and community-based business strategy. Throughout the project an Advisory Board consisting of partners from industry ensure that the content and activities of TPL intersect with the requirements of the industry.

2.2. A Brief Overview of Other Europe-based Textile Labs

In order to learn from the best practices in the field, during the starting phase of this research project, an overview of existing textile labs across Europe was created to identify their core operational models. During the next step selected labs were visited, analysed and evaluated. Looking at textile prototyping laboratories in an European comparison, a distinction can be made between accessibility and, as a result, their core clientele or target group(s) as shown in the table below (Fig. 3.). This overview does not claim to be complete, but serves merely to present a spectrum at the ends of which there are low-threshold, inclusive laboratories on the one hand and exclusive, industrially oriented laboratories on the other.

Organisation	Target Group	Accessibility
Textiel Lab (Tilburg, Netherlands)	Established designers and advanced academic projects	Inlclusive-curated
Fab Textiles, Fab Lab Barcelona (Barcelona, Spain) TextileLab, Fab Lab Amsterdam/ Waag Society (Amsterdam, Netherlands) FabLab Kamp-Lintfort, University Rhein-Waal (Kamp-Lintfort, Germany)	Open Source-driven students, early stage tech-transfer from academia	Inclusive
Textiles Interaction Lab / A:space Aalto University (Helsinki, Finland)	Students and self-employed designers	Inclusive-academic
Smart Texiles /The Swedish School of Textiles (Boras, Sweden) Design Research Lab (Berlin, Germany)	Academic projects / tech-transfer Research projects	Tech-transfer only
European Center for Innovative Textiles (Lillle, France)	Corporates	Commercial only
Culzean Textile Solutions (Ayrshire, Scotland)	SMEs and Corporates	Commercial only
Institut für Textiltechnik (ITA) der RWTH Aachen (Aachen, Germany)	SMEs and Corporates	Commercial and tech-transfer
Weber & Leucht GmbH Application Lab (Fulda, Germany)	SMEs	Commercial only

Figure 3. An overview of European textile prototyping labs featuring their accessibility level and main target groups. © TPL.

Of the platforms compiled here, the target groups were always of a very specialised orientation and as a result also their machinery and accessibility. In general, it can be said, that more easily accessible labs with a higher Open Innovation interest (e.g. TextileLab/Fab Lab Amsterdam, Fab Textiles Barcelona) tend to have a simpler machinery and they rather target students, self-employed makers and start-ups who use the machines by themselves or participate in workshops. A positive aspect here is the high grade of Open Innovation and exchange among the lab operators and users. The downside of open lab concepts is the limited complexity that can be reached in the creation of prototypes. In terms of complexity and transferability of prototypes to an industrial scale the TextielLab in Tilburg (for individual developments) and labs representing the commercial end of the spectrum (e.g. RWTH Aachen) are also of a great interest for the TPL concept, whereas those platforms remain quite closed concerning their accessibility.

As a conclusion to this overview it can be said that TPL targets the openness and flexibility of a local open lab, which still enables the development of complex and industry-compatible prototypes. Therefore the strategic challenge for TPL is, based on the analysis of the other textile prototyping labs in combination with the expertise provided by Fab Lab Berlin, to conceptualise and establish a more holistic lab model that meets the needs of various user types and development projects - from DIY to high-tech and industrial.

2.3. Strategic Pillars of TPL

Primarily the entire concept relies on the advantages of interdisciplinary collaboration between design, research and industry. By introducing design as a strong innovation factor and strategically placing it within the early-stage prototyping processes, TPL intends to achieve innovative products and thus strengthen the role of designers and design researchers within industrial and technological settings. The following methods and concepts are the pillars of a successful implementation of the concept:

1. Interdisciplinarity

> Interdisciplinary work sometimes has a tendency to be shallow as it brings together people who know a bit about many things – we should take care not to lose ourselves in the interdisciplinary process. But what is absolutely vital is being passionate about exploring new arenas and not giving in to standard solutions [12].

Interdisciplinarity is an experience-based activity [12], which demands highly agile project management and the ability of all participants (ideally) to reflect on the processes by keeping in mind the overall

interdisciplinary vision. This is difficult at times as in challenging situations the experts may tend to fall back to established patterns of thinking and acting.
TPL is being run by a consortium (Fig. 2.) from very broad fields of practical and theoretical knowledge jointly conducting practice-led research, where design is introduced as an integrative force for different scientific disciplines. Therefore the establishment of good strategies for cooperation and communication such as regular project progress updates and meetings on a rotational basis visiting each partner institution or joint themed hands-on workshops are crucial for the collaboration and stimulate the empathy towards the other disciplines.

One explicit project objective is to develop a common 'language', as often in interdisciplinary cooperations "the 'languages' of the diverse participants might be very different [...and] specific methods of reflection, motivation, communication and moderation are required" [8]. Thus, parallel to the concrete TPL Development Projects, interdisciplinary and 'soft' skills of every project member are developed further with the aim of overcoming disciplinary boundaries through practical experience [8] and through an ongoing reflective dialogue.

