From Textiles to Soft Robotics and the Emergent Approaches in Labs and Hands-on Practices

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At the intersection of art, technology, biology and science, the emergent field of Soft Robotics can be a beneficial and engaging topic for designers, artists, and educators, who want to implement transversal and innovative projects. Moreover, it enables inclusive learning about robotics and materials applying digital fabrication and biology, offering an explorative space for makers and professionals. This paper discusses the challenges of actuated materials and Soft Robotics inside the transdisciplinary program Fabricademy[1] and envision informal educational activities in shemakes.eu[2].

Fabricademy explores further the practices of wearable technology and the application of Soft Robotics in a distributed educational format, while shemakes.eu project engages participants from girls in STEAM to women innovators, introducing inclusive practices and digital skills during learning paths. Both aim to bring this complex knowledge into a hands-on approach in the labs, experimenting with different challenges from the concept of Soft Robotics, actuated materials and bio-based composites from a variety of applications. This paper will describe some of the practices and challenges starting with the concept, modelling, manufacturing, that participants and lecturers face during the workshops and lectures. Further, it presents the reflection to the research questions Interaction, interfaces, Fabrication, Inclusion and gender gap, illustrating the different paths that describe future practices from performative arts to healthcare solutions, reflecting a more comprehensive range of implications in sustainability, Industry 4.0 and innovation narratives. The goal of this paper is to highlight how the field of Soft Robotics is connected to the changes in the uses of materials such as soft goods and textiles. Consequently, we want to envision how the field of Soft Robotics and actuated materials can (re)shape the implications and applications of wearable technology in education and (re)define emergent approaches in the textile and clothing industry.

CCS CONCEPTS • User interface toolkits, Hardware, Emerging interfaces, Human-computer interaction (HCI), Haptic devices.

Additional Keywords and Phrases: Programmable Materials, Soft Robotics, Fabrication, Bio-inspired design, wearables, FabLabs, Digital fabrication Design Tools, Tangible Interfaces, Interaction Design, Fluidic, Pneumatic, Shape Change, Computational design, HCI

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1 INTRODUCTION

By definition, Soft Robotics is a broad field that uses the softness of an object, a piece of material or a system for building a robot satisfying a required softness to both its environment and its reception [3]. Soft robotic manufacturing from textiles and materials can be realized as components or as smart materials themselves [4]. Developments in Soft Robotics continue to explore the gap between machines and people [5]. . Soft Robotics is a key research theme in the development of biomimetic robots, which attempt to describe the idea of natural movements and, with examples from nature, to reproduce and simulate them and form shapes that fit living organisms, particularly human beings [6]. Over the last ten years, researchers in the fields of physics and chemistry a.o. have studied and developed soft robots that provide new capabilities relative to traditional, complex robots[7]. Recently, the exploration of robotics has been oriented towards HCI research and developments in other educational contexts outside the classroom, in learning practices between technology and the arts and in particular crafting[8] and biology.

This field has more recently further explored applications in wearables, textiles, and soft materials[9]. These experimentations, which are often carried out in labs, are becoming more and more attractive in connection with different actors involving universities, research institutions, schools, accelerator centers, and promoting cross-disciplinary knowledge as it is generated in FabLabs, where learning by doing takes place[10]. Furthermore, this approach starting from the experimentation of materials in conjunction with digital fabrication technologies allows interaction of different audiences in the concept of Soft Robotics.

in the following framework, we will then take a look at the development of Soft Robotics practices generated around Fabricademy from its inception in 2017 to 2021 and the relationship with the FabLabs ecosystem in activities in different contexts (schools, universities, laboratories), as well as the participation of diverse public and a large female audience.

2 FRAMEWORK

This evaluation began by looking at the Soft Robotics lecture[11] at the Fabricademy advanced postgraduate program, which is held at 45 locations and had a total participation of 116 women and 29 men from 35 different nationalities ranging in age from 17 to 65 years old[12]. We then analyzed the final projects that developed Soft Robotics practices in various applications such as rehabilitation, communication, and performance, which are described in more detail in Table 1.

