Education for Sustainability approaching SDG 4 and target 4.7

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Compilers

Universidad Pontificia Bolivariana

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In collaboration with the Colombian Node of the Learning Network on Sustainability (LeNS))

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Contents

Prologue 7
Lucas Rafael Ivorra Peñafort

Introducing a New Design Culture on Sustainability 11
Emilio Rossi
Alexa Mattram
John Stocker

DIY-Materials approach to design meaningful materials for the sustainability transition 37
Valentina Rognoli
Stefano Parisi
Barbara Pollini
Martina Taranto
Camilo Ayala-García

SDG Fortune Teller: A Tool to Promote the Sustainable Development Goals 67
Isabel Treidl

Education for sustainability in creative disciplines at Universidad Pontificia Bolivariana, Universidad de Medellín and Institución Universitaria Pascual Bravo at Medellín – Colombia 89
Ana Elena Builes-Vélez
Lina María Suárez-Vásquez
Juliana Restrepo-Jaramillo
Natalia Pérez-Orrego
Juan Diego Martínez Marín

The Universidad Pontificia Bolivariana and its commitment to sustainability education 109
Ana María Osorio – Florez
Carlos Ernesto Bustamante
Ana Elena Builes – Vélez

Teaching sustainability through materials: bridging circular materials and bio-design for new design curricula 125
Barbara Pollini
Jared Jimenez

Challenges to wearable design education from a sustainability perspective.................................. 152
Margarita María Baena Restrepo
María Margarita Baquero Álvarez
Mauricio Velásquez Posada

Crafts, art and product design from agro-waste of Nopal cultivated in Sonsón, Antioquia 171
Lina-María Agudelo Gutiérrez
Dubán Canal Gallego
Santiago Marzola
Mariana Peláez Rojas
Marcela Pérez Ramírez
Mauricio Vásquez-Rendón

Products Validation in the Design Project and Scopes in an Online Educational Environment...... 198
Alejandro Mesa Betancur
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DIY-Materials approach to design meaningful materials for the sustainability transition

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Abstract

The critical environmental conditions of the planet compel humankind to rapidly devise solutions able to minimize the impact of human actions on Earth. Environmental issues are urgent, so researchers and practitioners in the design field are committed to formalising new visions and pathways, willing to meet the SDGs of the 2030 agenda.

While formulating less affecting processes of making/manufacturing, a conscious practice of design recognises materials and their

management as a critical point for sustainable production. The material, formerly considered a step of the design process, now becomes the focus of the project; unfortunately, there is a lack of dedicated studies and initiatives to implement material awareness in design education. To envision an effective ecological transition, material design turns into an inescapable step when designing for sustainability. It's fundamental for design schools to invest in material education by establishing dedicated courses that boost this realm of knowledge, the material understanding, and to improve the making skills of new generations of designers.

This chapter focuses on the results of the DIY-Material approach used in the last few years at the Design School of Politecnico di Milano. The developed approach allows to teach students transversally how to design materials starting from a source, going through ingredients, compositions, recipes, and processes, creating material demonstrators, and defining the identity of the new material and its narratives. Here, a series of bio-based, bio fabricated material examples will be illustrated to describe the development of material pathways pointing towards an ecological transition through a DIY-Materials approach.

designers have always aspired to transform materials to design more flawless artefacts, and in the last decade, an original approach to material design emerged. It was defined as the DIY-Material approach, and it is based on the designer's self-production of material agencies. (Rognoli et al., 2015; Rognoli and Ayala-Garcia, 2021). The DIY practice allows the designer to be independent from industry, which conventionally provides industrial material support, and enables them to expand the set of materials that turn ideas into artefacts. The designer proposes some material concepts and reasons about how to develop them further using a transdisciplinary approach. The method empowers designers to look for alternative and unconventional sources of materials, prioritizing locally and abundantly available substances and ingredients that, most times, foster environmental sustainability and social innovations.

In 2015, in the Design Department of the Politecnico di Milano, we founded the DIY-Materials research group[1], and we elaborated the DIY-Materials Manifesto (Fig.1) to work, teach, investigate, and spread the DIY-Materials approach: designing materials for achieving alternative and sustainable solutions to conventional and sometimes problematic materials. To do so, Material Tinkering is applied as an iterative and systematic process of manipulating the material creatively for discovery and experimental purposes (Parisi et al., 2017). Material Tinkering (Parisi and Rognoli, 2017) is an unconventional approach to material development that entails creative and playful experimentation which fosters innovation through serendipity, learning-by-doing, and trials and errors. The process starts by selecting unconventional materials sources–often addressed as "hidden" sources–and by using open source "recipes" for materials making (as the ones for DIY bioplastics which are mostly available online). Afterwards, designers or students are encouraged to hack the recipes by altering the formula changing the proportions, adding new ingredients,