> Disciplinary boundaries are at the same time knowledge boundaries, as a subject matter is only perceived and analysed with the methods of the respective discipline. Thus, only a segment of reality is perceived. Practical problems do not have the borders – they are multifarious and eclectic. A disciplinary approach therefore can only grasp partial aspects and not the full complexity and interwoven relations of practical problems [8].

The interdisciplinarity of the project is also emphasised in this paper through the commitment of its plural authors, coming from various fields of knowledge and experience, e.g. textile design and education, design research, textile engineering, electronics research and Open Innovation, to report on the progress of the TPL project.

2. Design Thinking

> Design Thinking is mainly about building innovators who can use the Design Thinking paradigm to transform ideas into reality, to transform organisation, and to transform all aspects of life[9].

The term Design Thinking plays a major role not only in the overall concept of TPL but also in the execution of concrete Development Projects. A central working strategy is the use of design-driven innovation processes and user-centred design methodologies that are being introduced into the prototyping processes for the textile sector. Design Thinking at TPL is executed within and by the interdisciplinary *team*, within the physical *space*, and it is reflected by a *process* following inspiration, ideation and implementation [4]. The method of Design Thinking is being used as a structured and iterative creative process for developing custom and user-centred solutions to complex problems and therefore can contribute to more innovative products in the end.

3. Open Innovation

Open Innovation, as it is understood within TPL, is strongly referring to the idea of sharing knowledge in order to go beyond internal R&D structures and advance existing technologies by an open attitude and the inclusion of external ideas [6]. Creating an open space, such as Fab Labs and Media Labs already do, is an essential basis for this type of approach. Here, knowledge can be exchanged and built up collectively in the surrounding of an open platform. Within the TPL concept, the Open Innovation idea goes hand in hand with design processes, also meaning the design of an architecture of knowledge, as described by the term 'design turn' [11]. Knowledge is thus generated through theoretical as well as practical exchange and experiences.

> The 'design turn' is about transforming this fundamentally interdisciplinary shaping of knowledge into an open and conscious strategy through analytical and experimental procedures [11].

[9] Larry Leifer, Hasso-Plattner-Institut, Press release, 12 October 2015. [online] Available from: https://hpi.de/fileadmin/user_upload/hpi/dokumente/pressemitteilungen/2015/20151012_Zitate_DesignThinking_final.pdf [Accessed 10 June 2019].

Within the context of industry-research-design cooperations, Open Innovation is a new approach, especially in the traditional field of the textile industry, that shall be further tested and evaluated throughout the progress of the project.

4. Resource Sharing

Sharing knowledge is one important part of an Open Innovation oriented working strategy. But the concept of TPL relies not only on the idea of sharing knowledge, but also sharing of (otherwise unused) resources. In addition to the central TPL space (Central Lab) with basic prototyping equipment, a decentralisation of specific resources, e.g. machines and very specific technologies makes a strong addition to the development of a complex competence pool within the partner structure of the project. Especially textile-related machines are usually expensive requiring highly specific knowledge and a lot of experience to be operated. The TPL users are enabled to create first prototypes at the Central Lab and receive further development possibilities with specialists at the external Focus Labs as relevant. This leads to an increased efficiency in the development of innovative textile products and thus, a shorter time-to-market.

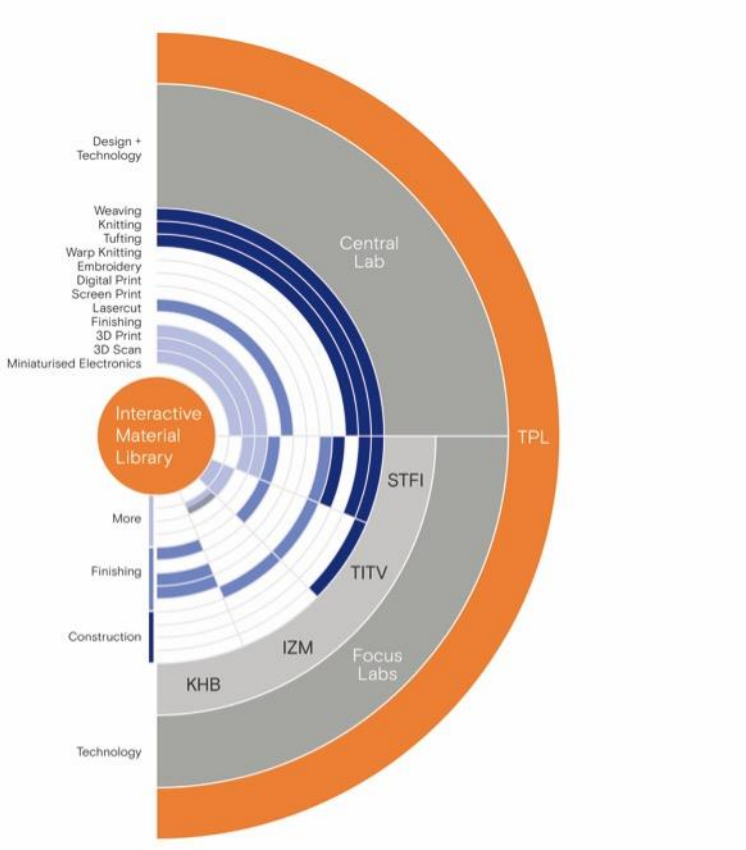


Figure 4. The technology set-up of the Central Lab and the Focus Labs within the TPL consortium. © TPL.