This paper focuses on the research questions in the frame of the workshop *Actuated Materials and Soft Robotics Strategies for Human-Computer Interaction Design*[10] around the following topics: interaction, interface, manufacturing, tools and resources, inclusion and bridging the gender gap. Especially in the analysis of the Fabricademy final projects that have a development time of two months in which the participants have to work on their own projects. During this time, participants reflect through textile and material manipulation (wearables, sustainability, industry 4.0). Since the analysis was made only in the prototype development, commercialization was excluded.

The second analysis was done through activities and workshops, such as the international conferences of the FabLabs, activities in universities and accelerators, in which the concept of Soft Robotics was introduced and worked from 2 hours to 5-day hands-on workshops, with an audience from a variety of nationalities and ages. More details are in Table 2.

2.1 Soft Robotics in Educational Practices at Fabricademy and Labs

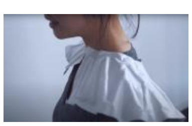
We start by introducing the topic of Soft Robotics with a look at scientific documentation and research approaches towards a second aspect of how to adapt these hands-on practices in different formats.

The aim is to grasp the concept of how the intersection of biology adapts to the "making" in the labs, exploring the principle of softness from soft wearables for inclusive design [13], fashion and art to large scale explorations. Below we will highlight some of the essential topics in the lecture on Soft Robotics by introducing the key challenges.

Bio-inspired Design: Soft Robotics within the field of Biomimetics focuses on taking information from nature, for example, changes and movement in nature, and interpreting it into flexible and conformable shapes that can be reproduced in a range of configurations. Exploration of this comes through making and manufacturing of components and materials. Ideation for bio-inspired design uses natures materials, processes, or structures as sources. Biomimetics explores the embodiment of function over mechanism but often the two are combined in soft robotics. As well as this, biologically informed design has the potential to enable a circular, sustainable and renewable design practice from the beginning of the development process[23].

Link to scientific and industry research: Making the complex understandable and debriefing recent projects while understanding the design, applications and implications of different projects both scientific and industrial and the details of their application and manufacture to guide the development of the prototype e.g. giving details of the design of pneumatics and their circuits, of the application of materials, especially with the techniques developed or available in the laboratory as well as sending the work to future actuator applications of all scales.

Table 1: Final Projects Fabricademy related to Soft Robotics from 2018 to 2021

Final Project Fabricademy SoRo	Interaction	Interfaces	Fabrication	Tools and Resources	Design for Inclusion	Bridging the Gap*[1]
 Adjustable Bra [14]	Exploration of cup fit using inflatables; adaptation on an existing textile product (bra)	Multimodal: Adaptation of the body	Parametric design and 3D scanning; shape adaptation to the user; implementation of sensing and actuation	Good support and documentation of the process; outsourcing the electronics platforms e.g. Flow IO enable a focus on further output	Including the individualization of severe asymmetries in breast volume (Anisomastia)	Raising women's self-esteem, recovering their emotional balance, enhancing their social and sexual relationships; *Welcoming differences*
 Soft Hood Air [15]	Functional and aesthetical exploration of the hood	Multimodal: Safety in mobilization	Pattern making by creating programmable materials and self-assembly	TPU and sealing by using laser cutting in a middleman format.	Personalization and availability in the open-source repository	Hood as a symbol in the society in fashion of work and revolution history. *Empowering*
 Under My Skin [16]	Interactive costume for performance	Multimodal: Device that reacts to anxiety mimicking animal reaction	Self-Assembly and Origami; constraints in 3D Printing molding on large surfaces	Sealing technique (TPU) can enable a quick solution on organic and large-scale surfaces	Reflect the feeling as a human that can mimic animal reaction fear, breed, and protection	Enable communication to invite sharing of feelings and collaboration with the audience**[2]; *Collaborative*

[1] * We address in this column the shemakes values fostering 'bridging the gender gap'.

