FabMaterials: A journey towards a tangible exploration of materials in prototyping

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Abstract

Materials are essential part of making. They enable designers, artisans, architects, sculptors, and engineers to prototype their ideas. Materials impact not only on the visual but also on functional aspects of a design. The process of selection and manufacturing is part of the design process which is not always considered explicitly enough. Rather then just using materials, the exploration of materials as fundamental part of the design process can create new value to the outcome. It enables the us to take different positions of working on a conceiving idea, changing and potentializing novel applications in the Fab Labs.

FabMaterials is a tangible archive of applied digital and manual manufacturing processes; made primarily at FabLab Kamp-Lintfort. This analog library, accompanied by a digital resource, explores the impact of materials, their application, their modification and process of creation (the journey). This study has the objective of encouraging and stimulating fab lab users to discover the possibilities of exploring and promoting the incorporation of prototyping focused on materials research. With this experimental-driven approach, we are looking into new frontiers of prototyping in Fab Labs.

Keywords

Material Prototyping, Archiving, Tangible Journey, Learning by Doing, Digital Fabrication

1 Introduction

A Fab Lab is not only a technical prototyping workshop, but also a place to share knowledge in a network connected to a global community of learners, educators, technologists, researchers, makers, and innovators (Fab Foundation, 2018). Users of the Fab Lab are of all ages, disciplines, and interests. A Fab Lab connects these people through a common space for sharing, exploration and testing - known as making. Machines, tools, consumables and expert advice are provided help this community to turn ideas into realities.

The creativity that arises out of the community has been the success of Fab Labs the world over. Relatively non-expert individuals are able, often in quite a short period of time, to learn the design tools (digital and non-digital) and master the basic skills required to produce sometimes very sophisticated solutions to technical challenges. The more dedicated maker might take a longer course such as the FabAcademy (Fab Academy, 2018) and be exposed to a wider range of skills and techniques which can then be incorporated into further designs.

These processes of making are very much grounded in the selection, adaptation, modification, tuning, and general integration of materials into the imagined design solution. The creativity of the solution is both enabled and limited by the maker's knowledge of the materials which are available to realise the dream. Materials are typically selected from a limited range, with success begetting success and further limiting the pool of materials as the maker builds on and incorporates solutions that worked in previous design

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iterations. This is not to say that the materials are necessarily simple or classic: a rut can be dug just as easily with 3D-printed PLA as it can with plywood or steel.

To avoid the potential well, or local minimum, problem, the maker's design process has to be informed by a wide-ranging knowledge of and experience with the materials available. Now new geometries and processing techniques are opened up and creativity can once again take pride of place in the maker's solution toolbox. But how is the maker to find this knowledge? Where is it stored? Books, webpages and computer databases are available if the keywords are known, and if they are not, then the local technical staff usually have the keys to the vault. Often it is a classic rummage through the junk drawer that provides the sought-for inspiration. These are all examples of materials databases which offer a multidimensional organisation of knowledge and information. They differ in the accessibility of their user interfaces.

Where existing book- and computer-based tools focus on keywords and a pre-structured user interface to the database, often dictated by the organisation of the database itself, FabMaterials aims to mirror the maker approach by encouraging creative, organic, messy, human sensory exploration of the knowledgebase. Instead of structured keywords, the tool here is the journey. In keeping with the documentation-driven philosophy of the Fab Lab community, our user interface is a physical library of case studies (journeys) that explore a multidimensional database of design and implementation success and failure. Each of the tiles in the user interface (Figure 1) includes a physical representation of the journey of a Fab Lab project and a link to the documentation which was prepared along the way. The new maker explores the journeys of predecessors (walks on the shoulders of giants!) with the recollection of the physical results and learns to share this information as part of the process.

Figure 1. FabMaterials: A tangible archive showcasing the outcomes of various design journeys at FabLab Kamp-Lintfort.

FabMaterials is intended both for local and global use. The physical elements of our user interface are necessarily local, accessible to visitors, students, practitioners, or future generations in the lab itself, but the journeys are also all documented electronically so that they can be shared either in electronic form or made by members of a remote Fab Lab to facilitate their local user journeys. The objective is to diffuse our experience out the world and that of other labs back into ours.

The FabMaterials interface and database also provide an excellent opportunity to investigate the effectiveness of the hands-on, journey-based approach to materials selection, innovative design and technical implications in prototyping. We have the possibility in the Fab Labs to explore in systematic research the process of prototyping and propose new applications through a material perspective. We hope that this approach will be extended to the communities of the Fab Labs and that we will have more participative experiences in which the exploration of the materials will be essential for the impact on the community from a creative, educational, cultural, environmental and social perspective.

This paper shows the range a of aspects in which the awareness of materials for prototyping in a Fab Lab environment is playing a significant role. Following questions will be addressed by this research:

- What relevance do materials have in the processes carried out in Fab Labs?
- How can we represent the complexity of the materials available and at the same time generate a fundamental understanding of the use and adaptation of the materials in digital manufacturing laboratories?

- How can a physical documentation of materials be integrated into the prototyping process? And how can we best share this knowledge with the Fab Lab community?
- How can new manufacturing techniques be generated through the introduction of new materials and thus define new manufacturing frontiers?