1 http://materialsexperiencelab.com/; https://www.diy-materials.com/; #diymaterials; @ diymaterials_polimi

Fig 1. The DIY-Materials Manifesto

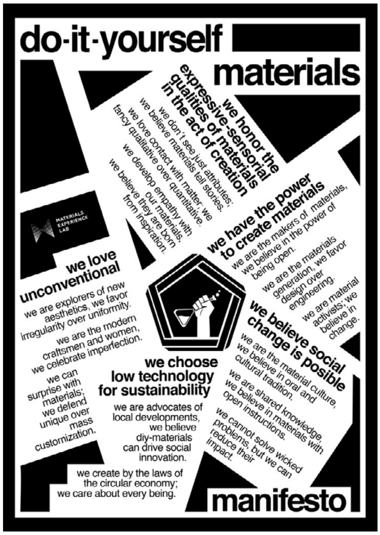

Photo credits: Camilo Ayala-García, 2017

and/or applying tools and techniques from other fields, often from different cultures and traditions. The synergic and unusual combinations of ingredients, techniques, and competencies foster creativity, potentially resulting in innovative material samples. This also carries practitioners on a journey towards unknown destinations, by sparking the reasoning on materiality itself and nurturing awareness of the designers' fundamental role in material making and in catalysing change in industry and society.

In this process, the tinkerer is invited to stretch the sources' potentialities to enhance their inherit performances and authentic expressiveness. Because of Material Tinkering activity, it is possible to produce "material drafts", underdeveloped material proposals ready for further development or to be used as a source of inspiration, and "material demonstrators", intentionally designed samples aiming to explore and represent processes or quality variants such as colour, thickness, texture (Rognoli and Parisi, 2021).

We observed that, in most cases, designers choose to start their material design process from bio-based and biocompatible sources that may provide a sustainable alternative to the linear paradigm "take-use-discard" and propose a more circular model of harvesting, consumption and end-of-life scenarios. In the DIY-Materials research group's practice, nature arises to be an inspiration and blueprint to many extents, encouraging the material designed to use a Bio-Driven approach for developing emerging materials for the ecological transition.

The Biological Metaphors to design new materials

The DIY-Materials approach also includes bio-driven experimentation, to where, both practically and theoretically, reached the definition of two biological metaphors to be applied in materials for design.

The first one concerns the classification system used for defining and describing DIY-Materials. To analyse over 150 examples in the literature, scholars subdivided self-produced materials, generated from a tinkering activity, into "kingdoms". They took inspiration from the first biological classification defined by Linnaeus in the XVII century by the name of Systema Naturae (Ayala-Garcia et al., 2017). Similarly, with Linnaeus' taxonomy, with DIY-Materials kingdoms too, the primary source was considered: the type of matter involved at the beginning of the tinkering process affects and drives the material invention process. Five kingdoms have been proposed (Fig.2), referred to as Vegetabile, Animale, Lapideum, Recuperavit, and Mutantis, each with its specific characteristics, qualities and properties (Ayala-García, 2019).

Fig 2. The DIY Materials Kingdoms and the reinterpretation of Linnaean taxonomy.

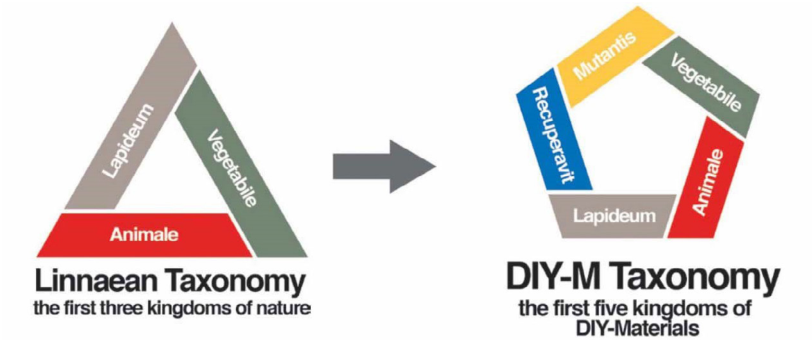

Photo credits: Camilo Ayala-García, 2017.

The material tinkering process itself includes phenomena that are analogue to biological ones. The word "tinkering" has been traditionally used in the evolutionary field (Jacob, 1977) concerning the learning process, only apparently casual, yet based on principles of maximal efficiency, of nature during evolution (Rognoli et al., 2017).

Here is clear the second biological metaphor that defines the leading practice useful to developing material drafts: variation and natural selection as two basic concepts of Darwin's theory of evolution.

Every new "generation" of materials produced by the tinkering activity presents slight variations that are not necessarily positive or negative, but sometimes can question the "survival" or not of the material.