2.4 Strategic Sharing of Technological Resources

As already previously noted, one of the core ideas of the TPL concept is a strategic way of sharing technological resources. The TPL infrastructure as a whole is divided into a Central Lab and several Focus Labs located at the partner institutes of the consortium (Fig. 4.). At the Central Lab, basic (textile) technologies such as weaving, knitting, 3D printing are available to allow an experimental and open approach to prototyping. The idea of the TPL's sharing model is, that prototypes created at the Central Lab can be transferred to the much more specific machines at the relevant Focus Labs in the second step. Especially within the context of technical textiles highly complex and expensive machinery is being used, which usually require specific skills to operate them. The resource sharing model of TPL offers a more sustainable approach to skills and machine usage resulting in less downtime of machines across the network.

An important element to connect and communicate the technological competences available at TPL is the Material Library. This systematic library is physically located at the Central Lab, where samples from every technology, machine and project are continuously collected and archived. The library serves as a tool to display technological possibilities of various machines and Focus Labs - all in one place. In the following chapter, the design and structure of the Material Library as a communication tool is explained as well as the role the sharing model plays in the execution of the TPL Development Projects. Additional tools within the context of the research project are the specifically developed Process Management Software and the E-textiles Toolkit, which are also introduced here.

3 TOOLS AND EXAMPLES FOR PRACTICE-BASED RESEARCH WITHIN TPL

3.1 Methodological Tools from Design and Design Research

The diversity of the TPL partners reflects the challenge of building up an interdisciplinary textile prototyping facility based on Open Innovation, where knowledge exchange and co-creation processes are the core of the project. As discussed earlier, TPL applies dynamic research methods, such as Design Thinking and collaborative workshops, which are the key approaches in our practice-based research environment. The goal of TPL is to facilitate innovation through design, while integrating all actors in the creation process. Thus practice-based research methods have been tested in different scenarios at TPL. Firstly, to define process management, textile sampling guidelines and to create communication tools. Secondly, to identify needs for the TPL Development Projects by offering ideation workshops and agile prototyping facilities.

3.1.1 TPL's Material Library

The Material Library contains a systematic collection of textile samples developed within TPL. It represents the technical possibilities of the TPL's Central Lab and Focus Labs, and the extensive range of textile competences available.

The overall system design for the Material Library was developed with the help of a local architecture studio, Studio IN. Together with the TPL members, three collaborative workshops were organised. The result was the definition of three use cases and different types of interactions with the Material Library and its samples. The workshops helped to provide the necessary guidelines to categorise the samples and to define the interaction with the library.

The three main user categories of the Material Library are designers, students and industry experts with an interest in the development of textiles and soft technologies. The structure of the TPL Material Library offers different levels of information tailored to the specific requirements of the users: from access to basic overview about textiles or in-depth information about specific materials for textile professionals to curated inspirational presentations for experts from other disciplines.

The Material Library is divided into three sections: Raw Materials, Textile Samples and TPL Topics (Fig. 5.). The Raw Materials section contains the basic materials such as yarns, foils and electronic components that are used to create the textile swatches. The proportionally largest area in the visualisation is the Textile Samples area comprising Constructed Textiles (e.g. woven, knitted and non-woven), Hybrid Textiles (representing various finishing techniques e.g. 3D printing, coatings, embroidery) and E-textiles. The curated TPL Topics section showcases selected textile samples for textile applications such as Mobility, Health & Wellbeing and Lightweight Constructions.