2 Foundation: The evolution of the materials library

Materials have arguably always been a fundamental part of the teaching of creativity, but it was during the Bauhaus movement (Figure. 2) that this integration was first formalised through the use of matter as a source of inspiration for developing design skills (Bauhaus100, 2018). Today, experimental material research is seen as an essential element of contemporary curricula in design studies (Pedgley et al., 2016). The development of methods based on the use of materials and do it yourself (DIY) materials promotes the participation of users in learning processes and understanding through the contribution of material considerations in the early stages of the design process (Giaccardi & Candy, 2009; Nimkulrat, 2012; Ingold, 2013; Ayala-Garcia et al., 2017) Also, these methods encourage the user to explore the limits of prototyping by exploring the transformation of materials through the processes of manufacturing and introduction of local and handcrafted materials (Manzini, 1989; Beukers & Hinte,2005; Peters, 2011; Peters, 2014)

The importance of incorporating real materials into the learning environment is ever more important as creativity moves to embrace the opportunities and freedoms offered by modern computerised design tools which, if they include material properties at all, do so only in simulation whose physics may or may not be particularly realistic. The rapid development of 3-D printing and the other tools available in facilities like the Fab Lab serves as a means of grounding this creativity in reality, as the designer can very quickly explore the limits of what is structurally and materially possible.

In Human-Computer Interaction the exploration of tangible interaction through prototyping is an excellent resource that creates interactive artefacts (Hamdan et. al, 2018; Yang, 2018) that merge physical and digital materials. Although there are few specific studies of material-centered interaction research, there are many authors who promote the use of material exploration practices (Zimmerman et al., 2007; Ozenc et al., 2010; Dove et al., 2017), giving the value of creating systematic research in the making process, which can benefit the development of prototypes, discovering new material properties and making a correct application of them (Wiberg et al. 2013; Odom & Duel, 2018).

Today, the exploration of digital and physical characteristics in the manipulation of materials such as programmable or self-assembling materials (Tibbits 2016, 2017; Mediated Matter, 2018), which do not exist in nature, allows a new approach in the creation of prototypes, exporting the frontiers between craftsmanship and digital personalization. Currently, these behaviors associated with more biological and intelligent processes are being explored in research laboratories by adding computational properties of the shape of the material and the construction for better performance of future products (adidas-FUTURECRAFT, 2018).

Virtual applications and open source platforms for the documentation and introduction of materials manufacturing needs have been launched in the last few years (Mota & Boyle ,2009; Raspanti, 2018; FabTextiles, 2013; Kretzer, 2017).

The Institute of Making's physical library uses hands-on exploration to encourage makers to think about new materials. The physical exhibition is complemented by an online version which reaches beyond the walls of the Institute. Materials in the IoM library are organised in a classical database keyword driven category (eg. animal, vegetable, mineral, composite), states (solid, liquid, gas), and descriptors (eg. magnetic, optical, fluorescent, odorific, recycled, edible). (Institute of Making - Materials, 2010). The IoM library uses a hybrid physical-virtual interface, but it does not lead the user on journeys of exploration into the use of materials in design.

Materiability is an online library of materials, tools and techniques which is again organised by descriptions and physical properties. It goes one step further and describes the uses of each material, i.e. what is it good for and what it is not, tricks and hacks, where to get it, who is using it, who is improving it. In addition,

it documents experiments, sharing tutorials (Kretzer, 2017), thereby documenting previous users' journeys into materials and design. Because the library is purely virtual however, its representations are limited to an audio-visual experience, and no physical interaction with the material is possible.

The Open Source Material Archive focuses on DIY sustainable materials from the laboratories of the Waag Society. The main scope of this library is to create a common environment in which multiple communities & researchers can share, interact, upload, search and download recipes of DIY materials coming from TextileLabs, FabLabs, BioLabs and creative research labs, mapping both Raw materials and Made materials (Raspanti, 2018). This archive was created to list DIY materials, mainly bio-materials; it doesn't address the use of the materials in design. .

Recognising the need for integration of materials and their processing, the Material Experience Lab (2018) has introduced a unique way of understanding and designing (with) materials by combining research methods, techniques, and tools from product design, social sciences, materials science, and engineering, which they call the "method materials experience" (Karana et. al., 2017). Their integrated approach opens opportunities for creativity in which not is included a library.

3 Synthesis of FabMaterials

The FabMaterials database is a collection of individual journeys into the maker world. The concept is of both an inventory and an archive: An inventory of the materials available in the Fab Lab to stimulate creativity through physical representation, and an archive of journeys taken by previous makers in the lab to demonstrate the process of creativity using these materials.

3.1 A journey through iterative prototyping

The link between creativity and biology is fascinating, when taxonomic classification is used to understand the variety of results, so we have been inspired by this relationship to visualize and understand this organic character of the practices performed in the FabLab as shown in Figure 2.a. and 2.b in the first shows the journey through the dyeing of fibres, (Figure 3) highlighting the different results of the samples while showing the variation by applying different procedures. it shows the progress of the prototype and how the first experiments are part of the design considerations, quickly visualizing the changes of the prototype and what ideas can be used again. This organic character is something that is going to be reflected in the library that is going to be introduced in the following chapters.