[2] **Supported by equal opportunities for women in fabrication for care at the Rhine-Waal University of Applied Sciences

Final Project Fabricademy	Interaction	Interfaces	Fabrication	Tools and Resources	Design for Inclusion	Bridging the Gap*[3]
 Serena Vest [17]	A wearable to combat anxiety and induce calmness	Haptic: light pressure, simulating a calmer breathing rhythm	Developing one's own microcontroller board brings a system-wide adaptation, yet miniaturization is needed for wearables	Pattern creation for non-fashion designers and documentation and material alternatives for sensing e.g., Eeontex (off the market)	Design for invisible disabilities such as anxiety disorder and people who find themselves in stressful situations	Featured project by Fabricademy for its technology development within a short time**; *Inspiring*
 Bodymimicry[14]	Artistic expression imitating animals that are capable of voluntary self-transforma-tion	Haptic: non-verbal expression through transformation	Computational couture, air and liquid fluids exploration, electronic design	Moulding and casting using laser cutting, 3D printing challenges	New ways of communicati on	Exploration of art at the intersection of design, science, biology and digital fabrication. *Equal / Inspiring*
 Expansion - Contraction [21]	Spatial exploration: in social awareness	Haptic	Enabling prototyping an installation on a small scale	How to reproduce the prototype on a large scale using a different electronic configuration for the architecture	Collaborative installation	Engaging citizens through an interactive installation; the intervention of a historical setting through Soft Robotics. *Collaborative/ Empowering*
 Knee-d [22]	Fluidic regulation of temperature	Multimodal: chemical changes device that supports healing process in knee injuries	A prototype that can be safe and easy to produce in home kitchens	How to scale up the technology for a portable or refillable device, how to implement lighter weight materials for fluidics	Easily repurposed DIY wearables for muscle and ligament injuries	Exploration at the intersection of chemistry, biomechanics and technology. *Collaborative*

Learning by doing: Involving the hands-on approach to understand what kind of methods and strategies in CAD and CAM can be applied in the development of Soft Robotics, and previously in what we call: *Soft prototyping* [30] [31], which refers to the making, hacking, and fabrication of projects that demand flexibility, allowing for an innovative form of communication and interaction. Digital manufacturing has been pushing the boundaries of how we manufacture, working on a small scale but with a high level of complexity. This development includes not only the use of machines but also an in-depth study of materials such as paper, textiles, biomaterials, electronics, and their applications, which can be explored in the FabLab.

Material driven design: As mentioned above, material experimentation has a significant role in applying textiles and soft materials, particularly by using biological strategies to generate intelligent materials or bio-composites. Fabrics and materials with a history and identity apart from their appearance and functionality also reflect circular design principles[32].

[3] * We address in this column the shemakes values fostering the bridging the gender gap

Table 2: Workshops and activities in conferences, universities and accelerators

Workshop	Interaction	Interface	Purpose/ Opportunity	Inclusion and Bridging the Gap
Workshop Fab14 [24]	Hands-on modelling	No electronics	Initial exploration of 2D materials and vinyl	
Workshop Fab15 [25]	Focus on modelling and casting	No electronics	Exploration of silicons and electronics	
Workshop from Soft Robotics to Biobotics [26]	Focus on bio-based materials	No electronics	Hybrid facilitation at home making Soft Robotics with bio-based materials	
Wust week Interactive/Media/Design - The Hague [27]	Exploration in big scale inflatables for collective human interactions	Multimodal	Haptic interaction and interfaces, setup for big-scale inflatables, IoT input	Inclusive and welcoming differences, all workshops enable the equal understanding of the concept regardless of the level of knowledge, including designers, engineers and amateurs, empowering further exploration and inviting people to explore the concept in advanced programs e.g. Fabricademy
Workshop FabLab accelerator space [28]	Fashionable Soft Robotics from their conception to the electronics	Multimodal	Explanation of 2 techniques and paper electronics for Soft Robotics.	
Workshop FabLab Techworks [29]	4D interaction with textiles and Soft Robotics	Multimodal	Exploration of a chain, exploring movement in 3D printing on textiles, bio-based materials and Soft Robotics fabrication	

Wearables in bridging the gender gap: Given the increased explorations of wearables in makerspaces and especially the use of open-source, Soft Robotics enables a space where there can be different responses to wearables that converge in practices that facilitate constructive learning, allowing a safe space for experimentation. It is the authors opinion that actuated and/or stimulus responsive materials such as those used in Soft Robotics worn on the human body provides an immediate, individual and immersive experience with technology which could offer new insight into Science and Engineering principles. Furthermore, the importance of combining the skills of textile craftsmanship, such as sewing, embroidery, knitting and weaving, with embedded electronics provides an inclusive understanding to other fields such as engineering and computer science. In recent years, women's participation in STEAM (Science, Technology, Engineering, Arts and Mathematics), biotechnology and textiles have increased thanks to a more diverse offer with programmes such as Fabricademy, Poderosas[33], Fabrication for Care[34]. They have promoted diversity and the engagement of women interested in the creative areas of design and fashion and the implementation of new digital fabrication technologies[12].