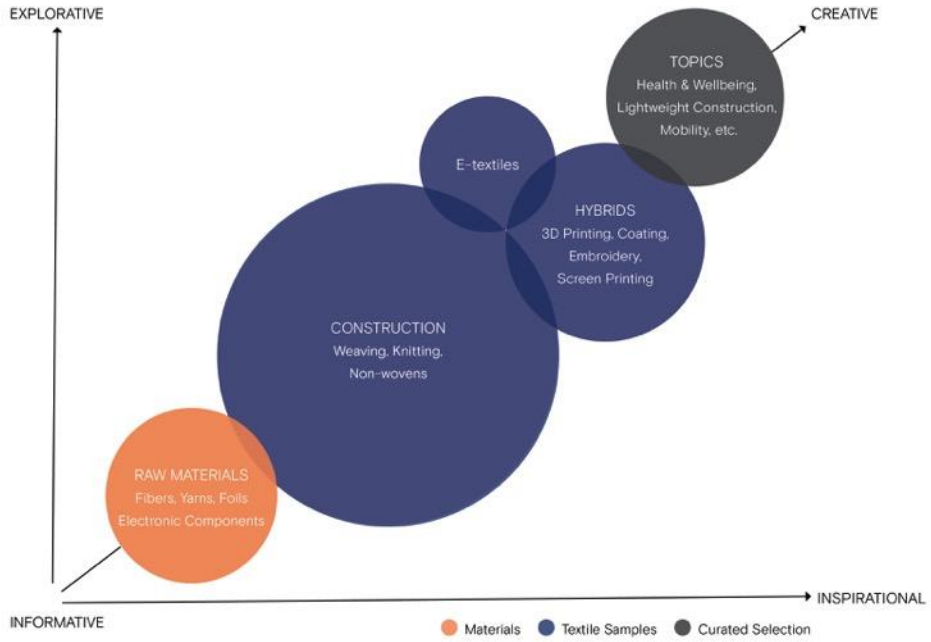


Figure 5. Schematic visualisation of the Material Library and its focus areas. © TPL.

Figure 6. Interactions with the Material Library and its textile samples. © TPL.

3.1.2 E-textiles Toolkit

As Smart Textiles and especially E-textiles are one of the defined focus research areas for the TPL Development Projects, the consortium decided to conceptualise a specific E-textiles Toolkit to foster knowledge transfer in this area between different user groups of TPL. The toolkit, still in an iterative development phase, is an intuitive and easy-to-use system, giving access to E-textiles not only to experts in electronics and programming but rather to users from the creative sector, such as textile designers and fashion professionals. In addition to criteria addressed by other already existing E-textile kits (e.g. didactics, creative use of technology), the following three aspects are being considered in the system design through means of miniaturisation and different ways of contacting:
- increased complexity of prototypes through modular system design;
- fast transferability to processing with advanced machinery;
- reliable industrial integration.

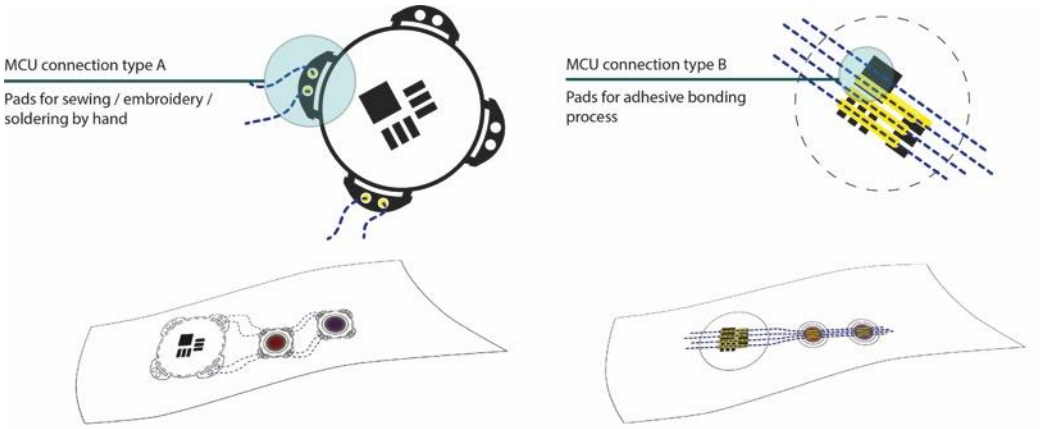


Figure 7. E-textiles Toolkit contacting: Manual sewing/embroidery/soldering (left), adhesive bonding [10] (right) and miniaturisation of the main control unit (MCU). © Kamil Garbacz / Fraunhofer IZM.

Another highly important criteria for the development of the TPL E-textiles Toolkit is its easy-to-use aspect. Therefore user workshops are organised throughout the development process to evaluate and implement the requirements of the target group. Based on the results from these workshops, the TPL E-textiles Toolkit offers multiple ways of electrical contacting (Fig. 7.) and comprises a set of electronic modules. A main control unit (MCU) – connected with a selection of different sensor and/or actuator units – collects data and controls. Besides, this MCU provides a wireless data interface to communicate with handheld devices and a complementary app. The goal is that the system automatically detects the selected and applied modules, and provides suitable user interface on the handheld device after connecting. To allow a quick start into the creative development of new prototypes, tutorials, workshops and a comprehensive instruction are currently being conceptualised..

3.1.3 Implementing a Customised Project Management Software (PMS)

A crucial aspect within TPL is the coordination and definition of the different phases involved in the process of the TPL Development Projects. For this purpose, a customised Project Management Software (PMS) is currently being developed (Fig. 8.), which helps to define the steps and tasks that need to be conducted within and for the respective TPL Development Projects, both in the Central Lab and the Focus Labs. With a support of this custom-made software it will be possible to assign tasks, reserve specific textile machines and estimate the duration of the project.