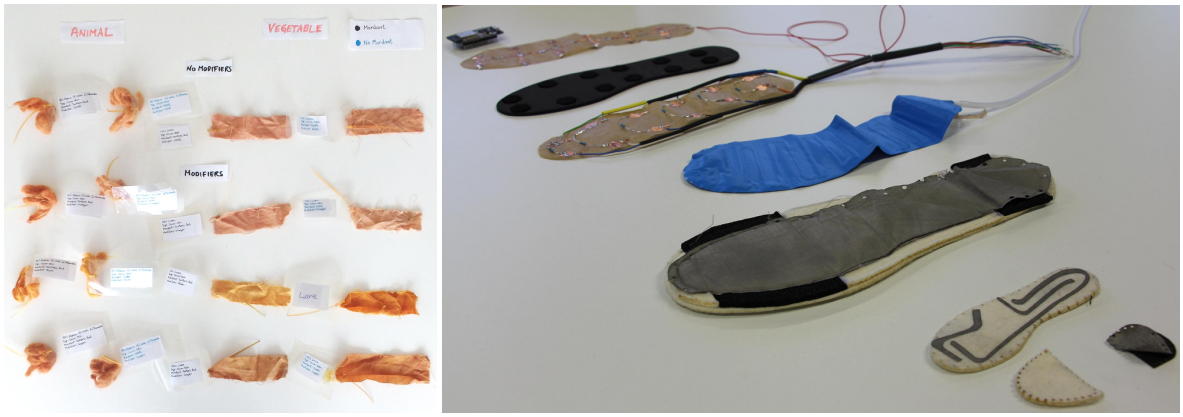

Figure 2.a. taxonomic classification of the natural dyeing fibers, showing the different shade changes by using different materials (Cheung, 2018). Figure 2.b. Prototypes through the development final project one step forward showing the range of materials and explorations to achieve her expected prototype (Akhibi, 2018

3.2 The Tiles: elements of a tangible interface

The FabMaterials interface consists of a collection of tiles, each displaying a representative material object (a "masterpiece") and links to the documentation of the "journey" that led to the creation of the object. The effect is akin to a self-guided tour through an art gallery - the masterpieces speak for themselves and

draw the visitor into the creativity, and the guidebook provides the visitor with the background on the journey taken by the artist to achieve the result.

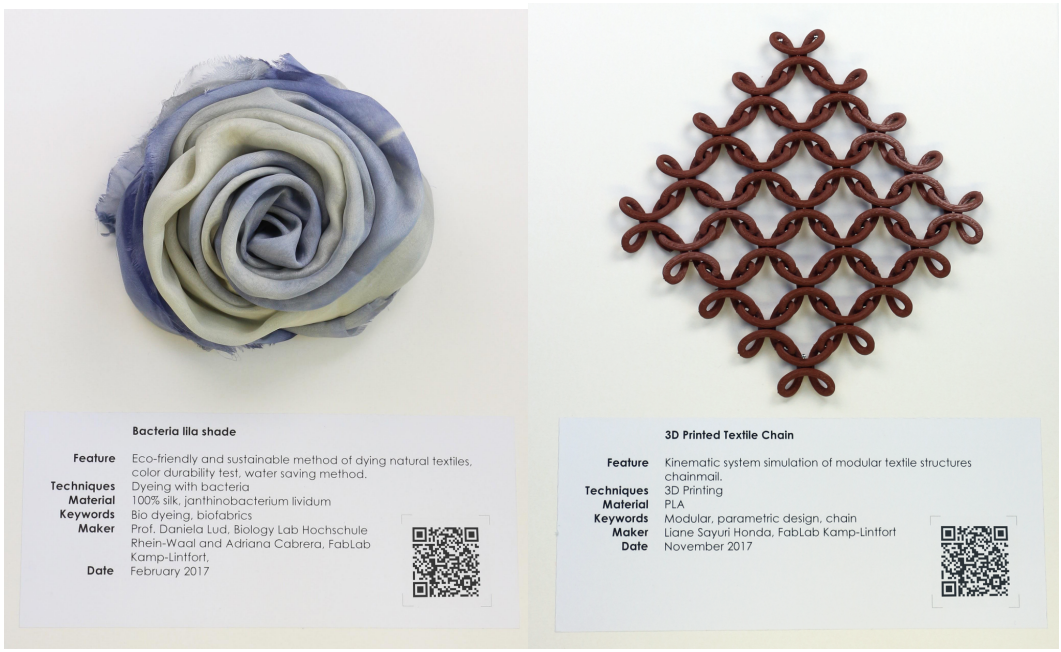

Figure 3. Some example FabMaterials tiles. Each tile in the interface presents a physical masterpiece, a quick textual summary, and a QR link to the detailed documentation of the journey that led to the masterpiece.

3.2.1 Elements of a Tile: The Masterpiece

Every journey has a destination. In FabMaterials, this is manifested in a "masterpiece" - a physical object which is the result of a unique combination of design, materials and manufacturing techniques which were learned through a process of iterative prototyping. The process is not a haphazard one - the goal represented by the masterpiece is always in mind - but it can often meander through many iterations. The careful documentation of these iterative explorations is the richness of the knowledge base that grows out of a Fab Lab.

Masterpieces were selected to provide a broad representation of the materials and techniques used in the Fab Lab. Collection for the FabMaterials library began in 2015, the year our facility was opened, and continues today. Some of the masterpieces were produced during testing of the machines with various raw materials, including products of suppliers of the region, as well as DIY materials. Others were made during lab sessions as part of our degree programs or during Academies of the Fab Foundation. Some further masterpieces were created outside of our Fab Lab, i.e. in other laboratories of the Rhine-Waal University of Applied Sciences (laboratory of traditional printing techniques and the microbiology Lab) or at the Textile Lab in Amsterdam, and at Fab Lab Bottrop.