'Variation' is the mechanism for finding the best and preferable solution. Just as 'variation' is the engine of evolution, for the designer, it means looking for the composition of new material. The difference between artificial and natural selection lies in its intention. Humans intentionally select (the characteristics of an animal race or plant species, as well as the features of a material), while nature seems to act without intentionality, according to arbitrary principles. Nature directly implements variations, not because they are useful or useless, but using them as raw material that will be shaped afterwards by natural selection based on the individual's survival success (Rognoli et al., 2017).

Introducing case studies

This chapter illustrates the results of the DIY-Materials approach used in the last few years, at the School of Design of Politecnico di Milano (2015-2021). The developed approach allows to teach design students, despite their course of study, how to design materials starting from a material source, going through ingredients, compositions, recipes and processes, to get material drafts and demonstrators, and define their identity and narratives. In the courses and master thesis, the students produce materials samples as proposals or concepts of alternative materials at different stages of development, from DIY to research in Lab. The methods used to deliver them are the Material Driven Design (MDD) method (Karana et al., 2015) and the Material Tinkering approach (Parisi and Rognoli, 2017). These protocols and procedures prioritize the active engagement of designers in developing the materials, disrupting the conventional paradigm of STEM-driven materials, where the role of the designer is limited to material selection and application. The MDD method considers the material as a starting point for the design process. It is focused on the notion of Materials Experience, namely the experience that users have through the materials of artefacts in their sensorial, emotional, meaning, and performative components. By understanding the complex experience of a distinct material and designing for enhancing Materials Experience (Karana et al., 2014; Pedgley et al., 2021), the designer will develop materials further and identify meaningful applications.

All the case studies described below result from integrating these approaches into the experimentation and design process of bio-based and bio-fabricated materials. They were conducted in the DIY Materials Research Group as research projects of the team or as Graduation Projects supervised by the group, some of them in collaboration with companies and design studios.

3.1 Case studies with Mycelium

Mycelium can be informally described as “the roots of fungi.” When inoculated in a biological substrate, such as straw, vegetal fibres, coffee ground, and sawdust, it grows on it, multiplying its size and mass in freeways and resulting in a white and solid mass with the appearance and properties of Styrofoam. The designer can exploit and orientate the natural growing process to enable a bio-fabrication process to make artefacts, different from conventional production and prototyping techniques (Karana et al., 2018). Growing design is a slow process, respectful of nature’s rhythm and requirements, that enacts cooperation between organisms, the designer, and the living matter itself. Mycelium, and the materials derived from it, represent a sustainable and increasingly tangible surrogate alternative to the ones from petrochemical origin. As a renewable, widely available, biological, and biodegradable substance, mycelium arises as one of the most promising sustainable surrogate materials to adopt for activating circular economy and cradle-to-cradle approaches. Introducing living materials in the design space testifies to the increasing dialogue between Design and Science (Langella, 2019), which draws inspiration from each other to deliver sustainable bio-based alternatives and new production models, supporting the development of a circular bioeconomy (Yadav et al., 2021).

For his master's graduation project titled "A Matter of Time" (Fig. 3), Stefano Parisi[2], as a pioneer in this field, started an experimental process from a mycelium-based composite material. He developed it further by defining a unique and meaningful material experience related to the passing of time, emphasizing the genuine, spontaneous, and dynamic features of the materials. For example, he included chia, flax and psyllium seeds which brought new expressive, technical, and manufacturing features related to handcrafting and tradition, similar to the process of clay modelling (Parisi and Rognoli, 2017; Parisi et al., 2016).

As a follow up to this exploration, the following master's graduation projects explored Mycelium application in different design sectors, from interior design to footwear, from toy design to biking accessories.

The project "Carie"[3] by Carlotta Borgato[4], an experimental study applied to bio-based fungal materials, focuses on their relationship with timber wood. The project analyses the relationship between wood and mycelium, testing through prototypes the level of compatibility and structural strength for each different wood essence. Then, the research has suddenly materialized into a concept product (Fig. 4).

The project "Organs - organic runners" (Fig. 5) by Deoshree Ravindra Bendre[5], in collaboration with the company Flocus[6] and ACBC[7], focuses on introducing zero impact bio-based material alternatives to the existing

2 Parisi S. (2015). A matter of time. Master Thesis supervised by Valentina Rognoli. School of Design, Politecnico di Milano, a.a. 2014/2015.

3 This project was carried on in collaboration with the Italian company Mogu (https://mogu.bio/), which is working on mycelium for interior design application as acoustic panel and floor tiles.