[10] Krshiwoblozki et al. *Electronics in Textiles – Adhesive Bonding Technology for Reliably Embedding Electronic Modules into Textile Circuits* (2013).

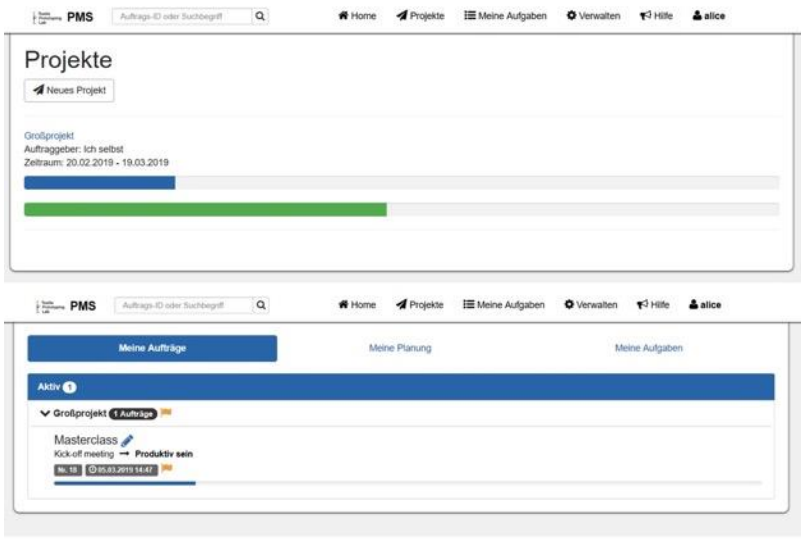


Figure 8. Project Management Software (PMS), work in progress. © TPL.

In order to understand and define each step involved in the execution of a particular TPL Development Project, the process chain has been visualised, as shown in Figure 9.. Here, three different types of users are defined: students, professionals and industry. The process starts when a new project proposal is received through an online application form on the TPL website. Once the project proposal is accepted by the TPL partners, it is necessary to sign a formal agreement with the applicant. This document includes the description of the different phases of the project, the definition of the project timeline, the degree of Open Innovation and the applicant's commitment to provide a selection of textile samples for the TPL's Material Library. The next step involves the definition of the different production and prototyping processes for the project using the Project Management Software (PMS). Once the final prototype is realised, a project documentation has to be delivered. So far this process chain has already been tested within the framework of conducted TPL Development Projects, realised with students and professionals from different sectors, in this paper discussed below as use cases.

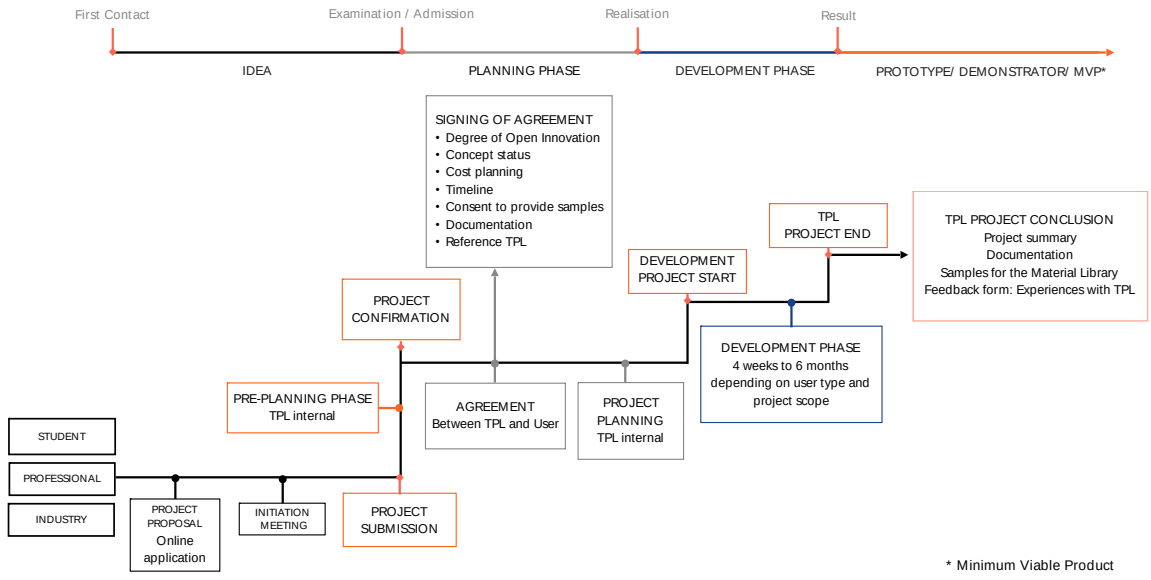


Figure 9. TPL's process chain, which informs the Project Management Software (PMS). © TPL.