3.2.2 Elements of a Tile: The textual caption

If a picture is worth a thousand words, then an object is worth many more, but neither is worth any without the pump-priming effect of the caption. The FabMaterials caption serves as the first interface to the journey that led to the masterpiece. The physical object makes the sensory connection to the user's creativity, and the caption then when the user's appetite to learn more about the journey. The choice of concepts and words to include in this short abstract was therefore given careful consideration.

- ***Feature:*** It refers to the constant functionality of the material and the purpose for which it was created. This also includes in the functional purposes and for which it has been designed including senso-aesthetic connotations of shape and construction in other libraries mentioned under properties (Kretzer 2017) or curiosities (institute of making, 2010).
- ***Techniques:*** refers to the manufacturing processes that have been used to produce the prototype or to reach its result. It also includes the digital processes in case of computational design as well as the tools that determine the manufacturing process.

- ***Materials:*** refers to the raw material used for this prototype. Especially for DYI materials additional information about the composition coefficient is needed. This section hopes to be extended in the digital version, About the procedure to use included in the documentation (Figure 5.) it and some material handling requirements such as temperature, elasticity, solidification time, among others are taken into account in its virtual documentation.
- ***Keywords:*** are used to characterize the process, material, techniques being used. These words shall encourage reflexion and discussion - but, of course, should also help to find appropriate solutions for similar challenges.
- Other characteristics or concepts that are related to its behavior or particularities of the model, which can serve later as tags to filter on the digital platform.
- ***Maker:*** refers to the author and laboratory or institution where it was created, respecting the authenticity and copyrights of the author.
- *The date:* is used to monitor the record of the materials and their processing.
- ***QR code:*** this is the link to the digital record of the journey. The user standing before the tile can immediately pull up the additional information and begin his or her own journey into the database behind the user interface.

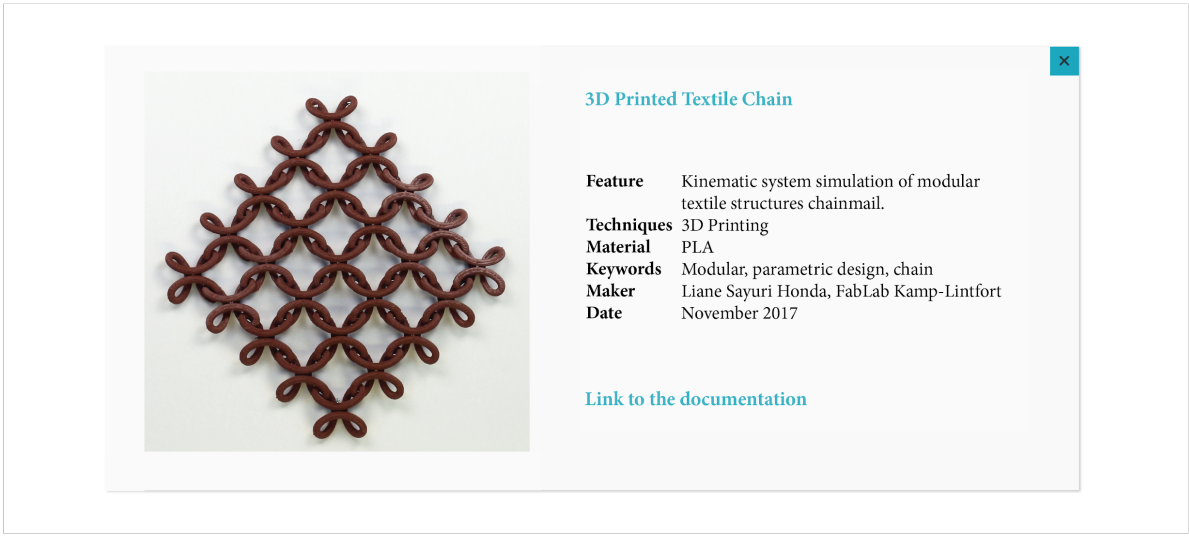

Figure 4. Virtual Tile. The online version of a FabMaterials tile. The same information is presented as on the real tile, along with a link to the rest of the documentation and is provided so that other Fab Labs and the community at large can access the information, albeit in a less tangible format (FabMaterials, 2018).

3.2.3 Elements of a Tile: The Journey

The tile is the both the end and the beginning of a journey of design. The end of the journey for the past project that generated the masterpiece, and the beginning of the new user's journey into a multidimensional database of materials and processes. The tile links to online documentation that takes the user through the steps of the journey, with all of its fits and starts, its dead-ends and workarounds, and through the materials selections, design decisions, and iterative prototypes that were created on the way to the masterpiece. Successes, failures, and lessons learned are described in detail, in the now established style of the FabAcademy.