4 Borgato C. (2019). Carie. Master Thesis supervised by Valentina Rognoli and Serena Camere (co-supervisor). School of Design, Politecnico di Milano, a.a. 2018/2019

5 Ravindra Bendre D. (2021). Organs – the Organic runners. Master Thesis supervised by Valentina Rognoli and Stefano Parisi (co-supervisor). School of Design, Politecnico di Milano, a.a. 2020/2021

6 https://www.flocus.pro/

7 https://it.acbc.com/

Fig. 3. A Matter of Time, by Stefano Parisi, 2015

Photo credits: A. Pollio, S. Parisi, 2015

Fig. 4. Carie, by Carlotta Borgato, 2019

Photo credits: C. Borgato, 2019

Fig. 5. Organs - organic runners by Deoshree Ravindra Bendre, 2021

Photo credits: D. R. Bendre, 2021

material applications in the footwear industry. The theme of the thesis orbit around the notion of "back to nature" by exploring and detecting natural material possibilities and re-introducing plant-based and organic materials in the industry, including mycelium and kapok fibres.

The project "MyHelmet" by Alessandra Sisti, focuses on the use of mycelium as a material substitute in the bicycle industry to exclude systemic waste (Fig. 6). This research and design process, in collaboration with the Dutch design studio MOM, led to the design of a bicycle helmet made of mycelium. The project is supported by shock absorption tests, material comparisons, FEM analysis, LCA assessment, and analysis of current safety regulations and standards.

The project "MYO - Mycelium technology for kids" (Fig. 7) - by Michela Grisa, aims to enhance the sensitivity and appreciation of biomaterials in society, by proposing a playful and interactive toy for kids that integrates the use of mycelium and technology, i.e., smartphones and tablets.

Fig. 6. MyHelmet by Alessandra Sisti with the Momo Studio, 2021.

Photo credits: A. Sisti, 2021

Fig. 7. MYO - Mycelium technology for kids by Michela Grisa, 2021

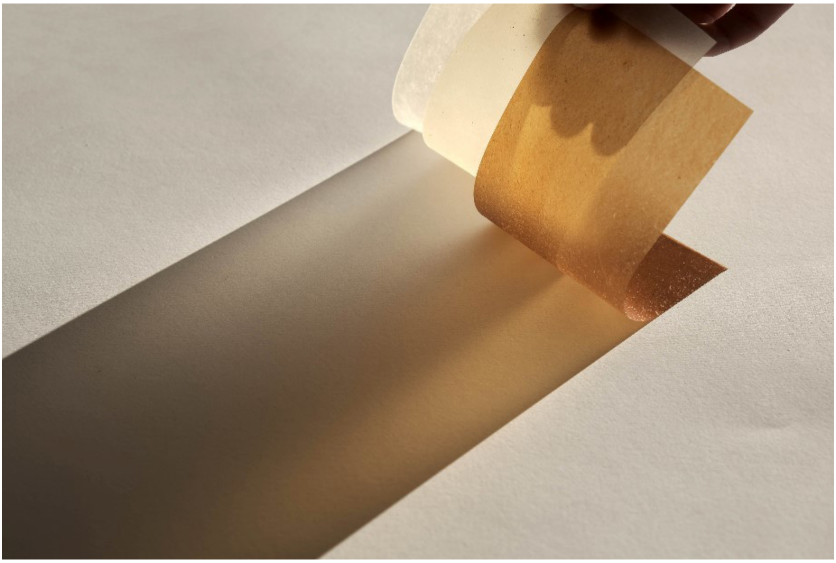

Photo credits: M. Grisa, 2021

Employing mycelium, the project aims also to improve and enrich the child's technological and interactive experience by making it more sensory using mycelium. The result is a prototyped toy that combines the world of touchscreen devices with biomaterials.

The research project "Living Interaction" by Elena Albergati (Fig. 8) focused on the interactive response of Mycelium to external stimuli, such as pressure, touch, and airflow. The result includes a method as a tool for designers to facilitate and guide the integration of microorganisms such as algae, fungi, and bacteria in future projects. To validate the method and the proposed thesis, detailed experimentation with live mycelium was presented to test its response properties to stimuli and evaluate its use as a biosensor in the Interaction Design field.