3.2 TPL Use Cases

In the following sections 3.2.1 and 3.2.2, two use cases are explained in more detail to illustrate the above described process chain of the TPL Development Projects; one was a realisation of a design

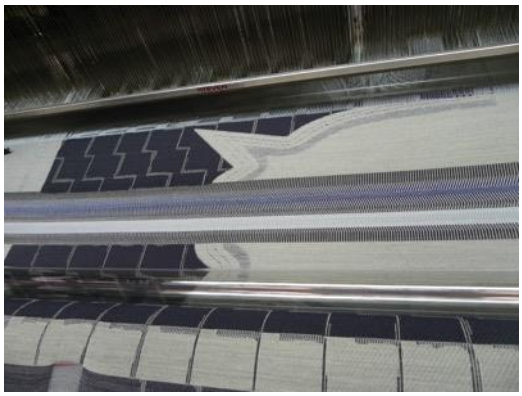
graduation project and the other one - a collaboration with the acclaimed German product designer Stefan Diez.

3.2.1 Use Case 1: Feelflight - Construction of a Novel Wearable for Long-Haul Flights

One of the very first projects executed within TPL in order to test its process chain was the project Feelflight. According to the Feelflight concept, the well-being of passengers on long-haul flights is supposed to be increased through a new wearable system, which enables individual thermoregulation. For this purpose, a jacquard weave made of a combination of special yarns was developed as part of a product design graduation thesis by Natalie Peter, employing the prototyping machines at the TPL's Central Lab. Further on the project development was continued at the Focus Lab of TITV Greiz, supported by an industry partner - a spinning mill developing specialised high-tech yarns - thus receiving the relevant technological and industrial support needed.

Within the strictly regulated context of flying, passengers usually experience long-haul flights as physically and emotionally stressful, which is why there is a strong need for solutions to increase their well-being. The traditional rectangular flight blanket has been transformed into a cape with added functionality, including heated areas for more comfort, that the passenger can 'wear'. For the technological implementation of the idea, weaving was chosen as the most appropriate technology.

Following the initial project meeting with the design student, first prototypes were developed using the TC2 loom at the Central Lab in Berlin. After several iteration phases and a subsequent evaluation, the project was further developed on a specialised industrial Jacquard weaving loom at TITV Greiz (Focus Lab) (Fig. 10.,11.). In order to accommodate the necessary transfer from the TC2 loom to the industrial loom, a common machine data format had to be established and a range of preliminary tests carried out to define suitable software intersections (compatibility) for the two looms. Through that, an agile development of samples and the final prototype was possible in a very short time - in two months.



Figures 10. – 11. Preliminary Feelflight tests and the production of the final design on the industrial Jacquard loom at TITV Greiz (Focus Lab). © TPL.

In order to allow faster processing after the weaving, the outlines of the entire cut pattern were embedded into the weaving pattern file resulting in an easy cutting-out of the cape after production. In addition, specially designed folding mechanisms were incorporated directly into the fabric structure, in order to achieve a uniform folding of the product for better handling during the daily usage. Thus, a lightweight wearable system with added functions, such as individually temperature-controlled zones and easy handling was developed with an aim to support the comfort of the passengers travelling by air (Fig. 12., 13.).

Through effectively designed iterative development phases, the team created the final prototype. This was then tested by Lufthansa within the context of Lufthansa FlyingLab[11], an established testing environment in form of a long-haul passenger airplane, which travels intercontinentally with novel applications on board.

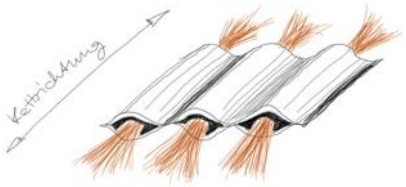
[11] Lufthansa FlyingLab. https://www.flyinglab.aero/en/fashionfusion/ [Accessed 10 June 2019].

Figures 12. – 13. Feelflight final prototype developed at TPL. © Natalie Peter.

3.2.2 Use Case 2: PLUSMINUS - Development of a Conductive Textile Strap as Part of a Lighting Solution

Within the context of another TPL Development Project, the TPL consortium collaborated with a German product design studio (Stefan Diez / Diez Office) and a Spanish lighting company (Vibia S.L.U.). The aim was to develop an innovative and functional lighting system. The outcome was a soft, conductive yet insulated textile strap that can incorporate a variety of bulbs for different lighting effects.

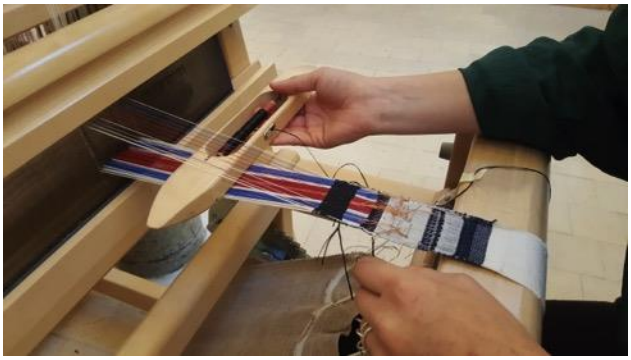
During the starting phase of the project several workshops were conducted. The TPL team discussed together with the design studio its initial idea of a lighting system based on a conductive textile belt regarding aspects of technical feasibility and production possibilities. The TPL team supported the external partner in terms of the definition of functional parameters for the envisaged end product by choosing suitable basic textile and conductive materials, and by developing the textile construction (functionally and senso-aesthetically). These first steps were performed within the network of the TPL's Central Lab in Berlin (Fig. 17.).