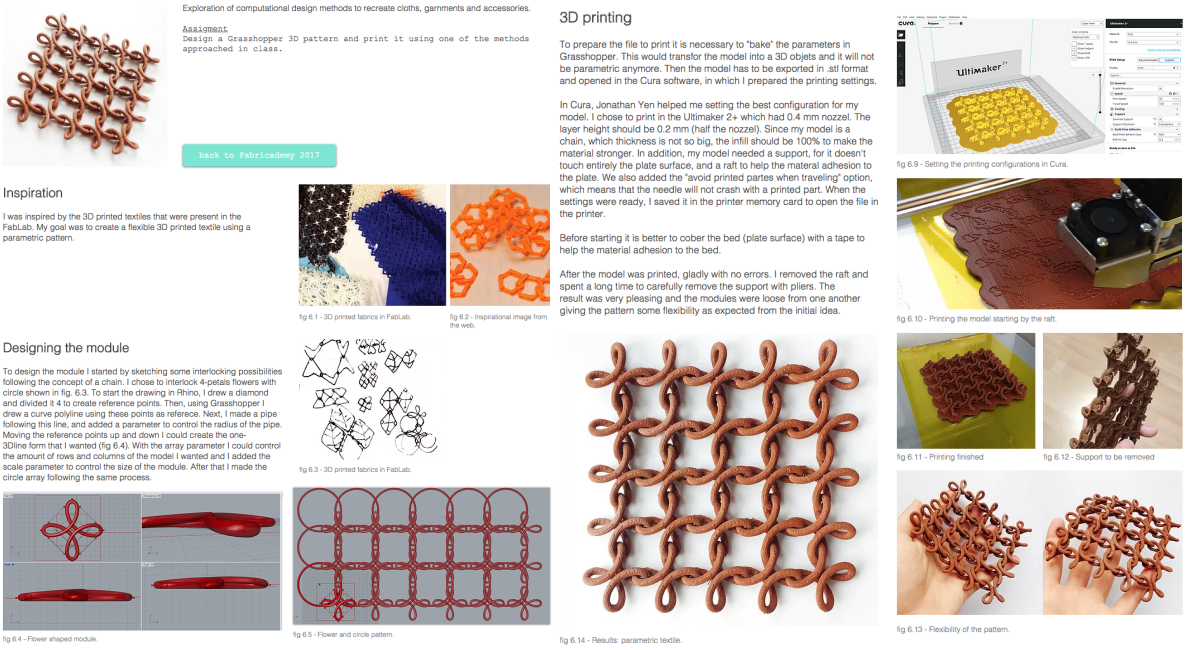

Figure 5. The virtual documentation of the FabMaterials design journey (Honda, 2018). This is a complete web-based description of the iterative design process undertaken to generate the masterpiece which is presented. This virtual tile is also available directly via a virtual version of the FabMaterials user interface, to enable remote access to the database.

3.3 The Matrix: organisation of a tangible interface

It is in the matrix (Figure 1) that FabMaterials really comes alive. Tiles are arranged in an aesthetically pleasant grid pattern, hung from rails placed before a simple off-white coloured wall. The use of simple white as a background colour is deliberate, to focus attention onto the masterpieces and the materials that make them up. Tiles in the grid are also deliberately not fixed, nor arranged in any extrinsically structured way. Users are free to move them around, and a rotation of tiles occurs as new journeys reach completion.

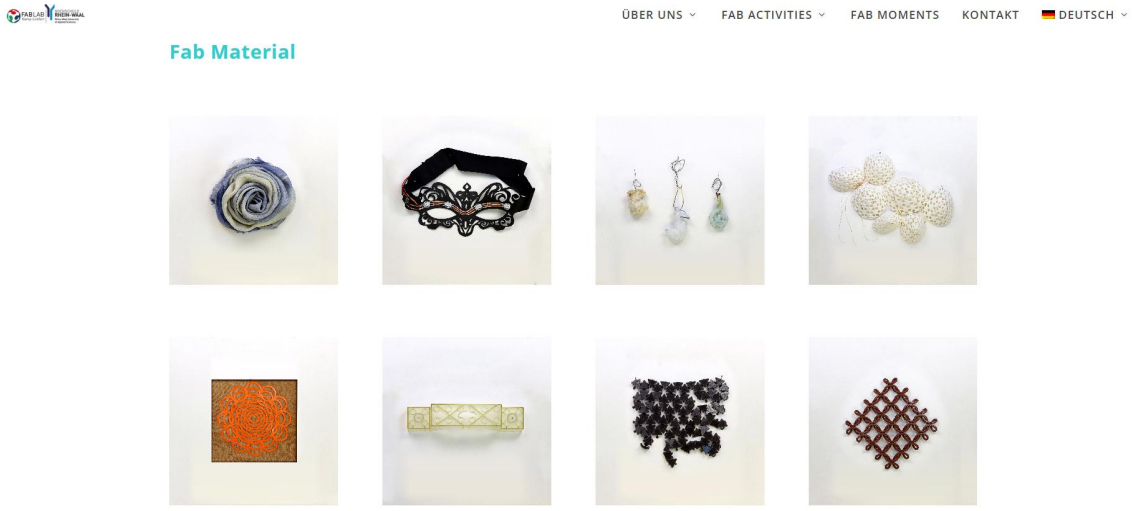

Figure 6. the digitized version of the Tiles. To minimise clutter-driven distraction on the small screen, the individual tiles are simplified to simple photographs of the masterpieces. The captions can be displayed by hover-over, and clicking on the photos leads as before with the QR codes to the online journey descriptions (FabMaterials, 2018) .