3 FINDINGS

Table 1. analyses ten projects in chronological order from 2018 to 2021 with different types of interactions and applications between design for disabilities, anxiety, protection, artistic expressions and performance in communication with the audience. There was a visible trend of migration from electronic version to chemical stimulation, demonstrating that the fabrication of Soft Robotics empathises with awareness and care for the environment, the city and the human being. Furthermore, a predominance in the development of haptic and visual modal interfaces was observed.

In chronological development: the first workshop presented the basic techniques of fabricating inflatables using vinyl. The second introduced the casting and silicone fluidics. The last one opens the thematic from Soft Robotics to biobotics in hybrid forms.

The workshops in university classrooms explored interactions in new territories for HCI students, while interactive media art students explored big spaces inflatables in collective reflections of media through interactive art. Finally, in the accelerator labs, the first workshop took up the application of fashionable robotics and the intersection of 4Dmatter introducing textiles and 3D printing in the world of Soft Robotics.

4 Discussion and Conclusion

Overall, the implementation of Soft Robotics and programmable materials in wearable systems is highlighted as a welcome field in fashion and textiles. These practices have the potential for growth in HCI research and exploration at the intersection of biology, technology, and digital manufacturing. In the following, we will underline some of the relevant points through research questions.

Fabrication tools and resources:

- New challenges arise in the creation of larger surfaces, the need for homogeneous flexible materials and technologies for their fabrication, and the scalability of systems in a human and architectural scale.
- Documentation of thermoplastic materials that allow easy manipulation and prototyping at home.
- The organic design of pneumatic circuits rules. Inline the practices of origami or self-assembly.
- The implementation of fashion design practices such as pattern making is necessary to develop materials suitable for body individualization and 3D scanning combinations.
- The flexibility and documentation of open resources enable action and access to a list of materials and recipes for DIY projects.

Inclusion and Bridging Gender Gap: Inclusion, rehabilitation, and health issues have been one of the main focuses of robotics and are still one of the most explored topics as we learn about alternatives adapted and familiar to human physiological and motor needs. Soft Robotics enables a safe environment and invites exploration without certainty of what the end result will be, no right or wrong. But with an ultimate purpose or a goal. It is the authors finding that in the workshops, the individuals experience, understanding the principles of actuation and reaction in Soft Robotics, engages the user in an immediate interaction with the material and the important critical reviewing functions as bending and strain mechanisms. In the meanwhile, this practice enable the exploration of cognitive and emotional features in prototyping for different disciplines.

Soft Robotics allows the exploration of narratives of nature and the gap between electronics, technology, and science. The topic brought the attention of different audiences regardless of gender and age and invited the participation of all levels of knowledge. While in the workshops (table2), most of the audience is mixed, a bias can be noted that the majority of participants who choose soft robotics as their final topic are women, as shown in table 1. This indicates empathy with the topic and a preference to develop the challenges of interaction applying soft robotics and actuated materials.

We mention the values that promote the gender vision brought by shemakes.eu (equality, collaboration, welcoming differences, empowerment, and inspiration), showing its application and dissemination in the final projects and workshops, framing the practices generated around Soft Robotics as a driver to bridge the gender gap. Soft Robotics is also a practical example to illustrate how to promote activities around the empowerment of the use of technology, learning by doing and innovating in the intersection of technology, science, and art.

Their development in the fashion sector can be very attractive and demonstrates the migration and influence from science to prototyping development and commercialization of Soft Robotics products. Therefore, it becomes more relevant to facilitate access to manufacturing tools through laboratories and educational practices such as the Fabricademy program and future activities in this field.

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