Figures 14. – 16. The initial TPL workshop with Studio Stefan Diez (top) and the resulting sketches of the possible textile construction (below, left and right). © TPL.

The further specific product developments were implemented at TPL's Focus Lab based in the Saxon Textile Research Institute e.V. in Chemnitz (STFI) (Fig.18.). One main focus of the work was the practical implementation of the strap's production on a shuttle weaving loom 'Type SL 1/150' from the company Mageba. Furthermore, the design, construction and testing of suitable weaving patterns was of high importance, realised by the TPL members. The team was able to execute the initial idea of the customers in a very short time (four months) through close cooperation with the industrial partners, the interdisciplinary structure of the TPL team, the broad machinery park and the corresponding know-how that is represented both at the TPL's Central and Focus Labs.

The industrial partner Vibia together with Studio Stefan Diez launched the final functioning lighting concept called 'PLUSMINUS' (Fig. 19.-20.) at the Milan Design Week in April 2019[12]. The product received highly positive feedback and attracted a lot of public and expert attention. Subsequently, the industrial partners are highly interested in continuing the cooperation with TPL to further optimise the prototype straps to be able to bring the final product to the market.



Figures 17. – 18. Weaving process of the conductive strap at TPL's Central Lab (left) and at STFI - Focus Lab (right). © TPL.

This use case demonstrates vividly how the infrastructure of TPL can enable companies, designers and stakeholders from other disciplines to develop new ideas and concepts through prototyping under industrial conditions with the help of an experienced interdisciplinary team offering know-how and equipment in the field of textile design and production, electronic textiles and soft technologies in general.

[12] Selected press reviews about 'PLUSMINUS':
Steafan Diez Designs a Lighting Collection for Vibia Based on a Conductive, yet Flexible Textile Cord, in URDESIGN [online], 24.04.2019, Available from: https://www.urdesignmag.com/design/2019/04/24/vibia-plusminus-stefan-diez/ [Accessed 10 August 2019].
Edelmann, Thomas. Groß und Klein mit System. In STYLEPARK [online] Available from: https://www.stylepark.com/de/news/euroluce-2019_salone-del-mobile [Accessed 10 August 2019].

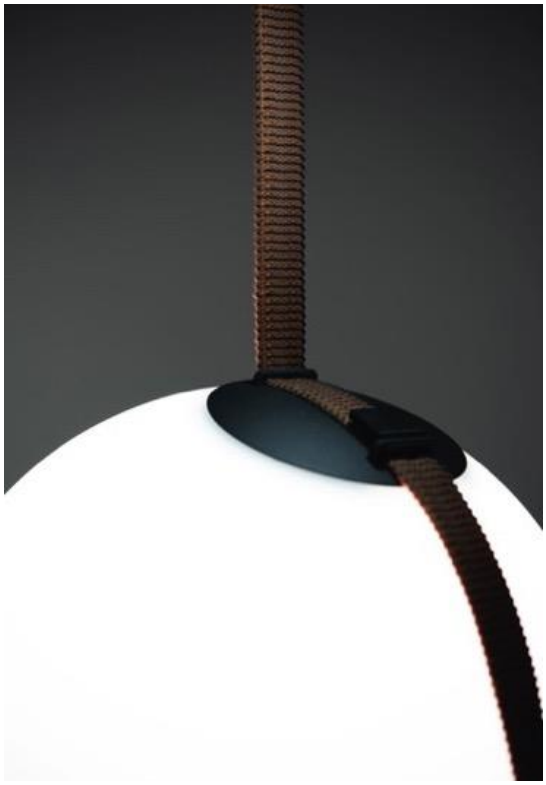


Fig. 19. – 20. 'PLUSMINUS' - the conductive textile strap for the lighting installation (left) and the final prototype, detail (right). © Daniela Trost/Vibia.

4 RESEARCH WITHIN THE CONTEXT OF OPEN INNOVATION

The concrete examples of textile product developments explained up to this point should be rounded off here by a closer look at our understanding of the concept of Open Innovation, as it represents an important strategic pillar for the innovation culture at TPL.

Yet before we discuss the term ‘Open Innovation‘ more in detail, we would like to briefly address the organisational model Fab Lab, which we have firmly integrated into our project based on the expertise of Fab Lab Berlin. This was a conscious R&D measure, not a secondary decision. We understand Fab Labs not only as places where means of production with digital interfaces can be made available to various actors at low cost but also as places where interdisciplinary networks can be formed that are based around the topic of 'physical products'. One group of actors relevant to TPL from these networks are independent product designers who are, so to speak, 'hardware generalists' and practice agile hardware product development. In addition, there are ‘tech all-rounders' who often not only master various programming languages, but also work on physical interfaces (Internet of Things / Connected Hardware). But whether these two potentials can be put at the service of professional, interdisciplinary textile research and development depends on whether the Open Innovation mode is successfully implemented. If not, these resources of Fab Labs remain untapped potentials.