The creative power of the FabMaterials matrix comes from the unstructured juxtaposition of the masterpieces, each demonstrating its own journey through materials and design. The first impression gives the user a feel for the variety and specification of physical properties of the materials and the

manufacturing processes in the Fab Lab. In a longer study, as the user begins to follow the QR codes into the documentation of the database, interrelationships between the various journeys begin to form in the user's mind at many different stages of the iterative process. It is these unexpected interrelationships which, like the synapses in a mind, provide the basis for creativity.

In order to reach the larger community outside our Fab Lab, we created a virtual version of the FabMaterials interface as well. The masterpieces are again presented on simple white tiles in a matrix arrangement, but in this version, the tiles are simplified to simple photographs (Figure 4); the text caption can be provided in a hover-over mode, and a click on the picture serves the same role as the QR code in the physical interface. Retained is the unstructured juxtaposition. Lost is the tangible appreciation for the materials.

4 A Taxonomy of FabMaterials

FabMaterials is a set of powerful tools. It is a juxtaposition-driven creativity generator for the Fab Lab user. For the student, it is a physical, tactile, tangible tool for learning about materials and the related manufacturing processes. For the design researcher, it is a novel research tool which allows for a systematic analysis of the features of, and techniques used to make, Fab Lab inventions in the context of the properties of materials.

4.1 Summary of the information collected

In our analysis of the masterpieces, we could identify more than 30 functional and aesthetic features (Figure 7). The most common features observed Bio based Products and an Eco-friendly Purpose - point to the awareness of Fab Lab inventors of the environmental impact of their creations. The prevalence of the Programmable feature highlights the importance of interactive objects. The large proportion of the Kinematics, Assistive Device and Wearable features is indicative of the orthotics/prosthetics theme prevalent in our Fab Lab. Biomimetic themes are reflected in the prevalence of features such as Self-Assembly and Lightweight.

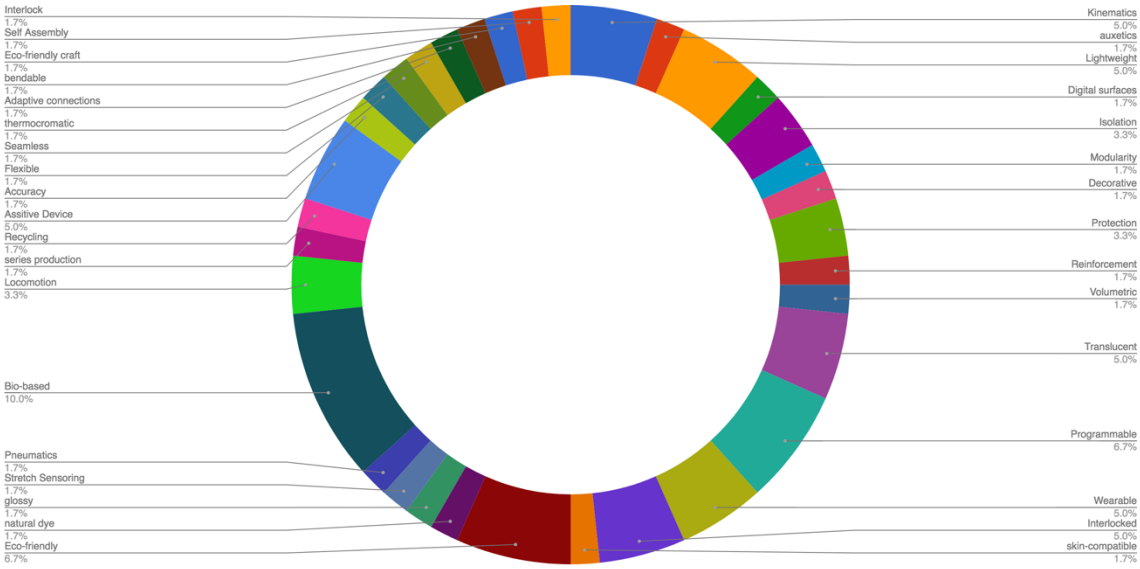

Figure 7. The relative prevalence of the main features found in the masterpieces produced in the Fab Lab Kamp-Lintfort since 2015.

Among all the techniques presented 3D Printing is the most frequently applied, this is not only related to the fact that the final models are 3D printed, but this technology is a tool to help in the creation and complementary of other processes such as moulding and casting, and soft robotics.

The process like the creation of biomaterials and composites is a process with a great exploration, and allow the participation of participants of different levels, that the manual work and the intervention of the maker influence the result. Other techniques recently experimented in the Fab Lab are the introduction of flexible electronics for the prototype of an embodiment interaction, in fields of research such as HCI

and disciplines related to the analysis and interaction of the human, displays a high interest of the participants and practitioners of the Fab Lab. Interestingly and perhaps not unexpectedly, traditional techniques such as cutting, milling, and moulding are substantially less commonly observed than the newer techniques (Figure 8).