Fig. 8. Living Interaction by Elena Albergati, 2021

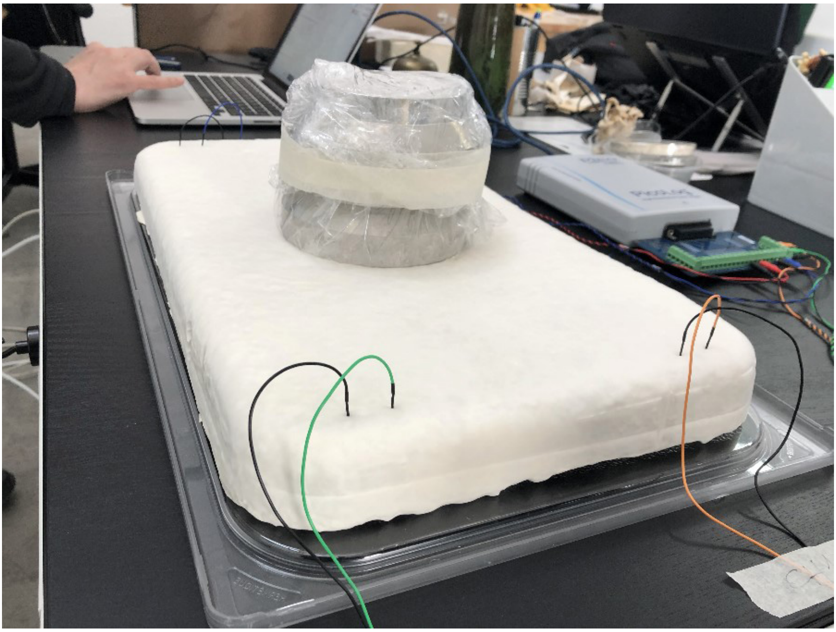

Photo credits: A. Albergati, 2021

3.2 Case study with Algae

Algae comprise a large family of organisms from which it is possible to get fibres, pigments, or powders to be used for producing materials from renewable, abundant, and biodegradable sources.

The DIY-Materials Research Group/Materials Experience Lab and Algae Geographies by Algae Platform Atelier Luma[8] have organized a 3-days workshop and research space to explore the potential of algae-based biopolymers. The material used in the workshop is produced by Atelier Luma and comprises bioplastic and micro-algae with a PLA matrix as filaments and pellets. The algae is used for aesthetic reasons, providing colouration, texture, and unique visual effects, and for functional ones, affecting the environmental and mechanical properties of the materials. During the 3-day workshop a selected number of design students, academics and practitioners have manipulated the material provided by Atelier Luma in cooperation with their designers and researchers, using the infrastructure and tools of the Prototype Workshop provided by Politecnico di Milano as enablement of the experimental activity. The traditional techniques to work with polymers, such as blow-moulding, thermo-forming and even advanced ones such as 3D printing, have been mixed and hybridized with unconventional processes coming from crafting and from the participants' creativity (Fig. 9).

'A Matter of Clay', a master graduation project by Elena Rausse[9], focuses on new possible expressive scenarios of ceramic material. Starting from a territorial survey of the town of Nove (VI) Italy, famous since 1400 for its ceramic processing, the research focused on the desire to renew the ceramic material through hybridization with other natural elements of the territory. Given a nearby river, the elements identified as

8 https://atelier-luma.org/en/projects/algae-platform

9 Rausse E. (2019). *A Matter of Clay.* Master thesis supervised by Valentina Rognoli. School of Design, Politecnico di Milano, 2018/2019.

Fig. 9. some results of the workshop at Politecnico di Milano with Algae Geographies by Algae Platform, Atelier Luma. Broken Nature, Triennale di Milano.

Photo credit: Z. Zhou, 2019

suitable for hybridization are algae in the immediate vicinity (Rognoli and Rausse, 2020). Given the algae's reproduction, speed and renewability have proved to be an excellent element. They were used both for the hybridization of the material before firing (on dough) and after firing (as a finish), opening new visions and expressiveness of the material (Fig. 10, 11). On the dough, the algae act as a thickener, allowing to get very thin thicknesses and very light objects while keeping them resistant. When used as a finish, they act as natural-based glazing by pigmenting the

Fig. 10, 11. A Matter of Clay.

Photo Credits: E. Rausse, 2019

surface of the ceramic with unexpected colours because of the acquisition of metals during the life of the algae in the water. These new scenarios allow new uses of ceramics: this new material is re-introduced into the economic cycle of the town of Nove and can be a starting point for the renewal of the ceramic culture of the town.

Students from the course "Designing Materials Experiences" (Parisi et al., 2017), run by the DIY-Materials Research group, used fibres from algae as a source for their materials experimentation in combination with DIY biopolymers, resulting in Egacomp material[10] (Fig. 12). Egacomp is derived from "egagropili", dead algae and marine plants aggregates in the peculiar form of spheres that are very common on Mediterranean beaches. Being the material translucent, it creates an effect of a captivating light. Besides this, the use of such material is a sustainable

[10] Egacomp material samples by Luisa Alpeggiani, Mattia Antonetti, Fabrizio Guarrasi, supervised by Valentina Rognoli, 2015.

Fig. 12. Egacomp material samples

Photo credits: L. Alpeggiani, M. Antonetti, F. Guarrasi, 2015

solution, since egagropili are massively infesting beaches and are difficult to dispose of because of the high content of salts.