Let us now explain how we understand the dazzling term ’Open Innovation’. It quickly arouses vague associations and invites one to understand it in terms of an open-minded attitude in relation to research and development. This is both its strength and its weakness: it can be connected to many 'innovation practitioners’, but is also frequently used in an inflationary manner. It is rarely used in the sense of its author. Henry Chesborough [6] understood Open Innovation to mean

> the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology [6].

On the basis of this definition, we identified three aspects, which are being considered when practicing textile-related R&D within the context of TPL:

1. On the one hand, this implies that the actors of Open Innovation take into account the R&D contributions of external actors quite largely and concretely. On the other hand, this understanding implies that the actors open up to third parties to a considerable extent, i.e. grant access to their own R&D. Hence, it should be noted that a narrow concept of Open Innovation requires an extensive exchange of R&D knowledge between several actors. One of the basic ideas of the TPL is that it provides an analogue and virtual framework in which different groups of actors interact with respect to textile research on an unprecedented scale. It should be easier for the different users of the lab - students, self-employed, researchers or SMEs - to develop products together, since the collaboration is accompanied by the TPL team. This reduces the costs associated with identifying suitable partners, handling prototypes and managing IP. From this perspective, TPL is an intermediary structure designed to facilitate Open Innovation.

2. A further aspect which shapes the understanding of the concept of Open Innovation in the TPL project is the question of the field of action or the industries of the actors.

Depending on the type of products, processes and services that are to be improved by Open Innovation, it functions better or worse. This is because certain topics can be shared more easily than others and because different cultures predominate in dealing with third parties and in opening up knowledge, depending on the sector. Therefore, it should be noted that the implementation of the Open Innovation principle is much easier in some contexts and appears impossible in others. In order to facilitate this principle within the context of TPL, we are in a process of developing the Project Management Software (as discussed in 3.1.3) that allows for easily sharing highly specific information about textile-related prototypes and processes.

3. A third aspect should be considered to complete the success factors of Open Innovation: Precisely because this approach places such high demands on the openness of those involved, favourable framework conditions are of importance. This refers to conditions that make it easier for Open Innovation partners to give the other partners involved insights into their R&D. One such measure, which is demonstrably used very frequently, is the establishment of so-called 'Open Innovation Labs'. It is based on the conviction that certain spatial conditions facilitate the exchange of knowledge because they provide ‚neutral' ground on which the participants can meet ‚halfway', so to speak. It should therefore be noted that intermediary structures can facilitate Open Innovation if the Open Innovation partners actually get involved with them, i.e. invest substantial time and other resources. At TPL we take this into account by pointing out to interested SMEs at an early stage that earnings from work within the TPL structure will not be generated overnight, but in the medium to long term and in various forms.

5 CONCLUSIONS

Functional and technical textiles are increasingly relevant in almost all areas of life such as medicine, sports, clothing and architecture. Within this context, on the rapidly growing markets related to these fields, design is becoming one of the most important drivers of sustainable economic success and product innovation. This is because the widely globalised textile production market, which provides access to specialised (technological) production opportunities alone rarely can provide an advantage over its competitors. Instead, intelligent and superior design qualities in combination with highly specialised technological facilities and the related know-how often make the final difference and determines the success of the product.

As discussed in this paper and illustrated through practical examples, the physical and virtual platform of TPL represents the attempt to minimise and overcome the gaps as well as shorten the time between product ideation, design-driven research and industrial production related to textiles and soft technologies. TPL as a platform for and network of relevant interdisciplinary partners makes use of the opportunity to initiate early-stage strategic collaborations between different groups of actors, and makes the design competencies accessible to established stakeholders such as SMEs and the industry. In particularly the inclusion of the young and independent designers and developers into this network is

being stimulated with an aim to boost the innovative potential of the German textile industry. This undertaking has to be seen within the current context, where especially within the German textile industry, design still tends to play a minor role in an early-stage product development. The TPL concept counteracts this situation by offering the industry a more individualised prototype and product development possibilities through strategic involvement of designers, product developers and technical experts to deliver an effective 'on-demand' and shortened time-to-market service through design-supported, industry-oriented prototyping.

The paper also illustrates that the practical implementation of Interdisciplinarity, Design Thinking, Resource Sharing and Open Innovation as strategies in a network such as TPL, can serve as a future-oriented way of creating a new culture for collaborations to revive the traditional industry with more innovative products and processes. Such strategic open collaborations, consisting of both established stakeholders from the industry and research as well as young independent design talents, function beneficially both ways and contribute positively to the reshaping of the future of the textile industry in Germany.

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