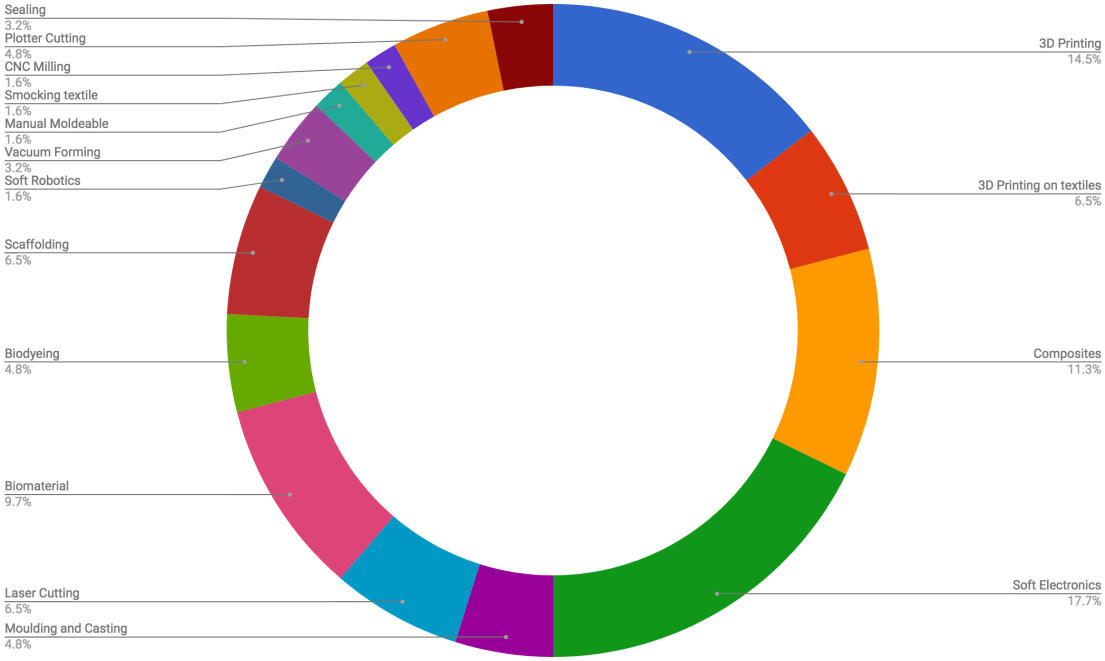

Figure 8. The relative prevalence of the main techniques used to make the masterpieces in the Fab Lab Kamp-Lintfort since 2015.

The relative prevalence of the features and techniques used are a reflection of the specialisation of the Fab Lab world in general and our lab specifically. It comes as no surprise that features and techniques related to biomechanics, assistive systems and biomimetics should be obvious in a Fab Lab that hosted an Fabricademy and personal Fabrication for care[15] focussed on such systems. The value of this tool to ours and other labs is to show those specialisations, either as something to be desired, or to highlight that a lab is getting too specialised and losing the ability to train makers across the spectrum of materials and processes.

4.2 About material relations

Until now it has been possible to analyze that these masterpieces have relationships either by the technique, by the digital origin, by the type of raw material, the most exciting thing is that no matter how similar they are, the magic of the small differences can be found, so we can establish comparisons and relationships as we will present in the following example.

In the sample of figure 9, is a digital construction of a 3D fabric built in Grasshopper and rhinoceros Fig. 8. and that can be digitally varied, from this construction the masterpiece was printed to integrate a process of textile simulation and kinematics of flexible modular parts with high precision.

[15] Fabricademy and Personal fabrication for care, is a variation inside of the of the Textile academy (Fabricademy, 2018). It was an interdisciplinary course at Rhine-Waal university of applied Sciences that focuses on the development of new technologies and sustainable impact applied in the textile, soft materials and assistive devices industry, the project aims to support the professional career of female students in disciplines which involve digital fabrication, contributing to gender equality and participatory research in academics. Fabricademy is an advanced training established by The Academany and Fab foundation with the philosophy of the MIT class format, which is a new global educational structure offering high-level education all over the globe

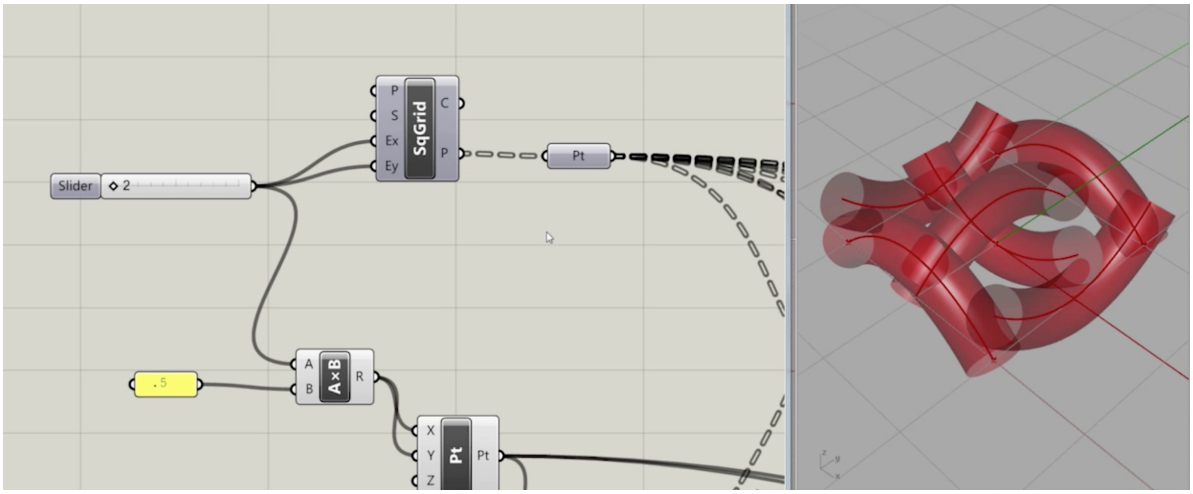

Figure 9. construction of a parametric weaving pattern, digital representation of the model.