3.3 Case studies with animal-based materials

In the DIY- Materials research group, we also explore the material sources provided by nature and mainly used by humans for food production. Most of the time, by-products and waste materials from the food industry are disposed of without considering them as valuable materials that might be re-integrated into a production loop. Waste materials can be elevated to a resource for new sustainable and non-polluting materials. These entail by-products from animal source food, such as skins, bones, scales, shells, etc. In the context of the food waste resources deriving from the various phases of the production cycle, the quantities produced are very varied and can reach up to 50% of the starting material; therefore, companies and producers are forced to face the problem of disposal of such waste. Sometimes the residual material is partially used in the production of food, compost, and biofuels. However, given the abundance and varied composition of these wastes, in recent years, there has been a growing interest in them and a search for methodologies to further applications.

The project "Fish Left- (L) over" by Claudia Catalani[11] investigates how by-products from the fish used for food production might be used as a valuable source for new materials with useful intrinsic values as biodegradability. More than a quarter of waste from fishing is discarded. It causes not only a significant environmental impact but also a loss of the potential value of these products. There's a growing pressure to reduce discarded, unwanted by-catches of EU fishing fleets and EU targets for smart and green growth, so it is necessary to rethink many of the Italian processes present in the fishing and aquaculture supply chain. In this thesis, scraps of fishmongers have been examined, and the properties of fish skin, scales and bones have been studied. For the project, C. Catalani collaborated with the Italian company Bue Marine Service[12], which has worked on fish leather under the project "Adriatic Skin"[13]. This project recovers the fish skin waste and transforms scraps into new material, on which innovative and significant application scenarios have been developed. Experimentation has been conducted using a DIY approach on scales and bones. The goal was to find a useful, functional, and low environmental impact material that could be a valid alternative to non-renewable resources (Fig. 13).

11 Catalani C. (2019). *Fish-Left-(L)overs.* A new life to fish waste. Master thesis supervised by Valentina Rognoli. School of Design, Politecnico di Milano, 2018/2019.

12 http://www.blumarineservice.it/

13 http://www.adriaticskin.com/

Fig 13. Fish Left (L) overs.

Photo Credits: C. Catalani, 2019

In the project "Development and scenario of DIY-Materials based on mussel shells" Chiara Stopponi[14] concentrated on the self-production of different materials, got using as a base the shells of mussels discarded in the various stages of food production and consumption in combination with natural binders such as casein, glycerol and polylactic acid (PLA) (Fig. 14, 15). The aim is to produce biodegradable and easily self-producing materials. The most promising result of the experiment is a filament to be used for 3d printing. The scenario envisaged for the use of these materials is that of a future circular restaurant, in which, according to the principles of the circular economy, the output, or waste, will be reintegrated in the loop as an input, a resource, for the restaurant itself. The reuse of food waste, besides giving an expressive and functional value to the material that derives from it, also aims

[14] Stopponi C. (2018). *Sviluppo e scenario di DIY-Materials a base di gusci di mitili.* Thesis supervised by Valentina Rognoli and Stefano Parisi (co-supervisor). School of Design, Politecnico di Milano, 2017/2018.

Fig. 14, 15. Development and scenario of DIY-Materials based on mussel shells.

Photo Credits: C. Stopponi, 2018.

to raise awareness of the problem of disposable plastics and their immediate disposal after use.

Similarly, the project “Pig-it Yourself“ by Gabriela Machado da Silva Lima[15] experiments on pig skin derived from food production as a component for producing animal-based biopolymers (Fig. 16). Pork is the most consumed animal protein in the world, responsible for around 38% of the world’s meat production, and generating residue and waste, from blood to skin, bones, to fat. These can be turned into a wide variety of products, including food, animal feed, fertilisers, and fuel. Despite all these by-products having the potential to be reused in some form, as mentioned, many times the market cannot cover the production. This portion not absorbed by the market generates serious problems related to waste and debris management, whose treatment incurs higher expenses to industries, especially in the countries lacking a recycling department for animal residue. The research can attest to the age-old

15 Machado da Silva Lima G. (2019). *Pig it yourself. Developing a new material based on pig skin.* Master thesis supervised by Valentina Rognoli. School of Design, Politecnico di Milano, 2018/2019.

Fig 16. Pig it yourself

Photo credits: G. Machado da Silva Lima, 2019

adage that states: “From the pig, nothing ever goes to waste: everything but its oink”. Virtually every single part of the pig can be transformed into new products or resources. There is, however, an open question related to how to do better to use of by-products such as pigskin. The issue to unravel is: “how to aggregate value to pigskin?” Even though there are known uses, Gabriela believes that “Pig It Yourself” can become an alternative in aggregating value to this by-product, especially the smaller, non-consumable fragments, not large enough to be turned into leather products. It would be a better, less wasteful form of utilisation of the scraps and better exploitation of its untapped economic potential.