The masterpiece simulated the flexibility of 3D textile printing, so this digital fabric file was used and printed on a 3D Systems printer to achieve accuracy and to observe the behavior of the 3D material and construction.

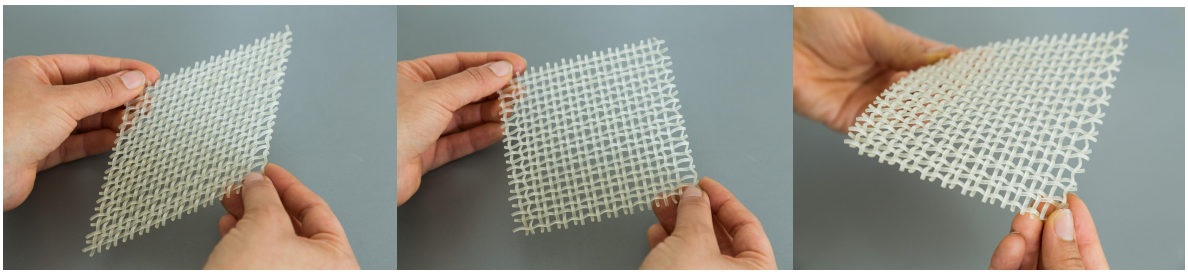

Figure 10. 3D printed model of representation of the constraints and possibilities in between the technic and the model as Masterpiece of flexible structures. material: HD laser 3D Printing Visijet M3 Crystal resin.

With the same aim in mind, we wanted to include the processes of a second sample in which the digital file was manipulated to generate a 3D weaving,

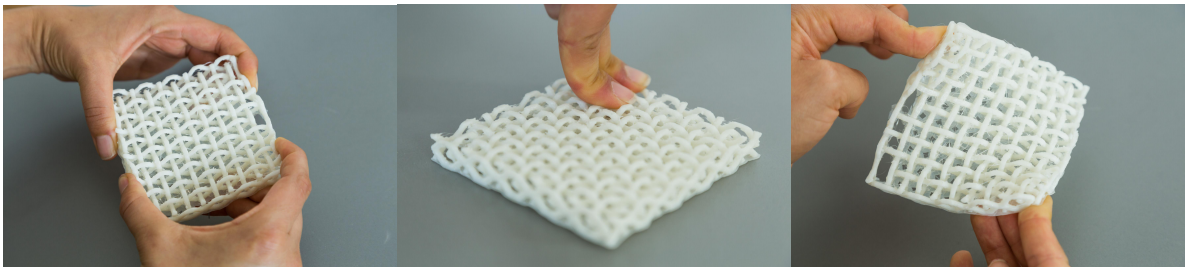

Figure 11. 3D printed pattern modified in grasshopper Fig. 8, to generate a 3D weaving making two interconnected layers of weaving, material: Flexible PLA FDM printing

On the one hand, the sample lost its initial kinematics of forces applied bi-directionally. After printing this prototype with a flexible material and with a deposition implication technique, this sample acquired rigidity and at the same time lightness, considering this process to be optimal for applications of insolation and applications that will be highly exposed to impact to the impact.

4.3 Relations between users

This information helped to localize and identify concepts and also to generalize the language and reading of the samples for all types of users, so that if a user or viewer of the Fab Lab at least with it is not able to understand the first idea because they made the samples and their characteristics. On the other hand, the user who is learning to use the techniques of digital manufacturing can also see to use this information and thus become familiar with how this prototype was made. For a third user who needs to resolve similar concerns, he will probably appreciate and use the information taken from the sample and identify the

elements of the sample. They can also find the information in the online version, finding links that it connects to more extensive documentation, which techniques and how he should use these techniques for proper implementation of the material and machines.

We could find four situations in which Fab Materials could engage users in the process of making. These facts are of crucial interest in demonstrating the potential of analog samples.

- The samples made to show what can be achieved with the machine and its potentials.
- Samples that are needed to describe how to develop the assignments with the participants of workshops of courses,
- Developed Samples in the prototype process that good or failed these samples are considered as an essential tangible part in the process.
- Samples that considered the variation of digital or physical materials, process variations, their correlations, and results.
- Finally, the fact of having samples as inspiring new ideas for future users.

5 Discussion and concluding remarks

In this paper, we study methods applied to material-oriented prototyping processes. We present our inquiries about the importance of materials in the manufacturing process, and how this approach can help and enable the creation of ideas. We give an emphasis to initial practices in material considerations in Fab Lab, and finally, we explain how this material prototyping process can be crystallized in the creation of an analog library as well as in its digital version.

We argued that materials are tangible sources that provide an intuitive overview, and reflections about the implementation of the material and its use. This approach can also lead to new types of applications that are not generally evident in the processes carried out in a Fab Lab. We envisioned a hands-on approach to the use of materials to generate a global interpretation of materials in prototyping and to encourage users to experiment with the variety of materials and processes that are implemented in the laboratory.

We have created an archive of materials which aims to raise awareness towards the introduction of materials into the manufacturing process and how to explore new frontiers of prototyping by exploring the use of materials in different manufacturing process, that reflects the flexibility of the technologies implemented in the lab. We expect to generate innovative process proposing new approach in creating machines or techniques more flexibles and inspired by the right use of materials.

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