3.4 Case studies with plant-based materials

Plants gave life to the atmosphere, the crucial point of the planet’s life. The vegetal world has always been considered a source of food and medicines, but we rarely take inspiration from them for improving our quality of life.

In the project "Cornstalk do-it-yourself materials for social innovation" by Karen Estefanía Rodríguez Daza[16], the idea of using corn stalk-based DIY-Materials to foster social innovation among Colombian small farmers is explored. This, to foster a rural development that respects the farmer's traditional practices and beliefs oriented toward collective progress and nature preservation. Hence, the theoretical review regarding social innovation, circular economy, DIY practices and materials is put to test by proving that corn stalks can be used as a raw material to make materials with no scientific knowledge, complex technology, and polluting elements (Fig. 17). In a second step, the theory and hypothesis were verified by interviewing Colombian farmers with whom the idea of using agricultural leftovers to produce DIY-Materials was shared and discussed during several workshops. This strengthens the vision that DIY-Materials have the potential of contributing to the creation of a more fair society where the farmers' identity and traditions are valued and their role redefined as entrepreneurs and innovators.

The project "Poli. Frutta" (Fig. 18) by Ilaria Giani[17] focuses on the use of fruit leftovers for the making of plant-based leather-like material. Similarly, Sofia Soledad Poblete Duarte focused on her Master's graduation project, "The Locked-down Material Lab. Crafting materials during Covid-19"[18] on the use of pectin derived from fruits and banana

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16 Rodriguez Daza K. (2017). Cornstalk *do-it-yourself materials for social innovation*. Master thesis supervised by Valentina Rognoli and Camilo Ayala-García (co-supervisor). School of Design, Politecnico di Milano, 2016/2017.

17 Giani I. (2017). ***Polifrutta***. Master Thesis supervised by Valentina Rognoli and Camilo Ayala-Garcia and Stefano Parisi (co-supervisor). School of Design, Politecnico di Milano, 2016/2017

18 Duarte Poblete S. (2021). *The Locked-down Material Lab.* Master Thesis supervised by Valentina Rognoli and Patrizia Bolzan (co-supervisor). School of Design, Politecnico di Milano, 2020/2021

Fig. 17. Cornstalk do-it-yourself materials for social innovation.

Photo Credits: K. Estefanía Rodríguez Daza, 2017

fibres for the making of biopolymers in a home-lab installed in domestic isolation and resource limitations within the recent COVID-19 Pandemic (Fig. 18).

Barbara Cerlesi[19] carried out a Master's graduation project based on the question of the language and communication skills of plants: could colour produced by plants be taken as an interface for people and designers? From the latest scientific news, we know plants developed thousands of languages, exploiting all their senses. To deeply understand one of them–colour–Barbara focused her research on grass, one of the most available vegetal organisms. In the project, she questions the possibility of plants reacting to environmental inputs by producing pigments we could archive, study, understand and then integrate as a design and inspiration tool for creative industries. By taking the role of

[19] Cerlesi B. (2019). Nature commands color. A research-based project on the intelligence of plants, questions the role of designers today. Master Thesis supervised by Valentina Rognoli and Stefano Parisi, Manuela Bonaiti (co-supervisors). School of Design, Politecnico di Milano, 2018/2019.

Fig. 18. The Locked-down Material Lab. Crafting materials during Covid-19 Photo

Credits: Sofia Duarte Poblete, 2020.

designer as the one f a translator, Barbara set a method to extract and analyse pigments through an altered version of Chromatography (Fig. 17, 18, 19, 20, 21, 22, 23), to archive them in a database–the Grass Map[20]–and to explore all the design opportunities that this research opened up. From this research, Nature Commands Colour (NCC) emerged. NCC is a colour palette software for designers derived from the database of grass-derived colours built by Barbara. Also, it helps in designing patterns inspired by the ones identified in nature. NCC introduces designers to accepting the temporality, seasonality, and location-based nature of the grass-derived palette. The concept of using the plant for natural dyes is explored on different scales, proposing a range of design opportunities developed as

20 http://www.grass-map.com/

Fig. 19. Nature commands colour.

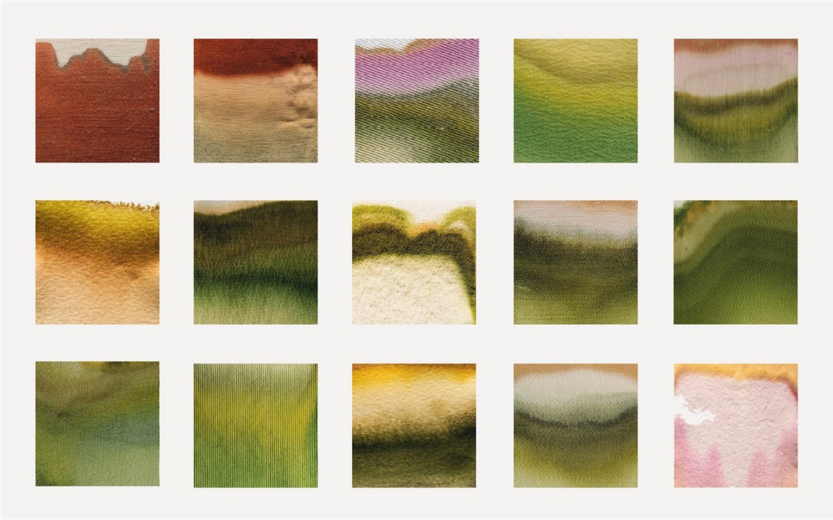

Photo Credits: B. Cerlesi, 2019

future scenarios or maquettes, from using the actual dye for biopolymers and natural fibers' pigmentation especially for sustainable fashion, to using the digital colour derived from NCC for bio-oriented brands' communication, to social design where the palette can inform citizens about the health of grass, atmosphere and soils.

Students from the course "Designing Materials Experiences" (Parisi et al., 2017) run by the DIY-Materials Research group used plant-based fibres combined with different techniques and natural compounds to develop a diversity of materials from paper to pH-sensitive inks, from biopolymers to textile. Students developed Greenet, by extracting fibres from waste celery, spinning them into threads, and weaving them into textiles (Fig. 20). The thread results to be resistant and quite elastic.

Fig. 20. Greenet material sample.

Photo credits: H. Aversa, S. Bettoni, A. Ertin, M. Wang, 2017

Expanding on the use of plants in the design space, the project "ReGrowth" (Fig. 21) by Nicla Guarino[21] (2022) focuses on the use of bio-based materials and living plants in garments design. An expedient to propose renewable and compostable resources for a more sustainable fashion industry, to introduce a new aesthetic and new customer experiences based on a new fashion temporality, determined by the growth and degradability of plants and on new relations of caring with the product.

Conclusions

Designers are increasingly hungry for experimental practices that involve the material side of the project. This curiosity denotes a growing awareness and a steady ethical posture towards the environmental problems that certain materials can trigger within the practice of design,

21 Guarino N. (2022). ReGrowth. Master Thesis supervised by Valentina Rognoli and Stefano Parisi (co-supervisor). School of Design, Politecnico di Milano, 2021/2022

Fig. 21. ReGrowth application in clothing.

Photo credits: N. Guarino, 2022

towards the repercussions on the products' life cycle and the materials' environmental role. Reflecting on the 'end of life' and committing to shift their practices toward circular and regenerative models, designers experiment mainly with sources of organic origin, sometimes leveraging waste streams, sometimes programming a cross-species design collaboration with living organisms such as fungi and algae. This research, by illustrating a series of relevant case studies in DIY-Materials design, aims to show the effectiveness of the MDD Method, combined with a DIY-Materials approach and the activity of tinkering to facilitate the development of alternative, sustainable and circular materials capable of enhancing, through narrative and storytelling, the final Material Experience. It results clear how bio-driven materialities appear to be relevant, not only in fostering a material ecological transition towards more eco-compatible productive futures, but these material agencies, and the narratives that motivate their existence, trigger a radical shift towards more tolerant, transversal, collaborative, integrated ecological practices of life.

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The Universidad Pontificia Bolivariana (UPB), through its School of Architecture and Design, with the collaboration of the Colombian Node of the Learning Network on Sustainability (LeNS), joined forces to address the relevance of incorporating sustainability more in the training of new architects and designers. Theydid it in this book to contribute to improving our society according to SDG4 and its target 4.7. Throughout the book, various approaches to understanding and proposing solutions to sustainability challenges are interwoven. You will find a framework to understand the need for a new culture of design and sustainability in chapter 1, which will be articulated with technical and social approaches in the learning processes in architecture and design. For example, technically speaking, you will see academic exercises for developing new and more sustainable materials in chapters 2 and 6. From the social side, you will find an analysis of wearables from the perspective of lifestyles in chapter 7 and the study of the value of traditional and ancestral knowledge in chapter 8. You will also find studies about different educational strategies, such as the development of a new educational tool in chapter 3, case studies about how UPB embeds sustainability in their pedagogical strategy in chapters 4 and 5 and the presentation of an educational experience in the framework of the new virtual pedagogical dynamics in chapter 9.

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